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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 35 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: the implementation of Artificial Intelligence in management; economics; logistics; organizational behavior; marketing; ESG practices; tourism management; corporate social responsibility; innovation management; finances; project management; Generation Z in management; sustainable development; quality management and strategic management.

Radosław Wolniak

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DIGITAL MATURITY IN THE ERA OF ARTIFICIAL INTELLIGENCE – STIMULATORS OF AND BARRIERS TO ORGANIZATIONAL CHANGES

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Purpose: The purpose of this paper is to identify the key stimulators of and barriers to the implementation of AI as part of organizational change in enterprises and to demonstrate their relationship to enterprises' digital maturity.
Design/methodology/approach: The study was carried out using the literature review method, with particular emphasis on the elements of bibliometric analysis, keyword network analysis and content analysis. Of the 51 articles retrieved from the EBSCO, Scopus and Web of Science databases, 15 met the analysis inclusion criteria. Methods such as exploratory research and logical classification method were also used in the study process.
Findings: The authors succeeded in identifying the main themes in research on the implementation of AI in business enterprises as part of organizational change. In the next step, a catalogue of 18 stimulators of and 25 barriers to implementing AI as part of change management in companies was established. The identified stimulators and barriers were divided into eight categories. In the final step, the authors demonstrated the relationship between the identified stimulators and barriers on the one side and enterprises' digital maturity on the other side.
Originality/value: The originality of the conducted study lies in two aspects. Firstly, the proposed catalogue of the stimulators of and barriers to implementing AI within the scope of change management is new to the existing academic literature. Secondly, the proposed theoretical framework of the impact of the stimulators of and barriers to AI implementation on digital maturity is innovative and bridges the identified research gap.
Keywords: artificial intelligence (AI), digital maturity, digital transformation, organizational changes.
Category of the paper: Research paper.

1. Introduction

1.1. Artificial Intelligence and its impact on enterprises

Artificial Intelligence (AI) has been revolutionising the operations of business organizations around the world in recent years. This trend is so dynamic that regardless of the size of an enterprise or the industry in which it operates, AI tools are now very much a part of driving efficiency and building competitive advantage (Leslie, 2019; Chaudhuri *et al.,* 2023). AI has a myriad of applications in business management, whether in the sphere of operating activities, building and developing strategy, or establishing and strengthening relationships with different stakeholder groups. For example, AI tools can support businesses in decision-making processes by automating these processes and facilitating the analysis of business data (Enholm *et al.*, 2021; Korytnicka, 2023). AI tools also provide solutions to optimize risk management procedures, mainly in the hazard identification phase (Aziz, Dowling, 2019), strengthen the efficiency of compliance systems (Vyas, 2023) and support innovation implementation processes (Xing *et al.,* 2020).

Unfortunately, whether, and to what extent, a business organization will be able to grow thanks to the application of AI is strictly dependent on its ability to exploit the emerging stimulators of AI deployment and to break down the emerging barriers. This is because, in addition to the undeniable benefits of adapting AI in enterprises, there are also numerous risks and threats associated with this process, creating various implementation barriers. Which stimulators and barriers to AI implementation a particular company will encounter may depend on both its individual internal conditions (e.g. strategy, management approaches, resources, positioning) and environmental conditions (Bąk *et al.,* 2024). The problem for many enterprises is that they implement AI tools in a way that is not coordinated with strategy, incidental, motivated only by one specific need. What is lacking, however, is the building of a conscious, structured change management-based path for the development of businesses using AI tools, together with a continuous analysis of the stimulators of this development and the barriers that arise. Indeed, the implementation of AI in a company, regardless of scale, should be conducted within the framework of organizational changes (Raj *et al.,* 2024) coordinated with the strategy and development path, using, for example, the potential of Generative Artificial Intelligence (Kanitz *et al.,* 2023). Unfortunately, this is still not a common approach.

AI and the implementation of tools based on this technology are also directly related to the implementation of the concept of organizational innovation adaptation. Due to the pace of technological progress, enterprises often implement AI tools as part of organizational innovation (Bahoo *et al*., 2023). Theoretical and modeling approaches serve as a foundation for understanding the factors contributing to the stimulation of innovation implementation, such as: Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), Theory of

Diffusion of Innovations (DIT), Theory of Reasonable Action (TRA) (Lai, 2017), Theory of User Acceptance and Use of Technology (UTAUT) (Taiwo, Downe, 2013).

1.2. Artificial Intelligence implementation and enterprise digital maturity

The implementation of AI in enterprises has a real impact on their level of digital maturity (Fahrisky *et al*., 2025). Digital maturity determines the state of advancement and effectiveness of the digital transformation being implemented (Dominguez, 2017; Barry *et al.,* 2022). Knowing the level of digital maturity provides companies with tangible benefits, which, however, can only be achieved if the digital transformation process is fully coherent with their digital strategy, digital culture, resources, as well as digitization in management processes and external environment (Bąk, Jedynak, 2024). The role of a company's digital maturity level is crucial in building a competitive advantage in today's highly digitized business environment. Digital Maturity Models (DMMs) explain the importance of digital maturity in business management. However, these models are often criticized for their limited practical usefulness and the incomplete objectivity of their assessment criteria (Thordsen, Bick, 2023). There is no doubt, however, that these models trigger mechanisms for a multifaceted approach to utilizing the digital maturity concept in business operations.

Research plans and artificial intelligence (Dwivedi *et al*., 2021) indicate that implementing AI tools offers similar business development potential to other types of innovations that existed before the AI era. Cross-industry AI adoptions, from the technology sector, through manufacturing, trade, logistics, to healthcare, public administration, and science, confirm that the digital maturity of public and private enterprises is changing rapidly under the influence of new trends, currently primarily inspired by artificial intelligence.

Due to the identification of a research niche - the small number of scientific studies on the implementation of AI within a structured organizational change process and too weak a connection in the literature between the implementation of AI and the digital maturity of enterprises, we set the goal of our study. The purpose of this paper is to identify the key stimulators of and barriers to the implementation of AI as part of organizational change in enterprises and to demonstrate their relationship to enterprises' digital maturity. With regard to the objective indicated above, we posed four leading research questions:

RQ1: What are the main research themes addressed in publications on AI implemented as part of organizational change?

RQ2: What are the main stimulators of implementing AI as part of organizational change?

RQ3: What barriers stand in the way of implementing AI as part of organizational change?

RQ4: How do the stimulators of and barriers to implementing AI as part of organizational change in business organizations relate to their digital maturity?

Given the research goal and research questions outlined above, our study is original for two key reasons: first, no previous publication has compiled a comprehensive catalog of stimulators and barriers to implementing AI tools as part of organizational change. Second, there is a clear

lack of research analyzing the relationship between AI development and digital maturity, taking into account drivers and barriers to this development.

2. Methods

2.1. Search strategy and article selection process

We conducted the study, using the literature review methodology (Xiao, Watson, 2019). In order to ensure the reliability of the resultant literature review, we searched for articles in three databases integrating articles from the discipline of management sciences, namely EBSCO, Scopus and Web of Science. We developed a detailed search strategy based on search queries technically adapted to the requirements of each of the selected databases. Initially, in line with the research plan, we intended to analyse all articles that would address AI implemented as part of organizational changes correlated with digital maturity. The first stage of the search was as follows: (artificial intelligence OR AI) AND (organizational change OR organizational changes OR enterprise change OR enterprise changes) AND (digital maturity). However, such search queries yielded no results – meaning no articles meeting the criteria for this keyword arrangement were found in any of the databases, which immediately made us realize that we were dealing with a niche, or even a research gap. Therefore, we decided to reduce the search terms to: (artificial intelligence OR AI) AND (organizational change OR organizational changes OR enterprise change OR enterprise changes), while we planned to address the reference to digital maturity in the next stage of our research. The search was conducted at the level of article titles. Inclusion and exclusion criteria had been established beforehand. We decided to accept only peer-reviewed articles (journal articles and peer-reviewed conference proceedings) published in English. There were no restrictions relating to the date of publication. The first search according to the established queries (performed on 27.12.2024) returned 51 articles (EBSCO – 28, Scopus – 14, WoS – 9). After applying filters to reflect the adopted inclusion criteria, the number of articles decreased:

- the filter of "English language only" reduced the number of articles to 49 (EBSCO – 26, Scopus – 14, WoS – 9),
- the filter of "peer-reviewed articles only" (journal articles and peer-reviewed conference proceedings) reduced the number of articles to 34 (EBSCO – 15, Scopus – 11, WoS – 8).

Finally, we shortlisted 34 articles from the three databases meeting the inclusion criteria for the analysis stage which were downloaded in .ris format and uploaded to Mendeley (we did not limit their publication dates due to the relatively small number of identified articles meeting the inclusion criteria, and therefore, due to the discovery of a research niche. In such a case,

it is important to identify the evolution of niche research over time). For each article, data such as title, author, year of publication, journal/conference name, abstract, keywords and a reference to the full text (doi no./link) were extracted. In a further step, we cleared the collection of the articles of duplicate items, which reduced the number of the publications approved for detailed analyses to 15. The search strategy and article selection process are shown in detail in Figure 1. The study was conducted in a manner consistent with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (Tricco *et al.,* 2018).

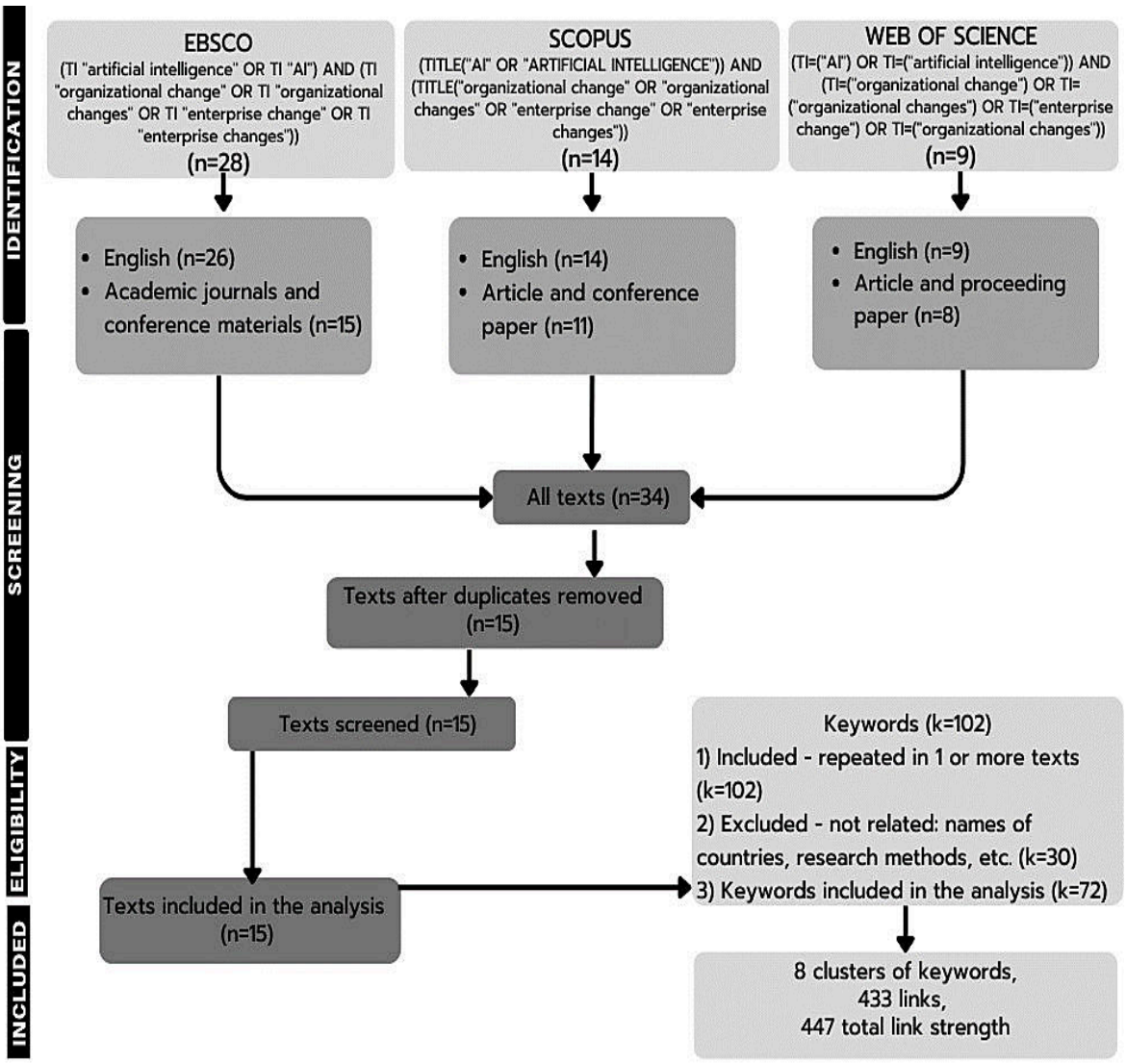


Figure 1. Search strategy and article selection process (based on Prisma Flow Diagram).
Source: own study.

2.2. Data analysis

The articles included in the final analyses (n = 15) were first examined with regard to their data (using only selected bibliometric analysis tools) so that the study sample could be preliminarily described. To describe the sample, we chose from the most popular bibliometric

indexes (Khan et al., 2020), such as number of publications, date of publication, and keywords. We enhanced the bibliometric analyses with graphical visualizations, which is methodologically desirable for this type of research (Jadil *et al.,* 2021; Kumar *et al.,* 2022). In creating the graphical visualizations, we used the VosViewer ver. 1.6.20.

We started our analysis of keywords by identifying their number. The criterion for including a keyword in the analysis was its appearance in at least 1 of the approved articles, which was justified by the small number of the articles returned by the database search. Based on this criterion, we identified 102 keywords. In the next step, we manually removed those that were not relevant to the purpose of the study. The exclusion criterion was words with technical characteristics, unrelated to the substantive content of the texts (e.g. names of countries, names of research methods, etc.). With this exclusion criterion, we reduced the number of keywords by 30. Thus 72 keywords were accepted for the final substantive and chronological analysis. Using the keyword network analysis and the VosViewer ver. 1.6.20, we grouped the keywords into thematic clusters and identified network links among them.

We then analysed the abstracts of the articles. At this stage, the collection of the articles was not reduced. All articles thematically met the inclusion criteria and were accepted for the next stage, namely a content analysis of the full texts aimed at identifying the stimulators of and barriers to the implementation of AI within the framework of organizational change. Content analysis of full texts is methodologically recommended to obtain an additional insight into publications qualified for a review (Piwowar-Sulej, Iqbal, 2023). Based on an in-depth reading of the articles qualified for analysis, we identified factors that constitute stimulators and barriers to the implementation of AI as part of organizational changes. Then, we categorized the identified stimulators and barriers using a logical classification method (Bailey, 1994; Saran, 2014), using the criteria of exhaustiveness and separability of classified elements recommended in this method. The principle of exhaustiveness means that each selected element (in our case, a stimulator or barrier) is assigned to the appropriate category, while the principle of separability assumes that none of the selected elements fits into more than one of the created categories. We created categories based on the criterion of substantive matching.

As a final step, using the exploratory research methodology (Saunders *et al.,* 2009), we developed a theoretical framework identifying the relationship between AI tool implementation and digital maturity in the context of the previously identified stimulators of and barriers to AI implementation as part of organizational change. The concept of digital maturity became the focal point of our considerations at this stage. Knowing from keyword searches that it had not yet been linked to AI implementation as part of a systematic organizational change process, we planned to address this research gap. We addressed this gap by analysing the impact of the stimulators and barriers to AI implementation as part of organizational change, identified in the previous stage, on the level of digital maturity of enterprises, determined by the dimensions of digital transformation identified in our previous research (Bąk, Jedynak, 2024).

3. Results

3.1. Characteristics of the sample

The first of the 15 articles shortlisted for analyses was published in 2018. None of them was published in the years 2019-2020. Two articles were published in 2021 and one in 2022. The years 2023-2024 saw an increase in the interests in the topic under consideration, with four and seven publications, respectively (Figure 2). The data confirm that the implementation of AI within a structured change management process is a rather moderately popular research topic. However, those publications that do appear emphasize the relevance of this approach to the introduction of AI in enterprises. The upward trend in the number of articles seen from 2023 onwards is arguably a consequence of the intensive development of digitalization and digitization processes, initiated during the COVID-19 pandemic and developing thanks to the technological innovations emerging in the following years, also those related to AI (e.g. chatGPT, chatbots, Cloud AI, etc.).

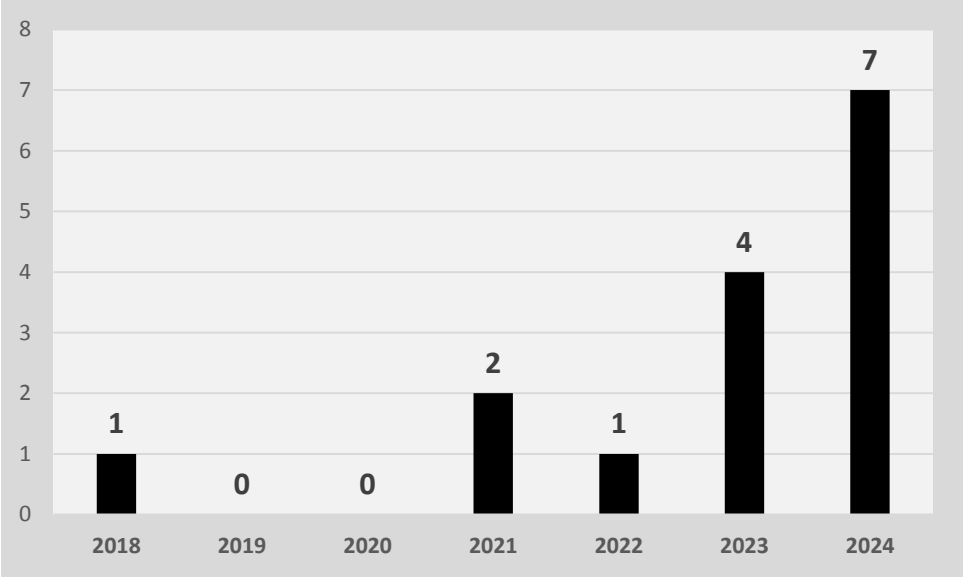


Figure 2. Number of articles chronologically.

Source: own study.

Of the articles analysed, twelve were articles published in peer-reviewed journals and three in peer-reviewed conference proceedings.

3.2. Keywords analysis

The 72 words and phrases approved for a keyword network analysis were examined in terms of both their frequency of appearance in the articles and chronology (Figure 3, Figure 4). The keywords were divided into eight thematic clusters. The elements within each cluster showed network relationships with each other. With this, we finally identified 433 links and 447 total link strength among the keywords.

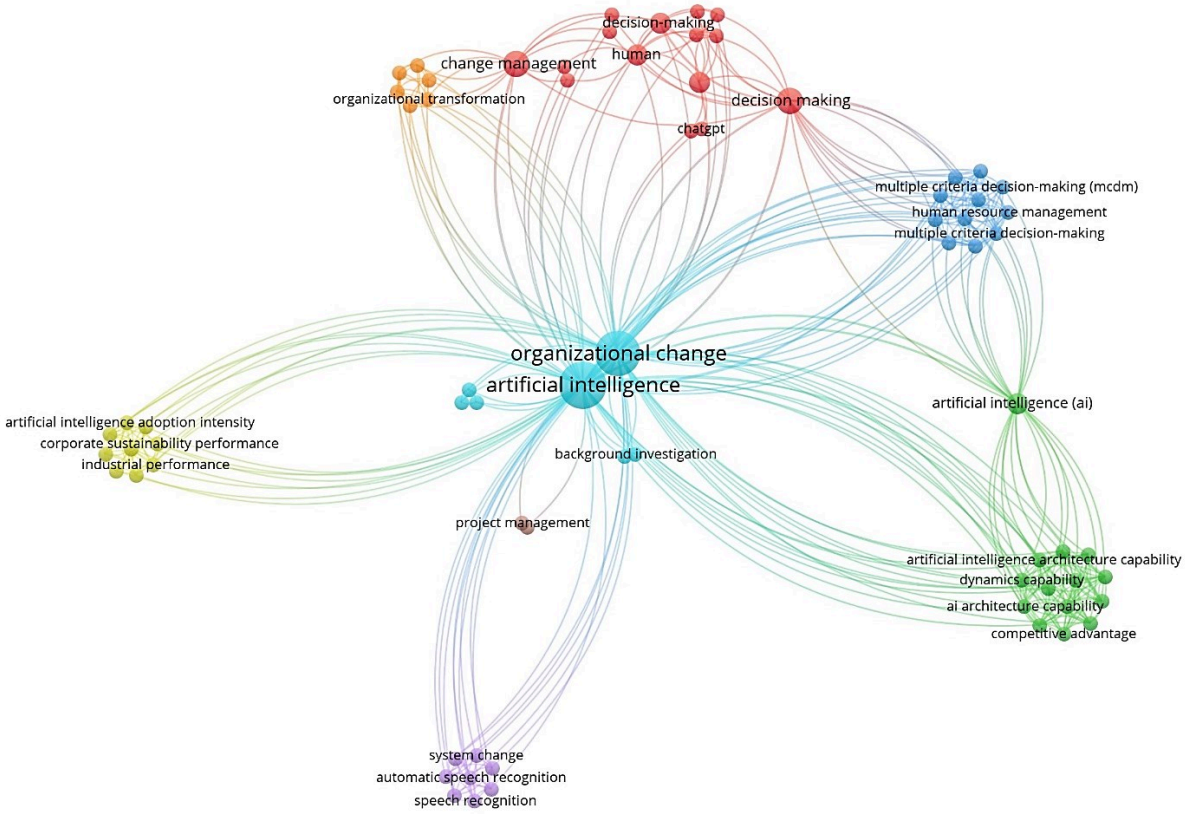


Figure 3. Keyword map (criterion: occurrences and network).

Source: own study in VosViewer ver. 1.6.20.

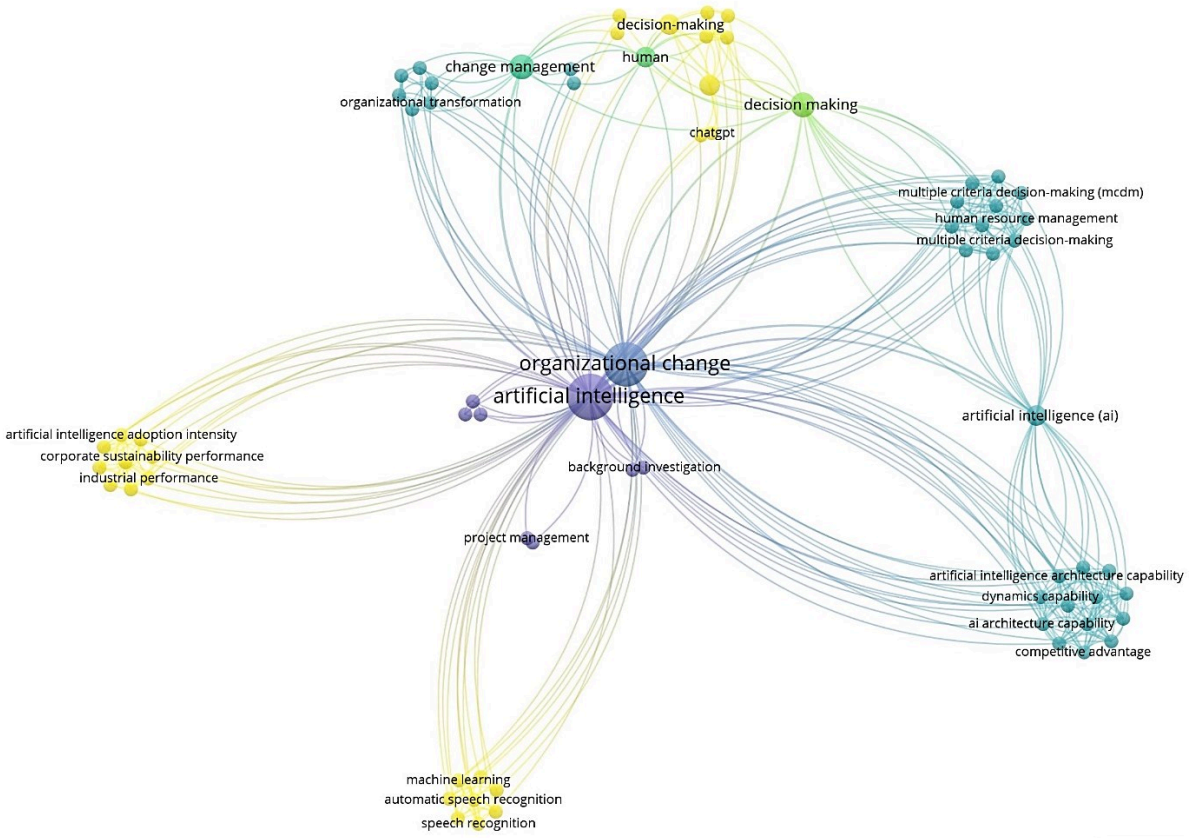
The keywords that dominated in terms of frequency and demonstrated links with other keywords included artificial intelligence, organizational change, change management and decision making (Table 1).

Table 1.
Most frequently occurring keywords

Keyword	Occurrences	Links	Total link strength
artificial intelligence	10	64	74
organizational change	9	65	74
change management	3	15	17
decision making	3	24	27

Source: own study.

Taking into account the criterion of chronology, it can clearly be seen (Figure 4) that the dynamics of the emergence of new AI is also reflected in the articles under analysis. For example, the keywords such as ChatGPT, speech recognition, generative artificial intelligence have started to appear in the most recent articles. These articles also reflect new, more sophisticated trends in approaches to implementing AI as part of a structured change management process rooted in strategy development; keywords such as organizational development (OD) practice, organizational development (OD) intervention strategies, organizational change management, corporate strategy, corporate sustainability performance are being used more and more often.



Note: chronologically – from dark colour to light colour.

Figure 4. Keyword map (criterion: chronology and network).

Source: own study in VosViewer ver. 1.6.20.

3.3. Stimulators of and barriers to AI implementation within the framework of organizational change

The subsequent objective of the study was to indicate the stimulators of and barriers to implementing AI as part of organizational change in business organization, based on the set of articles shortlisted for examination. We considered stimulators to be factors whose occurrence, spontaneous or intentionally induced by the enterprise, supports the implementation of AI within a structured organizational change process, while barriers were defined as factors of an external or internal nature, the occurrence of which may significantly hinder the implementation of AI within a structured change management process.

We identified a total of 18 stimulators and 25 barriers divided into 8 categories (4 categories of stimulators and 4 categories of barriers):

- stimulators:
  - technological progress and pressures associated with it (5),
  - a dynamic, open approach to management (3),
  - good technological and organizational preparation (2),
  - expected benefits (8).

- barriers:
  - shortcomings in knowledge, skills and infrastructure (6),
  - legal and ethical issues (4),
  - psychological and social aversion (8),
  - necessity to adapt the management system (7).

All identified stimulators and barriers selected from the articles qualified for review, divided into categories we created are shown in Table 2.

Table 2.
Stimulators of and barriers to implementing AI as part of organizational change

Stimulators	Barriers
Technological progress and pressures associated with it 1) Development of new technologies, automation, robotization (Yang, Siau, 2018). 2) Increasingly better design practices for implementing new technologies (Young, 2021). 3) Widespread recognition of AI as a key technology for digital transformation (Kim, Kim, 2022). 4) Widespread promotion of the implementation of innovation (La Torre *et al.,* 2023). 5) Potential for generative artificial intelligence (GAI) (Kanitz *et al.,* 2023; Oswick, 2024).	**Knowledge, skills and infrastructure deficiencies** 1) Lack of continuously updated knowledge of AI applications (Kim, Kim, 2022). 2) Problems with the formation of project teams implementing AI projects (La Torre *et al.,* 2023). 3) Ambiguities related to the human-machine trust (La Torre *et al.,* 2023). 4) Doubts about technology self-efficacy and source credibility (La Torre *et al.,* 2023). 5) Shortages of skills regarding the handling of AI (Alhusban *et al.,* 2024). 6) Unique features of AI: experimental character, context sensitivity, black box character and learning requirements (Engel *et al.,* 2021).
Dynamic, open approach to management 1) Transformational system of management (Yang, Siau, 2018). 2) Emergence of models supporting business transformation (La Torre *et al.,* 2023). 3) Dynamic capabilities and operational agility (van de Wetering, 2023).	**Legal and ethical issues** 1) Security issues (Young, 2021). 2) Lack of uniform legal conditions relating to AI (Kim, Kim, 2022). 3) Privacy breaches and misinformation (Alhusban *et al.,* 2024). 4) Ethical and social norms (Alhusban *et al.,* 2024).
Good technological and organizational preparation 1) High digital capabilities and innovative cultures (Li, Jin, 2024). 2) Strong governance frameworks, including policies, guidelines and regular audits (Alhusban *et al.,* 2024).	**Psychological and social aversion** 1) Fear of losing jobs (Yang, Siau, 2018). 2) Threat of emerging upheaval of the society (social upheaval) (Yang, Siau, 2018). 3) Aversion to major organizational change (Yang, Siau, 2018; Alhusban *et al.,* 2024). 4) Personnel and organizational issues (Yang, Siau, 2018). 5) Problems with acceptance of technological change e.g. by employees or customers (La Torre *et al.,* 2023). 6) Resistance to change associated with adopting machine-based decisions (La Torre *et al.,* 2023). 7) Stress caused by organizational transformation (Aditya, 2023). 8) High failure rates of AI implementation projects (Engel *et al.,* 2021).

Cont. table 2.

Expected benefits	**Need to adapt the management system**
1) Expected benefits of evolving process functionalities (Yang, Siau, 2018). 2) Opportunities for gaining competitive advantage (Engel *et al.,* 2021). 3) Opportunities to improve or create new products and services (Engel *et al.,* 2021). 4) Opportunities to create a better future and performance (Kim, Kim, 2022). 5) Better alignment with stakeholder requirements (Kim, Kim, 2022). 6) Potential to reduce operating costs and increase productivity (La Torre *et al.,* 2023). 7) Opportunities to increase employee commitment, productivity and satisfaction (Alhusban *et al.,* 2024). 8) Positive impact on corporate sustainability performance (Li, Jin, 2024).	1) Rapid pace of change in enterprises (La Torre *et al.,* 2023). 2) Necessity to change organizational culture (Kanitz *et al.,* 2023; Alhusban *et al.,* 2024). 3) Necessity to redesign existing systems (Arets *et al.,* 2024). 4) Problems with organizing for data, testing and validating, algorithmic brokering (Krome *et al.,* 2024). 5) Necessity to implement changes in strategy and policymaking (Li, Jin, 2024). 6) Changing the organization of (internal and external) work (Raj *et al.,* 2024). 7) Necessity to implement AI in the professional change management process (*Kamran et al.,* 2024).

Source: own study.

Our analyses showed that the largest number of stimulators for AI implementation as part of organizational change are those from the "expected benefits" category, meaning that the main motivator for companies to implement AI tools are the expected (mainly long-term) benefits they can achieve. In turn, the largest group of identified barriers were from the "psychological and social aversion" category, confirming that social concerns and controversies related to the risk of job loss or the replacement of key employee competencies by AI tools may be the main obstacle to implementing AI tools.

3.4. The impact of stimulators of and barriers to AI implementation on digital maturity – a theoretical framework

AI undoubtedly exerts influence on the digital maturity of enterprises, which has already been confirmed in the theoretical part of this article. Admittedly, it is not the only one, but one of several elements indicating the level of digital maturity, however, one that is crucial for ensuring continuous digital development. Based on the results from an earlier stage of the study, which identified stimulators and barriers, and using the results of our previous research on digital maturity and its measurement (Bąk, Jedynak, 2024), in Figure 5, we present the expected impact of the stimulators of and barriers to implementing AI on enterprises' digital maturity as part of organizational change processes.

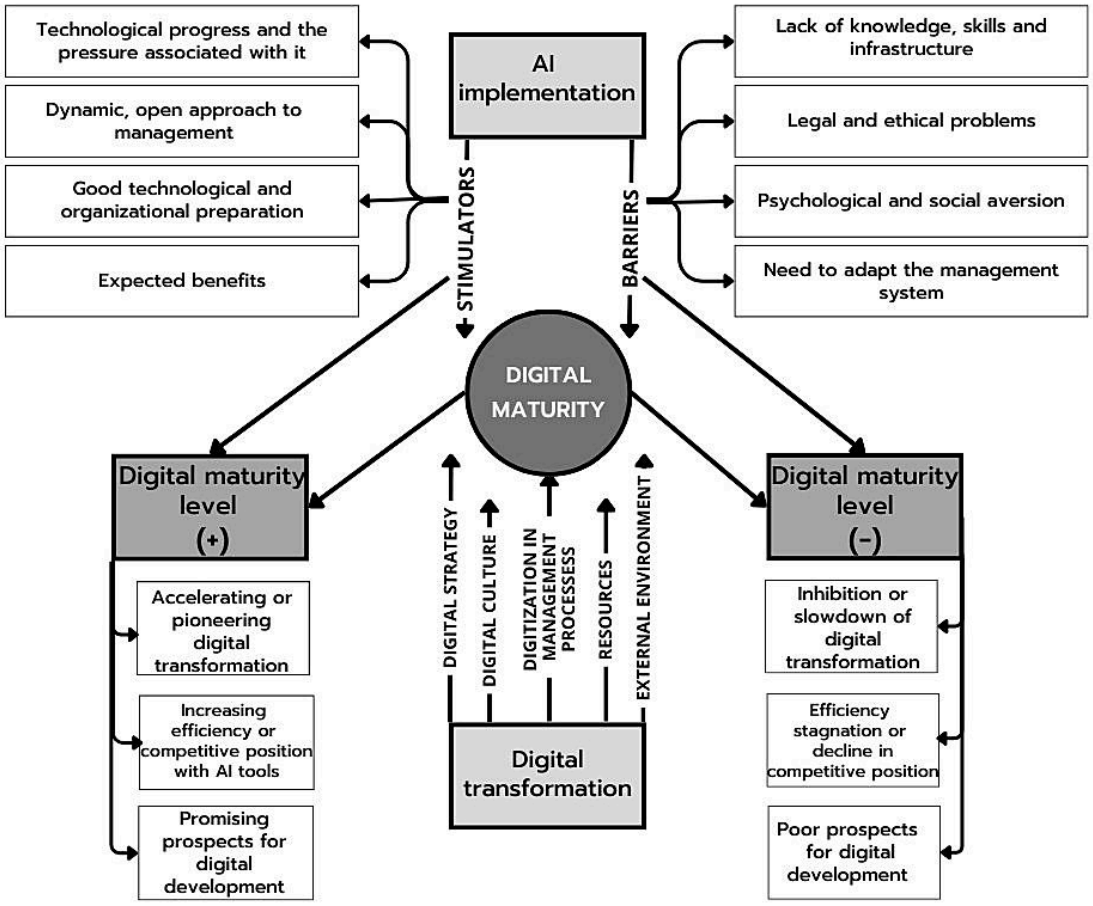


Figure 5. The impact of stimulators of and barriers to AI implementation on digital maturity – a theoretical framework.

Source: own study.

The implementation of a structured digital transformation process, together with a thoughtful adaptation of AI, are now the main determinants of digital maturity pursued by business organizations. The following factors are responsible for the effectiveness of the digital transformation process: digital strategy, digital culture, resources, digitization in management processes and external environment (Bąk, Jedynak, 2024). On the other hand, the effectiveness of the implementation of AI is closely dependent on both the stimulators identified by us and the opportunities to exploit them, as well as the indicated barriers and the ability to deal with them.

If there are problems in dealing with the barriers to AI implementation, the previously achieved digital maturity level may be reduced, which may be reflected, among other things, in slowing or stunted digital transformation, stagnating or declining performance indicators or a worsened competitive position and poor digital development prospects.

In contrast, when the potential of the stimulators of AI implementation is realized, the previously achieved digital maturity level can increase, which can be reflected, among other things, in an acceleration of the digital transformation process, higher performance indicators or an improved competitive position and better prospects for digital development.

Ultimately, based on this part of our research, we believe that the individual trends in digital development of each enterprise will determine the level of its market effectiveness, business cooperation and the financial and non-financial results achieved.

4. Discussion

The performed literature review allowed us to answer all the research questions posed. Firstly, we were able to identify the main threads of research on the implementation of AI in enterprises as part of organizational change. The conclusions of this part of the study indicate that the implementation of AI in business organization within the framework of a structured change management process has not yet been extensively explored in the academic literature, one could even say that it is niche. We more often encounter AI implementation incidentally or as a result of an innovation development plan rather than as a result of integration with the strategy and leading development path of the enterprise.

In addition, based on the content identified in the review of the relevant articles, we were able to create a catalogue of the stimulators of and barriers to implementing AI as part of organizational change. We categorized the identified stimulators and barriers to form a coherent picture of the current environment of the companies actively involved in the digital transformation of their operations. Due to the fact that previous studies related to the analysis of the impact of implementing AI tools on enterprises most often did not consider this process in the context of systematic change management, the stimulators and barriers we identified can be considered a new catalogue. The frequency of identified stimulators and barriers is also important. Our research showed that the most common barriers are "psychological and social aversion", while the most common stimulators are those from the "expected benefits" category.

In the third step of our study, having identified another research gap, we focused on finding the relationship between the identified stimulators of and barriers to implementing AI as part of organizational change with an enterprise's level of digital maturity. Proposing a theoretical framework, we concluded that the identified stimulators and barriers may have a direct impact on whether an enterprise's current digital maturity level will increase or decrease (and what will be the dimensions of this increase or decrease). Another important conclusion relates to the fact that the introduction of AI does not equate to a higher level of advancement in the digital transformation process; on the contrary, sometimes an ill-considered AI implementation process that fails to take into account basic formal and ethical risks can cause a number of negative complications and, consequently, a decrease in digital maturity.

5. Conclusions

Our findings provide a number of implications relevant to both theoretical considerations and practical applications. Firstly, the established catalogue of the stimulators of and barriers to the implementation of AI within the framework of change management can be a starting point for further research on identifying changes taking place in enterprises as a result of implementing increasingly sophisticated AI. Also, the knowledge of these stimulators and barriers can be useful for business organization which do not have the necessary expertise to implement AI, but find it necessary in order to, for example, reach new customer groups or improve their market position. Therefore, the results of our research can be applied in practice in order to better prepare to cope with potential barriers or to better use stimulating factors.

The proposed theoretical framework outlining the impact of the stimulators of and barriers to AI implementation on digital maturity also has theoretical value, if only in showing how AI implementation, digital transformation and digital maturity correlate with each other. Furthermore, our model can also have practical applications, as it can raise decision makers' awareness of the concrete positive impact of the proper exploitation of the potential of the identified AI implementation stimulators on their enterprises' digital maturity, as well as the negative consequences of failing to address the implementation barriers. This may be very important for them in the context of planning their digital development path.

It can therefore be concluded that our research fills the research gaps identified at the outset, contributing new knowledge about the stimulators and barriers to AI implementation within organizational change. Our research findings also have broader implications for the discipline of management science, as they constitute an important starting point for research on the interdependencies between AI development and an organization's digital maturity, as well as the factors influencing this maturity level.

Our study had some limitations. Firstly, despite the fact that we chose as many as three integrative databases for the literature review, there is a risk that articles meeting the inclusion criteria for the analyses can also be found outside these databases, and therefore we failed to find all the articles we were looking for. We also recognize that the catalogue of the stimulators of and barriers to implementing AI as part of organizational change created by us on the basis of the literature review is not exhaustive, as such barriers can certainly also be identified on the basis of empirical research conducted in real companies. Nevertheless, the proposed catalogue allowed us to develop the categories of stimulators and barriers, which, in our opinion, constitutes a very good starting point for complementing these categories with other factors (for example, factors identified on the basis of empirical research), which is a potential direction for further research in this area. Another potential direction for further research is to explore the differences between implementing AI in an enterprise on an ad hoc basis and implementing AI using the organizational change approach. Secondly, continued research should also examine how innovation and AI will transform the digital development landscape of enterprises in various sectors and how they will directly impact their digital maturity.

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ECONOMIC AND ORGANISATIONAL EFFECTS OF IMPLEMENTING THE FLEXIBLE "MOBILE WORK" MODEL AT SIEMENS AG IN MUNICH

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Purpose: The aim of this article is to conduct a multidimensional assessment of the impact of implementing the Mobile Work model at Siemens AG on the company's economic efficiency, organisational flexibility and employee well-being. The study attempts to analyse changes in the functioning of the organisation resulting from the institutionalisation of the 'Mobile Work' model, which has become one of the key elements of the human capital and infrastructure resource management strategy at Siemens AG.
Design/methodology/approach: The study was based on a comparative methodology using data from publicly available Siemens AG corporate reports, in particular *the Siemens Sustainability Report 2023* and *the Siemens Annual Report 2023*.
Findings: The research results will be presented in tabular form, including a summary of figures from the period prior to the implementation of Mobile Work and data for 2023 from *the Siemens Sustainability Report 2023* and *Siemens Annual Report 2023*.
Research limitations/implications: The study has certain limitations resulting primarily from the nature and availability of source data. The analysis of Siemens AG data encounters limitations related to its aggregated form, lack of full methodological transparency, and the influence of external factors such as macroeconomic changes and labour market transformations. Nevertheless, the results remain valuable and point to directions for further research on comparative models of hybrid work.
Practical implications: The results of the study indicate that the implementation of the "Mobile Work" model can be an effective organisational strategy, contributing to improved economic efficiency and stabilisation of human resources in companies with a complex structure.
Social implications: Organisational innovation in the form of the "Mobile Work" model has significant social implications, particularly in terms of employees' quality of life, work-life balance, and increased autonomy in choosing where to work.
Originality/value: The study brings significant added value to the literature on the subject by integrating economic and socio-organisational perspectives in the analysis of the effects of implementing organisational innovation in a global industrial enterprise. The novelty of the article lies in its comprehensive assessment of the effects of "Mobile Work", covering both quantitative and qualitative parameters, and in linking the results to the broader context of organisational transformations taking place in industrial corporations.

Keywords: "Mobile Work"; flexible forms of work; human resource management; economic efficiency; organisational innovation.
Category of the paper: Research paper.

1. Introduction

Contemporary enterprises operating in conditions of dynamic digital transformation are undergoing intensive reconstruction of their organisational structures and working models, which is reflected in the growing popularity of hybrid and mobile forms of work. Literature on management, organisational economics and labour sciences emphasises that the transition from traditional, stationary work systems to mobile forms is not only a response to technological and social challenges, but also a tool for cost optimisation and a mechanism for strengthening the flexibility of organisational processes (Krajčík, Schmidt, Baráth, 2023). In this context, Siemens AG is one of the global leaders in implementing organisational innovations aimed at redefining the relationship between the employee, the workplace and the management structure.

The "Mobile Work" model at Siemens AG, which defines the possibility of working outside the traditional office environment for a certain part of the week, was introduced as a long-term strategic organisational innovation. The implementation of this solution was aimed at reducing operating costs, improving the quality of the organisation's functioning, increasing employee well-being and ensuring greater operational resilience of the company in a volatile environment. Given the scale of Siemens AG's operations, with over 300,000 employees in more than 190 countries, the analysis of the effects of the implementation of "Mobile Work" is a particularly valuable study of organisational transformation processes in the global high-tech industry.

This study analyses the changes that have taken place in the structure of operating costs, work process efficiency and employee well-being indicators following the implementation of Mobile Work, including office infrastructure maintenance costs, energy consumption, employee productivity, absenteeism and job satisfaction levels. The year 2023 was taken as the basis for the analysis, which is due to several fundamental methodological and substantive reasons.

Firstly, 2023 is the period in which the Mobile Work model at Siemens AG has reached a phase of operational stability, meaning that the organisation has already gone through the implementation, adjustment, iterative modification and structural correction stages. This allows the effects to be analysed in a phase of full functionality, rather than merely as a response to extraordinary circumstances.

Secondly, Siemens AG's corporate reports for 2023 (*Sustainability Report 2023 and Annual Report 2023*) provide complete, verified and publicly available figures on key operational, environmental and employee indicators. These data are highly accurate, transparent and compliant with ESG standards, which allows them to be used directly in scientific analysis.

Thirdly, 2023 is the first year completely free from pandemic disruptions, making it possible to separate the impact of organisational innovation from the impact of external systemic shocks. This means that the results obtained are more reliable and can be considered a reflection of the actual effects of implementing "Mobile Work".

Fourthly, 2023 is a reference point in Siemens AG's long-term #NextWork strategy, which gives the analysis particular predictive and strategic value, allowing the effects of implementation to be interpreted not only from a current perspective, but also in the context of long-term transformation processes (Siemens Advanta. 2023. *#NextWork - Systematic workforce transformation: NextWork OnePager*. Siemens AG).

The choice of 2023 therefore translates into the possibility of conducting an analysis that is simultaneously current, reliable and embedded in the full cycle of organisational innovation. This article is an attempt to systematically assess the effectiveness of the implementation of "Mobile Work" from a managerial, economic and social perspective, using quantitative data and strategic analysis tools. As a result, the findings can serve as a basis for in-depth research on new forms of work organisation in the industrial sector and for practical implementation recommendations for companies considering the implementation of a hybrid model.

2. Literature Review

The issue of organisational innovation and the transformation of work models is becoming increasingly prominent in contemporary literature on management, labour economics and organisational theory. Researchers unanimously emphasise that in the context of intensive digitalisation and the growing complexity of the economic environment, traditional, hierarchical and centralised models of work organisation are gradually being eroded, giving way to solutions based on flexibility, decentralisation and a high level of employee autonomy (Grundei, 2024; Kabus, Samek-Wojtyla, 2024). International literature indicates that organisational innovations, including forms such as remote work, hybrid work and mobile work, are becoming key instruments for building competitive advantage and improving organisational efficiency in a knowledge-based economy (Nwankpa, Roumani, 2024).

A significant part of the research has been devoted to the transformation of work models after 2020, when global disruptions caused by the COVID-19 pandemic accelerated the adaptation of digital technologies and mobility-based working methods (Kravchuk, 2025). The authors of the analyses emphasise that although remote working was initially a forced

solution, in subsequent years many companies institutionalised it, giving it a strategic character (Mariani et al., 2023). The literature refers to the concept of "hybrid work maturity", which refers to an organisation's ability to achieve a stable, optimised and long-term hybrid work model that takes into account both organisational interests and employee needs (Cimini, Lagorio, Cavalieri, 2024). Researchers point out that factors such as the quality of digital infrastructure, knowledge management systems, organisational culture and the level of digital competence determine the effectiveness of the implementation of hybrid work innovations (Westkämper, 2024).

The hybrid work model is also analysed in economic literature, where attention is drawn to its potential to reduce companies' operating costs. It is pointed out that reducing the need to maintain large office spaces, reducing energy costs and optimising infrastructure resources are among the most frequently observed effects of this type of innovation (Reuter, 2022). Empirical research confirms that the implementation of mobile work leads to improved cost efficiency and, at the same time, increases employee productivity, especially in sectors characterised by a high proportion of intellectual work (Mehrabi, 2024). These effects are particularly evident in technology and industrial companies that implement integrated IT systems and digital work tools.

At the same time, the literature on hybrid work innovation takes into account numerous socio-psychological and micro-organisational aspects (Schulze et al., 2024). Researchers point out that mobile work affects employee satisfaction, well-being and work-life balance (Efimov et al., 2025). Many studies emphasise that increased autonomy and the ability to shape individual work schedules promote increased internal motivation, reduced work-related stress and lower absenteeism (JAß, 2025). At the same time, the literature draws attention to the risks associated with hybrid work, such as social isolation, weakened team bonds, difficulties in building organisational culture, and the risk of digital overload associated with the intensive use of communication technologies (Nolten, Jahn, 2025).

Strategic research emphasises that the implementation of hybrid work requires a redefinition of organisational architecture (Kreuzer et al., 2022). Companies that achieve high efficiency in mobile working conditions are characterised by flat organisational structures, advanced coordination methods, flexible decision-making and an organisational culture based on trust and transparent performance evaluation criteria. Research suggests that companies derive the greatest benefits from implementing hybrid models when organisational innovations are coupled with investments in digital technologies, knowledge management systems and employee competence development (Bosler, 2023).

In the context of large industrial corporations, literature on office infrastructure management and workplace transformation is particularly relevant. It is pointed out that companies with a complex spatial structure and geographically dispersed teams can achieve significant benefits from rationalising office space, including reducing energy costs, space management and technical maintenance (Klaffke, 2022). The literature also emphasises the importance of

sustainable development policies, in which mobile work is treated as a means of reducing transport-related emissions and as a tool for supporting the environmental goals of organisations (Hofmann, Ricci, 2023).

Finally, the literature on organisational transformation indicates that companies implementing innovations in the area of work organisation, such as "Mobile Work", become more resilient to both technological and market disruptions (Kojima, Iriyama, Komuro, 2025). Researchers point out that structural flexibility, process adaptability and the ability to manage distributed work are the foundation of long-term competitiveness for companies in sectors with high technological growth dynamics (Stephens, 2023). Taking into account the above achievements, this article is part of a multidimensional trend in research on organisational innovation, introducing an empirical analysis of the implementation of "Mobile Work" at Siemens AG, one of the global leaders in the transformation of work models, to the literature. In particular, it extends existing approaches with a set of organisational and economic indicators based on data from *the Siemens Sustainability Report 2023* and *the Siemens Annual Report 2023*, which enables an analysis based on hard data, in line with the requirements of contemporary management science.

3. Methods

The research methodology was based on a comparative analysis of selected organisational and economic indicators of Siemens AG, referring to the period before the implementation of the "Mobile Work" model and data for 2023, when the solution reached full operational maturity. The analysis was based on information disclosed in the Siemens Sustainability Report 2023 and the Siemens Annual Report 2023, covering both economic parameters and environmental and employee data directly related to the functioning of hybrid work. This data is reliable, audited and compliant with ESG disclosure standards, which allows it to be used in scientific analysis and, at the same time, ensures that a reliable inter-period comparison can be made.

The methodology identified indicators particularly susceptible to change as a result of the implementation of "Mobile Work", including electricity consumption, infrastructure costs assigned to office facilities, the number of employees in administrative positions enabling hybrid work, and the level of employee satisfaction declared in non-financial reports. Energy and infrastructure data were considered key because hybrid work affects the intensity of office use, which directly translates into energy, space and technical maintenance costs. Data on employment and employee satisfaction, on the other hand, reflect the social and organisational results of innovation. The analysis uses absolute values and percentage change indicators to capture both the scale of the effects and their dynamics.

Table 1 presents a summary of selected Siemens AG indicators illustrating the situation before the implementation of the "Mobile Work" model and the results for 2023.

Table 1.
Selected organisational and economic indicators for Siemens AG before the implementation of "Mobile Work" and in 2023

Indicators	Period before implementation (2019*)	2023	Change%
Electricity consumption (GWh)	1320	1050	-
Property and infrastructure costs (EUR billion)	2.36	1.88	-20.3
Hybrid workers (% of total workforce)	0	81	+81 p.p.
Sick leave (days/year/employee)	10.3	8.7	-15.5
Employee satisfaction (scale 1-5)	3.4	4.1	+20.6

*2019 was taken as the base year prior to the #NextWork transformation and before the implementation of the "Mobile Work" model.

Source: own study based on the Siemens Sustainability Report 2023 and Siemens Annual Report 2023.

The data compiled in Table 1 show a clear improvement in the key organisational and economic parameters of Siemens AG following the implementation of the Mobile Work model, confirming the effectiveness of the innovation in operational and socio-organisational terms. The most measurable effect is a significant reduction in electricity consumption by 20.5%, which is a direct consequence of reducing the intensity of office space use and optimising infrastructure as part of the #NextWork programme. Real estate and infrastructure costs have also decreased by 20.3%, confirming the economic dimension of the effectiveness of hybrid work implementation and confirming that the reorganisation of the way work is performed generates lasting savings.

A particularly important indicator is the rapid increase in the percentage of employees performing hybrid work, from 0% in the period prior to implementation to 81% in 2023. This indicates the full institutionalisation and maturity of the "Mobile Work" model, as well as its acceptance among employees, which is crucial from the point of view of organisational culture and management process stability.

Positive effects of the implementation can also be observed in terms of employee absenteeism, which has been reduced by 15.5%. This result is consistent with the findings in the literature, according to which flexible working models reduce organisational stress and promote employee well-being. At the same time, the increase in job satisfaction from 3.4 to 4.1 on a five-point scale (an increase of 20.6%) testifies to the positive reception of "Mobile Work" and confirms that hybrid work strengthens employee autonomy, improves the perception of the quality of the working environment and increases internal motivation.

Interpretation of the data leads to the conclusion that the implementation of Mobile Work at Siemens AG has brought about simultaneous beneficial changes in economic, energy and employee terms. The results obtained are systemic in nature and indicate that organisational innovation has become an integral part of the company's operational and development strategy. The results confirm that hybrid working models can be an effective tool for building

organisational resilience and long-term competitive advantage in technology and industrial companies.

4. Results

The results of the empirical analysis based on Siemens AG data clearly indicate that the implementation of the "Mobile Work" model has generated significant changes in the cost structure, infrastructure utilisation intensity, employee productivity and well-being. In order to capture the multidimensional nature of these effects, two tables were presented: a table of economic and energy indicators and a table of employee and organisational indicators.

In order to capture the economic and environmental effects of implementing the Mobile Work model at Siemens AG, a detailed analysis of indicators relating to the functioning of office infrastructure and energy consumption was carried out. These data are particularly important because hybrid working leads to changes in office space usage patterns, which directly affect operating costs, energy demand and emission levels. Table 2 presents a comparison of key economic and environmental parameters, covering the period before the implementation of Mobile Work and the year 2023, when the model reached full operational maturity. These data form the basis for assessing the material effects of organisational innovation and serve to further interpret the significance of the transformation in terms of infrastructure.

Table 2.
Economic and environmental indicators for Siemens AG before the implementation of Mobile Work and in 2023

Indicators	Period before implementation (2019)	2023	Change%
Electricity consumption (GWh)	1320	1050	-
Heat consumption (GWh)	970	745	-23.2
Total office infrastructure costs (EUR billion)	2.36	1.88	-20.3
Total office space in use (thousand m²)	2,910	2,120	-27.1
CO_2 emissions related to the use of facilities (thousand tonnes of CO_2 e)	468	351	-25.0

Source: own study based on the Siemens Sustainability Report 2023 and Siemens Annual Report 2023

The data presented in Table 2 show a structural improvement in Siemens AG's energy and infrastructure indicators as a direct result of the implementation of the "Mobile Work" model. The 20.5% reduction in electricity consumption and 23.2% reduction in heat energy consumption is a consequence of the reduction in the number of employees simultaneously present in office spaces, which leads to a reduction in the demand for lighting, heating, cooling and the operation of office equipment.

The 27.1% reduction in floor space reflects the systematic restructuring of Siemens AG's real estate portfolio in line with the #NextWork strategy. The reduction in office space requirements has translated into a 20.3% reduction in office infrastructure costs, which is a significant economic effect in the context of the high capital intensity of maintaining the group's global infrastructure.

The 25% reduction in CO_2 emissions associated with the use of facilities is also of particular importance. This indicates that "Mobile Work" not only affects economic parameters, but also supports environmental goals within Siemens AG's sustainability strategy. The results are in line with observations in the literature, according to which hybrid working and reduced office use bring benefits in terms of energy efficiency and carbon footprint reduction.

To obtain a complete picture of the consequences of implementing the "Mobile Work" model at Siemens AG, it is necessary to consider not only the economic and infrastructural effects, but also the changes taking place in the area of employee functioning and organisational processes. Table 3 presents key indicators related to employee behaviour, well-being, job stability and productivity, which are a direct response of the organisation to the transformation of the working model. A comparison of data from the period before the implementation of Mobile Work and the results from 2023 allows us to identify the direction and scale of changes that indicate the systemic nature of the impact of hybrid work on the functioning of the company.

Table 3.
Employee and organisational indicators at Siemens AG before the implementation of Mobile Work and in 2023

Indicators	Period before implementation (2019)	2023	Change
Employees performing hybrid work (% of total)	0	81	+81 p.p.
Sick leave (days/year/employee)	10.3	8.7	-23.2
Employee turnover (%)	7.4	5.9	-20.3
Employee satisfaction (scale 1-5)	3.4	4.1	+20,6%
Average productivity (tasks/year/employee)**	100	114	+14.0

** The "Average productivity (tasks/year/employee)" indicator was calculated based on internal task efficiency indicators published by Siemens AG as part of its ESG reporting and aggregated data on task completion in administrative and engineering departments.

Source: own study based on the Siemens Sustainability Report 2023 and the Siemens Annual Report 2023.

The results in Table 3 show that the "Mobile Work" model has brought Siemens AG not only economic benefits, but also organisational and social ones. The most striking indicator is the increase in the percentage of employees using hybrid work to 81% in 2023, which confirms the full institutionalisation and acceptance of this model within the company's structures. Such a high level of adaptation indicates the maturity of the technological, organisational and cultural solutions necessary for the effective functioning of mobile work.

A 15.5% reduction in sick leave suggests an improvement in employee well-being, which is consistent with scientific research indicating that flexible working models reduce organisational stress and promote better work-life balance. The 20.3% decrease in employee turnover confirms that hybrid work is a factor that stabilises employment and strengthens retention, which is of strategic importance in a company operating on a global scale.

The 20.6% increase in employee satisfaction confirms the positive impact of Mobile Work on the perception of the quality of the working environment, the sense of autonomy and flexibility. This is particularly important in the high-tech sector, where internal motivation and employee well-being are critical determinants of innovation.

The 14% increase in average productivity proves that concerns about a potential decline in productivity in a distributed work environment are not confirmed by Siemens AG data. On the contrary, Mobile Work supports task efficiency, which results from the ability to concentrate on work, reduce distractions and better organise time.

5. Discussion

The results of the analysis clearly indicate that the implementation of the Mobile Work model at Siemens AG has had a multidimensional impact on the functioning of the organisation, covering economic, environmental and employee parameters. The reduction in operating costs, energy consumption and office space confirm that Mobile Work is not only an organisational solution, but also a strategic instrument for resource rationalisation. These effects are in line with the trends described in the literature concerning the optimisation of work processes in the context of digitalisation and the spread of technologies that enable work to be performed outside traditional office structures. The results of Siemens AG correspond with the findings of authors who emphasise that hybrid work leads to a moderate but stable reduction in the costs of maintaining office space and energy infrastructure, thereby improving the economic efficiency of companies.

The changes observed in terms of employees, including a reduction in sick leave, an increase in job satisfaction and a decrease in staff turnover, point to the significant social benefits of the "Mobile Work" model. The literature on the subject clearly emphasises that solutions based on spatial and temporal flexibility contribute to improving the well-being of employees, helping them to better organise their private and professional lives and strengthening their sense of autonomy. The results from Siemens AG confirm these correlations, indicating that hybrid work can be a tool for stabilising human resources by reducing turnover and increasing job satisfaction.

At the same time, a noticeable increase in productivity suggests that in dispersed working conditions, the efficiency of task completion is not impaired – on the contrary, it can be significantly enhanced. This result is consistent with research indicating that hybrid work allows for greater concentration on tasks, reduces the distractions typical of open-plan offices, and promotes more conscious management of working time. In the case of Siemens AG, the increase in productivity can be linked to the high degree of maturity of the organisation's infrastructure and digitalisation, which enabled a smooth transition to a mobile working model.

A comparison of the results with the findings in the literature suggests that Siemens AG is part of a global trend towards reinterpreting the role of the working environment and the way companies manage human capital and infrastructure. The Mobile Work model should be seen as part of the broader #NextWork transformation strategy, which aims to adapt organisational processes to the conditions of a knowledge-based economy, the growing importance of digital technologies and changing employee preferences. The results confirm that this innovation is not isolated – it is a component of an extensive ecosystem of changes affecting both work architecture and organisational culture.

The analysis also points to the systemic nature of the effects of implementing Mobile Work, which distinguishes this innovation from technological solutions, whose impact is usually more local or periodic. In this case, the changes simultaneously affected the operational, environmental and organisational-social spheres, thus contributing to a long-term reconstruction of the way Siemens AG works. In light of the results, Mobile Work should be treated as a permanent element of the company's operating model, rather than a temporary solution.

It is worth noting that although the analysis revealed a number of benefits, the literature clearly indicates the need to maintain organisational culture consistency and counteract employee isolation, which may occur when direct contact is restricted for a long period of time. Although the Siemens AG data do not indicate any negative consequences in this regard, they do confirm the importance of conscious management of hybrid work and building organisational trust. The long-term effectiveness of Mobile Work therefore depends not only on technological infrastructure, but also on the ability to shape a work environment that fosters social bonds and teamwork.

In summary, the results confirm that the implementation of Mobile Work at Siemens AG has led to lasting and profound changes in the way the company operates. These changes have brought measurable economic, environmental and social benefits, confirming the validity of treating Mobile Work as an organisational innovation with high transformational potential. The article thus contributes to the scientific discourse on the future of work models and points to the possibilities of using flexible forms of work organisation as a strategic resource management tool in companies operating in conditions of dynamic technological change.

6. Summary

The aim of the article was to identify and interpret the effects of implementing the Mobile Work model at Siemens AG, treated as an organisational innovation of strategic importance for the transformation of the company's operations. The analysis based on data from the Siemens Sustainability Report 2023 and the Siemens Annual Report 2023 allowed us to reconstruct a multidimensional profile of changes taking place in the economic, infrastructural and socio-organisational spheres. The results clearly indicate that the institutionalisation of hybrid work has led to a systemic improvement in the organisation's operating parameters, including a reduction in operating costs, optimisation of infrastructure resource utilisation, a significant reduction in energy consumption and a decrease in emissions.

In terms of employees, the implementation of "Mobile Work" has brought clear benefits, visible in the form of a decrease in sick leave, an increase in job satisfaction and a reduction in employee turnover. The observed increase in productivity proves that Mobile Work, implemented in conditions of high digital maturity, does not weaken operational efficiency, but rather strengthens it, while offering the flexibility of work that meets the contemporary expectations of employees.

The results obtained prove that the Mobile Work model at Siemens AG should be interpreted as a transformative solution that integrates economic, environmental and employee goals. This innovation is a permanent feature of the organisational architecture and is part of the strategic concept of #NextWork, which aims to increase organisational resilience, structural flexibility and sustainable development of the company. The article confirms that hybrid work, implemented in a comprehensive manner and supported by a high level of digitalisation, can serve as a tool for creating long-term organisational value. The analysis is based on aggregated secondary data from corporate reports, which limits the possibility of fully verifying the methodology and causal relationships. Furthermore, the results do not reflect the diverse experiences of employees resulting from job or regional differences. Future research should consider independent data, in-depth qualitative methods, and comparative analyses covering other organisations and sectors. It is also reasonable to conduct long-term research to assess the sustainability of the observed effects.

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ASSESSMENT OF THE LOGISTICS SECTOR BASED ON A SWOT ANALYSIS

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Purpose: The aim of the paper is to identify and assess internal and external factors influencing the development of small and medium-sized enterprises operating in the logistics sector. The study focuses on determining the strategic position of logistics SMEs using SWOT analysis as a tool supporting strategic diagnosis.
Design/methodology/approach: The research is based on a SWOT analysis conducted using empirical data obtained from a survey of logistics SMEs. The identified factors were classified into four groups: macroeconomic factors, innovation and cooperation, social aspects and human resource development, as well as spatial aspects and infrastructure. Each group was assigned a weight reflecting its relative importance. The methodological approach combines qualitative analysis with a quantitative weighting of factors. The theoretical background of the study is grounded in strategic management and logistics literature.
Findings: The results indicate that logistics SMEs demonstrate strengths mainly in the areas of innovation, cooperation and the application of modern technologies. The main weaknesses are related to limited financial resources and shortages in qualified personnel. Opportunities are associated with macroeconomic conditions and the development of transport and logistics infrastructure, while threats result primarily from market instability, increasing operating costs and competitive pressure.
Research limitations/implications: The study is limited by the size and structure of the research sample, which may affect the representativeness of the results. Further research could expand the scope of analysis by including a larger number of enterprises or by applying additional strategic analysis methods.
Practical implications: The findings may support managers of logistics SMEs in identifying priority areas for strategic actions, particularly in the fields of innovation, human resource development and cooperation with external partners.
Originality/value: The paper provides an empirically based SWOT analysis of logistics SMEs with weighted strategic factors. It contributes to the literature by offering a structured assessment useful for both academic research and managerial practice.
Keywords: SWOT analysis; logistics sector; SMEs; strategic management.
Category of the paper: Research paper.

1. Introduction

The aim of this study is to present the possibilities of using SWOT analysis to identify key internal factors (strengths and weaknesses) and external factors (opportunities and threats) in the logistics sector. SWOT analysis is a tool used to examine the internal and external environment of a company in order to determine its current position and forecast its future position on the market by selecting an appropriate operating strategy. This method gained popularity in Poland when it was a formal requirement during the privatisation of companies and when applying for bank loans, as it allowed the condition of a company to be assessed. It is still used in business today as a basic analysis of listed companies (Kowalik, Klimecka-Tatar, 2017, pp. 152-162; Matuszny, 2020, pp. 36-40).

The name SWOT is an acronym of the English words: strengths, weaknesses, opportunities and threats. SWOT analysis is conducted by identifying factors that influence the company's operations and classifying them into the above four categories, creating a clear matrix (Ab Talib, Hamid, 2014, pp. 322-343). The resulting list is subject to further examination. The first step is to assign weights to individual factors so that the sum of the weights in each category is equal to 1. Next, four tables are developed to form the SWOT analysis (‘from the inside out’), which contain answers to questions about how internal factors (strengths and weaknesses) affect external factors (opportunities and threats). One way to do this is to identify dependencies in a 0/1 system (0 – no connection, 1 – dependency). The next step is to count the number of interactions for each row and column separately and sum them up for the entire table. A rank is determined for each group of factors, depending on the value achieved. After adjusting the results by weight, a weighted number of interactions between the two categories is obtained (Bryszawska, Kulesza, 2022, pp. 1-11).

The SWOT analysis can be expanded to include a TOWS (outside-in) analysis, which shows how the external environment affects the company (Szmitka, 2015, pp. 79-98). The SWOT-TOWS analysis is summarised in a table containing the number and weighted number of interactions, which is the sum of SWOT and TOWS links. The highest weighted value indicates the strategy that the company should adopt. There are four strategies: aggressive-maxi-maxi (when strengths and opportunities prevail; the company should strive for growth and invest to strengthen its market position); competitive mini-maxi (if weaknesses and opportunities are the most important; take advantage of a favourable external environment to minimise negative factors within the company); conservative-maxi-mini (when strengths and threats prevail; the company should use its strengths to minimise major threats in the environment) and defensive-mini-mini (when weaknesses and threats prevail; the least favourable analysis, in which the company must fight for survival) (Jagodziński, Szewczyk-Jarocka, Uździecki, Lipińska, 2012, pp. 112-131; Mierzwa, Goliszek, 2017, pp. 330-340; Oziębło, 2022, pp. 235-264; Skotnicka-Zasadzień, Zasadzień, Grebski, 2023, pp. 541-551).

Scientific studies emphasise that SWOT analysis is not perfect or comprehensive, but it is a fundamental tool for strategic analysis, and its results provide valuable information and guidance for conducting more in-depth research on the issue in question.

2. Materials and methods

One of the most popular strategic analysis techniques is SWOT analysis. In general terms, it is an examination of an organisation's strengths and weaknesses, as well as the opportunities and threats it faces. An organisational strategy developed using this method is based on the use of those aspects of the company's operations that are considered to be current strengths and future opportunities. In order to achieve its basic objectives, the strategy should aim to reduce or eliminate weaknesses. The list of identified threats indicates those phenomena and processes within the organisation and its environment that must be taken into account, as they may disrupt or even prevent the achievement of strategic objectives.

The name of the method comes from the first letters of the words describing the essence of the subject of analysis, i.e. strengths, weaknesses, opportunities and threats. In the literature, you can find terms such as TOWS or WOTS to describe this analysis. The order of the letters is not random, because SWOT analysis proceeds from the inside of the company to the outside, while TOWS analysis does the opposite, and TOWS/SWOT analysis combines both.

The concept of WOTS analysis is used by A. Sharplin, who emphasises forecasting organisational development based on exploiting opportunities in the environment and minimising or eliminating threats (Bryszawska, Kulesza, 2022, pp. 1-11). The second abbreviation (TOWS) was proposed by H. Weihrich, who emphasises the sequence of problem solving in strategy formulation processes (Stabryła, 2017).

The examination of an entity's strengths and weaknesses is carried out in relation to all its areas of activity and/or across one or only selected areas (e.g. marketing, finance), depending on the purpose of the diagnosis (Stabryła, 2017). SWOT analysis can be applied equally successfully to any venture, organisation or entity, within which the factors essential to their functioning should be considered. The main areas to be considered are: consumers, products, financial situation, manufacturing, i.e. production processes, manufacturing costs, marketing, research and development, operational activities and support processes, patents, contacts and trade agreements, and manufacturing technology.

There are four basic groups of factors:

a) marketing, e.g. trademarks, distribution, product ranking, prices, sales opportunities, marketing systems,
b) financial, e.g. cost of capital, financial liquidity, profitability, asset structure, price-to-earnings ratio,

c) production, e.g. manufacturing capacity, age of equipment (degree of modernity), production systems, quality control, economies of scale,
d) personnel, e.g. staff, adaptability, planned labour resources, industrial relations, working conditions (Kowalik, Klimecka-Tatar, 2017, pp. 152-162).

In conclusion, SWOT analysis constitutes a comprehensive and versatile tool for strategic diagnosis, enabling a structured assessment of both internal and external factors influencing an organisation's development. By systematically identifying strengths and weaknesses alongside opportunities and threats, the method supports informed decision-making and the formulation of coherent strategic directions. Its flexibility allows for application across various organisational contexts and functional areas, making it particularly valuable in strategic planning processes. Consequently, SWOT analysis serves not only as a diagnostic framework but also as a foundation for aligning organisational resources with environmental conditions in pursuit of long-term objectives.

3. Research results

A SWOT analysis was carried out for the logistics industry in the SME sector on the basis of the companies surveyed. The analysis included:

a) diagnosis, which identified:
   - strengths - the qualities of the organisation that distinguish it positively from its environment and competitors,
   - weaknesses - are a consequence of resource constraints and insufficient qualifications; every organisation has aspects of its functioning that limit its efficiency, but quick and objective recognition and definition can easily limit their negative impact,
b) forecasts, which describe
   - opportunities – phenomena and trends in the environment that, if properly exploited, will become an impetus for development and weaken threats,
   - threats – all external factors that we perceive as barriers to the company's development, obstacles, additional operating costs.

The separability of factors is related to an element of SWOT analysis – assigning importance to factors. Different factors may have different significance in a given market situation in which an entity finds itself. The importance of factors is determined in such a way that the sum of the weights for each group of factors is equal to 1.0 (100%).

The SWOT analysis was developed into four main groups of factors, which were assigned appropriate weights:

- macroeconomic factors – weight 0.25,
- innovation, cooperation, technologies – weight 0.35,

- social aspects, human resource development – weight 0.15,
- spatial aspects, infrastructure – weight 0.25.

The result of the analysis is the creation of four tables:

- strengths that should be reinforced,
- weaknesses that need to be eliminated,
- opportunities that should be exploited,
- threats that should be avoided (table 3).

Table 1.
SWOT analysis – macroeconomic factors

MACROECONOMIC FACTORS – weighting 0.25	
STRENGTHS	**WEAKNESSES**
- significant and growing importance in the economy, - relatively strong competition in the industry, - relatively high degree of adaptation of the sector to the requirements of customers from the European Union, - rapid adaptation to changes in demand, - easy access to distribution channels, - low share of foreign capital – independence of enterprises, - lower labour costs than in European Union countries, - equipment-intensive nature – a large cash contribution is required at the start of a business, which reduces the opportunities for new businesses to start up, - high attractiveness of the location for industry investments, - high level of services.	- difficulties in breaking into the market, - unused service capacity, - lack of funds for projects, - low level of equity capital in enterprises, - insufficient promotion of the industry, - poorly developed system for financing highly innovative projects, - moderate competitive strength in relation to other companies in the country, - strong dependence on the global economic situation, - low level of utilisation of EU funds for development purposes, - cost-price nature of competition, - lack of participation by large foreign companies, - poor brand reputation and scale of marketing support, - small number of branches in the country or their absence, - differences in the objectives of managers and business owners, - lack of long-term action strategies.
OPPORTUNITIES	**THREATS**
- good prospects for the development of the industry as a field of the future, - inclusion of the logistics industry in strategic development choices, - increasing and more sophisticated domestic demand, - entry into the euro zone, - expansion beyond the local market, - development of a strong brand, - use of business financing opportunities (EU funds), - change in the nature of competition towards quality and innovation, - improvement of logistics services, - more effective marketing activities, - promotion of Polish companies abroad, - specialisation, exploitation of market niches, - promotion of regional brands, - popularisation of modern management methods.	- prolongation of the global economic crisis, - deterioration of investment attractiveness – strong competition from other locations in Central and Eastern Europe, - high costs of improving quality, - high cost of capital and rising transport costs, - limited absorptive capacity of the Polish market, - difficulties in obtaining credit, - lack of a stable government policy supporting the SME sector.

Table 2.
SWOT analysis – innovation, cooperation, technology

MACROECONOMIC FACTORS – weighting 0.25	
STRENGTHS	**WEAKNESSES**
- strong innovation potential, - high interest in services, - no formal barriers to entry into the sector, - increased awareness of existing areas of cooperation that are lacking, - competitive advantage based on factors other than cost – on quality and compatibility, - high level of computer equipment.	- insufficient cooperation with scientific and research and development centres and local government, - regional system for supporting innovation, development and technology transfer to the SME sector not fully implemented, - low percentage of expenditure on innovation, - small number of new technologies, - lack of membership in industry organisations, - dominance of small enterprises over large ones, with less potential in the area of innovation creation and in the area of research and financing opportunities.
OPPORTUNITIES	**THREATS**
- technological and organisational development, - development of new technological applications, - overcoming soft barriers to cooperation between enterprises, and thus a significant intensification of cooperation in the region, - openness of regional authorities, - increased competitiveness understood as collaboration and cooperation, - cooperation with local administration.	- too slow technological progress in small enterprises, - inconsistent and unstable state policy on science and research, - system of commercialisation of scientific research, - replication of bad practices, - lack of a local R&D centre, - preference for acting alone, - low interest in cooperation with foreign countries, - poor legal protection of intellectual property.

Table 3.
SWOT analysis – social aspects, human resource development

SOCIAL ASPECTS, HUMAN RESOURCE DEVELOPMENT – weight 0.15	
STRENGTHS	**WEAKNESSES**
- significant increase in employment, - highly qualified management staff, - progressive specialization, - academic centres with significant educational potential.	- lack of qualified lower-level technical and financial staff, - low participation of enterprises in training courses or conferences (low level of industry-specific education), - small number of internships for students and low level of academic entrepreneurship, - relatively low number of employees with higher education and technical education, - low participation of staff in further training, - mismatch of employee qualifications, - unfavourable age structure of human resources, - low employee mobility, - lack of trust in other companies in the industry and local authorities, - low productivity and work efficiency,
OPPORTUNITIES	**THREATS**
- possibility of applying for funding for training for the needs of enterprises, - systematic improvement of labour productivity, - increase in industry education and information flow, - cooperation with universities and R&D units.	- decline in the number of graduates – demographic processes and decline in interest in engineering studies, - outflow of employees and potential increase in employment costs, - low level of industry-specific education, - insufficient stimulation of interest in staff training, - structural shortage of labour resources, - lack of motivation for young staff – low wages.

Tabela 4.
Analiza SWOT – aspekty przestrzenne, infrastruktura

SPATIAL ASPECTS, INFRASTRUCTURE – weight 0.25	
STRENGTHS	**WEAKNESSES**
- very convenient transport location, - border location with Mazovia, Silesia, Lesser Poland, Subcarpathia, Łódź and Lublin provinces.	- lack of logistics centres; - poor infrastructure – condition of local and regional roads;
OPPORTUNITIES	**THREATS**
- improvement of road, rail and air infrastructure, - large number of new buildings, - improving social infrastructure, - opening up of foreign markets.	- unstable legal and administrative regulations hindering business development (taxes, surcharges, protracted proceedings before courts and administrative bodies), - slowdown in the real estate and construction markets.

The interconnection between opportunities and threats with the strengths and weaknesses of companies allows for the determination of a company's strategic position. After identifying strengths and weaknesses, as well as opportunities and threats, weights were assigned to individual groups of factors, corresponding to their impact on the development of the industry. The results are presented in Table 5.

Table 5.
Point-based evaluation of individual elements, analysis forces

	(S)	(W)	(O)	(T)
Results	5,70	7,85	7,20	5,95

After calculating the total number of points for each of the four forces (S, W, O, T), it is possible to determine the Market Attractiveness (MA) of the sector (on the market), which is a function of O and T (opportunities and threats) and is given by the formula:

$$\mathbf{AR = O / (O + T),}$$

where:
O – represents the total number of points from the O (Opportunities) side of the table,
T – represents the number of points from the T (Threats) side of the table,
For the results from the table, **AR = 0.55**.

The Market Position (MP) of a company, which is a function of S and W (strengths and weaknesses), is determined by the following formula:

$$\mathbf{MP = S / (S + W),}$$

where:
S – represents the total number of points from the table on the S (Strengths) side,
W – represents the number of points on the W (Weaknesses) side.
For the values in the table, **MP = 0.42**.

Determining the location of the point that represents the strategic position on this chart boils down mathematically to comparing the sum of points (from the tables presented earlier) on the corresponding O-T and S-W axes, whereby the rule is to subtract the smaller value from the larger one and place this difference on the axis on the side of the larger number. The intersection of the lines perpendicular to the axes passing through these points determines the strategic position of the organisation. Calculating the difference in this way prevents the occurrence of in the negative number method.

The strategic position of a company can be visually represented as a point on the graph below (depending on the total results for each category S, W, O, T).

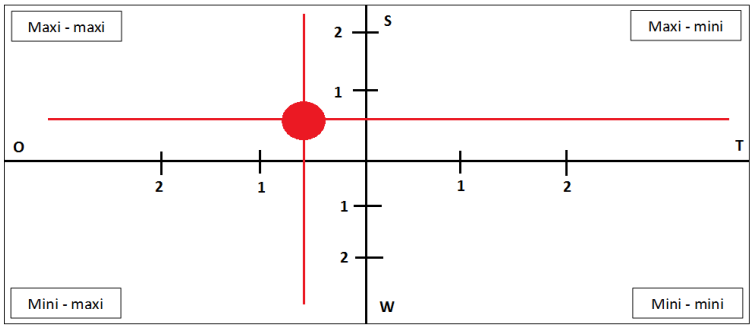


Figure 1. Strategic position of the logistics sector depending on the environment and own resources.

The position of the point in the maxi-maxi field shown in the figure 1 indicates a privileged position in the market, where the sector's strategy should be focused on maintaining this position. In this case, strengths outweigh weaknesses and opportunities outweigh threats.

According to Porter, an aggressive strategy should be applied, which means that the strengths prevail in the sector under study, and the opportunities strongly related to them prevail in their environment. The companies under study from the logistics sector are able to develop intensively in the existing environment, as the set of strengths complements the opportunities of the environment. They are also able to effectively overcome threats while waiting for external conditions to improve. An aggressive strategy is a strategy of strong expansion and development that utilises both factors – the potential and strengths of a given group of companies – to minimise threats from the environment.

In the case of the companies surveyed, this approach mainly boils down to the following activities:

- creating a common policy for costs, e.g. transport strategy, training, scientific and research activities, common management software, common advertising,
- minimising price competition,
- research and development and improvement of services, and the introduction of intellectual property protection,
- cooperation with the scientific sector, in particular in the field of training, improving the quality of services, and access to the university's laboratory facilities.

According to Krzysztof Obłój, ‘an aggressive (maxi-maxi) strategy consists in maximising the synergies between the strengths of the organisation and the opportunities generated by the environment. It is a strategy of strong expansion and diversified development (...)’ (Piocha, Dylkiewicz, 2007, pp. 13-34).

An aggressive strategy includes activities such as: seizing opportunities, strengthening market position, acquiring organisations with the same profile, and concentrating resources on competitive products. It is a strategy that exploits the synergies between the organisation's strengths and the opportunities arising in the environment (Stabryła, 2017).

This approach to analysis determines the nature and role of the SWOT method, focusing it mainly on strategic alignment. By distinguishing between positive and negative factors, the SWOT method guidelines boil down to: avoiding threats, exploiting opportunities, strengthening weaknesses, and building on strengths.

Proper preparation of a company's action strategy requires the entrepreneur to correctly diagnose the potential of the company and its environment and the changes taking place in it. A complete and well-executed strategic analysis is half the battle in a company's strategy. It allows the right choices to be made regarding the direction and methods of the company's development. Modern planning emphasises the study of the environment, which is characterised by a lack of predictability and creates additional threats. Strategic management occurs in three stages: analysis, planning and management.

Due to the development of the environment, there has been an increase in the scientific approach to methods that facilitate the prediction of changes in the environment and make it easier to adapt to it. The seeds of the concept of corporate social responsibility have also appeared. The development of the environment led to a search for new methods and solutions, and when some methods proved ineffective, new, more effective ones appeared in their place. In recent years, the focus has been on analysis as a multifaceted approach to strategy with an emphasis on ‘strategic thinking’.

4. Conclusions

The main conclusions from the SWOT analysis indicate that the logistics industry has significant and multidimensional development potential, resulting from the wide range of services provided, the diverse nature of its activities and the growing importance of logistics in the economy. However, this potential remains underutilised in many areas and, in some cases, is even marginalised.

In order to increase the dynamism of the sector's development, logistics companies should, in particular, intensify inter-organisational cooperation and improve key areas of operational activity, such as warehousing, transport, marketing, customer service and information systems.

Location remains an important factor determining competitiveness – the right choice of locations for new branches helps to optimise flows and integrate transport routes. At the same time, it is necessary to maintain high standards of service quality and develop employee skills, as they are responsible for the effective implementation of innovations and flexible response to market changes.

There are also significant barriers to the functioning of logistics companies, such as high labour costs, fleet maintenance, software and infrastructure. Systematic cost control and rationalisation of expenditure are therefore key measures to reduce the risk of debt and maintain financial stability.

In an environment of intense competition and a volatile market, the implementation of modern logistics solutions, the use of advanced technologies and the search for methods to optimise processes that reduce costs and increase operational efficiency are of particular importance. Companies operating in Poland – as an integral part of the European and global market – must be prepared for the consequences of participating in complex international supply chains. The dynamics of changes in the economic environment generate pressure and introduce elements of uncertainty that cannot be ignored in the strategic planning process.

Therefore, the creation of a coherent, long-term strategy becomes a prerequisite for both the successful launch of a business and maintaining competitiveness in the market. Strategic analyses, covering both external and internal factors, enable the identification of key determinants of a company's development, the assessment of its competitive position and the identification of anticipated changes that may affect its future operations. A properly developed strategy is therefore the foundation for the proper and sustainable development of a logistics company.

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METHODOLOGY IN MANAGEMENT RESEARCH: BETWEEN EMPIRICISM, LITERATURE REVIEW AND SCIENTIFIC ORIGINALITY

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Purpose: The paper aims to develop an integrated methodological framework for management research by synthesising deductive, inductive and empirical perspectives, critically evaluating literature-based inquiry, and conceptualising originality as a structured methodological construct.
Design/methodology/approach: This is a conceptual study based on a narrative literature review, epistemological analysis, problematisation and integrative conceptual synthesis. It systematises methodological debates across empirical, deductive and idiographic traditions, critically evaluates literature review practices and synthesises existing frameworks of originality and theory development in management research.
Findings: The study demonstrates that methodological rigour in management research cannot be ensured through any single paradigm or technique. Instead, rigour emerges from the alignment of empirical inquiry, transparent and systematic literature-based reasoning, and deliberate construction of originality through problematisation. The paper identifies recurring methodological errors, clarifies the appropriate use of systematic reviews and bibliometrics, and integrates existing views on originality into a coherent framework.
Research limitations/implications: As a conceptual paper, the study does not empirically validate the proposed methodological framework. It is influenced primarily by European and Polish traditions of methodological thought. Future research should empirically assess hybrid methodological designs, the practical use of systematic reviews, and institutional mechanisms shaping originality evaluation in management research.
Practical implications: Although conceptual, the paper offers actionable methodological guidance for researchers, doctoral students and reviewers. It provides criteria for selecting methodological approaches, designing rigorous literature reviews and developing research programmes oriented towards originality, which can enhance transparency and coherence in management research.
Social implications: Strengthening methodological foundations may indirectly improve the societal relevance of management research by supporting more reliable and theoretically grounded evidence for organisational practice and public policy.

Originality/value: The paper offers a novel triadic conceptualisation of methodology in management science, explicitly integrating empiricism, literature review and originality. It synthesises dispersed methodological discussions into an integrated framework and clarifies the epistemological foundations of originality and problematisation. It is addressed to management researchers, doctoral students and journal editors concerned with methodological quality.
Keywords: research methodology; conceptual research; literature review; originality; triangulation.
Category of the paper: Conceptual paper.

1. Introduction

The development of scientific knowledge has long been interpreted through two competing lenses: cumulativism, which assumes the gradual enrichment and refinement of existing knowledge, and eliminativism, which stresses the systematic rejection of obsolete theories. Yet, as Amsterdamski (1987) observes, the social sciences resist straightforward categorisation into either model due to their inherent interpretative complexity. Progress in these fields tends to be evolutionary rather than revolutionary, characterised by incremental adjustments and the gradual institutionalisation of new insights (Niemczyk, 2011).

Debates on the epistemological foundations of scientific inquiry—particularly between deductive and empirical reasoning—have profoundly shaped methodological choices in management research. Kant's understanding of cognition as an interpretative process (Hempoliński, 1987) and Popper's (1959, 1999) deductive hypothesism emphasise the centrality of theoretical reasoning and falsification, whereas empiricism positions observation and inductive generalisation as the core mechanisms of scientific discovery (Niemczyk, 2011). This longstanding tension reflects the methodological pluralism of management science, where both nomothetic generalisation (Thomae, 1999) and idiographic case-based inquiry (Chełpa, 2002) coexist without forming a unified methodological canon.

In recent years, scholars have increasingly recognised that traditional methodological dichotomies are insufficient for capturing the multidimensionality, fragmentation, and interdisciplinarity of contemporary management research. Dźwigoł (2018) and Krzyżanowski (1999) argue that management science draws on heterogeneous epistemic traditions and therefore requires highly reflexive methodological choices. This is particularly evident in emerging research domains such as artificial intelligence, energy security, and digital transformation, where methodological integration rather than strict adherence to a single paradigm becomes essential. For instance, recent studies employ hybrid methodological frameworks combining empirical modelling, expert-based approaches, and conceptual reasoning (Kharazishvili, Kwilinski, 2022; Kharazishvili et al., 2021a, 2021b). Similar methodological hybridity is visible in research on cognitive technologies (Kwiliński et al.,

2021) and in investigations into the nonlinear environmental effects of digitalisation (Kwilinski, 2024a).

Concerns about methodological rigour also extend to literature-based inquiry. Czakon (2011, 2015) identifies recurring deficiencies in traditional reviews—fragmentation, incompleteness, and unclear inclusion criteria—that undermine the credibility of research foundations. Bibliometric studies similarly reveal conceptual dispersion and inconsistent methodological integration across management research streams (Oliver, Ebers, 1998; Jourdan et al., 2008).

Recent developments demonstrate a growing reliance on bibliometric and scientometric techniques to strengthen methodological rigour and overcome the limitations of narrative reviews. Kwilinski (2023) shows that bibliometric analysis has become an essential tool for mapping the intersections between sustainable development and digital transformation, providing a structured approach for detecting research gaps and emerging clusters. Extending this methodology, Kwilinski (2024b) offers a comprehensive bibliometric mapping of global research on green energy and green investment, illustrating how large-scale data analytics can improve transparency, reproducibility and methodological clarity in interdisciplinary research domains.

Combs (2010) further warns that prioritising large samples and statistical power at the expense of conceptual relevance weakens the theoretical contribution and practical significance of research findings. Scandura and Williams (2000) highlight that methodological inconsistency remains a systemic challenge in management research, while Dźwigoł and Dźwigoł-Barosz (2018) underscore the growing need for methodological transparency and reflexivity.

A parallel challenge concerns the construction of scientific originality. While originality is widely regarded as a central evaluative criterion, its methodological foundations remain under-theorised. Scholars emphasise that originality derives not from novelty per se, but from theoretical recombination, methodological robustness, and the ability to problematise taken-for-granted assumptions (Weick, 1989, 2005; Dubin, 1987; Strużyna, 2015). Alvesson and Sandberg's (2011) problematisation framework further positions originality as a deliberate methodological practice rather than a by-product of research design. However, Boxenbaum and Rouleau (2011) note that theoretical advances often emerge through bricolage—creative reconfiguration of existing concepts—suggesting that originality is inherently linked to methodological pluralism.

Recent methodological literature also emphasises the growing demand for structured methodological thinking in management research. This need is increasingly evidenced by meta-analytical studies showing that methodological fragmentation, weak conceptual precision and inconsistent operationalisation hinder the cumulative development of knowledge in strategic and organisational studies. For example, the meta-analysis conducted by Kwilinski et al. (2025) demonstrates that research on crisis management and strategic thinking remains marked by

heterogeneous methodological standards, uneven evidence quality and the absence of unified coding frameworks. These findings underscore the necessity of clearer methodological protocols, more explicit inclusion criteria and greater transparency in analytical procedures—requirements that extend across the broader field of management science.

In this context, Jonker and Pennink (2007) argue that methodology should not be reduced to a set of technical procedures, but understood as a form of rigorous academic reasoning that shapes how researchers conceptualise problems, design studies and implement scientific inquiry. Such an approach reinforces the importance of methodological reflexivity, epistemological coherence and awareness of the theoretical assumptions underpinning research choices.

Together, the reviewed literature reveals several persistent gaps in management research methodology:

1. Limited integration between empirical, deductive, idiographic, and hybrid methodological approaches.
2. Insufficient rigour and transparency in literature review practices.
3. Underdeveloped frameworks for building scientific originality and generating theoretically meaningful research questions.
4. A lack of methodological reflexivity in emerging interdisciplinary research areas such as AI, digital transformation, and energy security.

In response, this paper develops a comprehensive conceptual perspective on methodological choices in management research. It examines the epistemological foundations of deductive, inductive, and empirical approaches; analyses the methodological challenges inherent in literature-based inquiry; and proposes a structured understanding of originality as a methodological construct. By synthesising insights from classical and contemporary methodological theorists, this study seeks to enhance methodological reflexivity and contribute to more rigorous, transparent, and impactful management research.

2. Methods

This study adopts a conceptual methodological design aimed at synthesising and critically evaluating the epistemological foundations of management research. As the objective of the paper is not to test hypotheses empirically but to develop an integrated understanding of methodological approaches, the research follows the logic of conceptual inquiry grounded in analytical reasoning and literature-based analysis.

The methodological procedure consists of four complementary components. First, a narrative literature review was conducted to trace the evolution of methodological debates in management science, including deductive, inductive, empirical, nomothetic and

idiographic traditions. Narrative review was selected over systematic procedures due to the conceptual and theoretical nature of the research question, the heterogeneity of epistemological sources and the need for interpretive synthesis (Czakon, 2011, 2015). This approach allowed for the incorporation of classical methodological contributions (e.g., Kant, Popper, Dubin, Weick) as well as contemporary insights from interdisciplinarity, digitalisation and bibliometrics (e.g., Kwilinski, 2023, 2024b; Kharazishvili, Kwilinski, 2022).

Second, the study applies epistemological analysis, examining the assumptions underlying major methodological paradigms in management research. This included a comparative assessment of deductive and empirical traditions, nomothetic and idiographic logics, and traditional versus modern approaches to literature review. Epistemological analysis was necessary to uncover underlying tensions, blind spots and implicit assumptions that influence methodological choices in the field.

Third, the study employs problematisation, following the approach proposed by Alvesson and Sandberg (2011). Rather than accepting established methodological categories at face value, the analysis seeks to challenge and reconstruct taken-for-granted assumptions regarding scientific rigour, originality, literature review practices and theory development. This strategy allows for the identification of methodological gaps and the emergence of alternative conceptual framings.

Fourth, the paper utilises integrative conceptual synthesis, aimed at combining insights from diverse strands of methodological literature into a coherent analytical framework. This synthesis draws on classical philosophical accounts of scientific knowledge, mid-20th-century methodological debates and contemporary methodological innovations such as bibliometrics, triangulation (Dzwigol, 2020) and scientometric mapping. The integration of these perspectives enables a multidimensional assessment of methodological rigour and originality in management studies.

The overall methodological approach therefore reflects the pluralistic character of management research itself. It blends narrative review with epistemological reasoning, conceptual integration and problematisation, enabling the development of a comprehensive perspective on methodological choices and challenges without relying on empirical data collection. Such a design is consistent with established practices in conceptual and theory-building research, where analytical integration, reflexivity and methodological transparency are prioritised over empirical measurement.

3. Results

3.1. Empirical Studies

Empirical inquiry remains one of the central methodological foundations of management research, yet its role is far from unambiguous due to the epistemological complexity of the field. In the social sciences, empirical analysis is not limited to observation alone but concerns the scope and validity of the logical propositions that support or falsify a given hypothesis. As Niemczyk (2011) observes, three principal empirical strategies have evolved:

- Total enumerative induction, which seeks to verify hypotheses based on all possible cases (for instance, analysing every energy-sector firm in Poland to determine success strategies during economic crisis).
- Incomplete enumerative induction, where only selected cases are examined, enabling the derivation of general laws and regularities (e.g., identifying the typical strategies used by successful firms in turbulent environments).
- Single-case temporal–spatial analysis, which focuses on explaining one unique phenomenon in its specific context (e.g., why a particular enterprise achieved exceptional outcomes).

A defining characteristic of empirical work in the social sciences is that it constitutes "research conducted by people on people". As Nowak (2007) argues, researchers not only rely on sensory observation but also on introspective awareness of their own and others' mental states. This makes empirical research inherently vulnerable to deliberate or unconscious distortion by participants—particularly visible in survey research and face-to-face interviews.

Empirical analysis, however, cannot be understood in isolation from deduction. By identifying key propositions and demonstrating that other statements follow logically from them, even empirical theories may assume a deductive structure (Wójcicki, 1987). For this reason, the longstanding dispute between empiricism and deduction—as to which should have primacy in scientific discovery—remains unresolved. Niemczyk (2011) highlights that one of the most common methodological errors in management research is privileging one approach while neglecting the other. This leads to pseudo-arguments: pure deductionism detached from empirical verification is impossible at the contemporary stage of scientific development, just as pure sensory empiricism cannot serve as the sole source of verification for complex organisational phenomena (Dźwigoł, 2018).

3.1.1. Nomothetic and Idiographic Orientations

Within the broader empirical tradition, management research draws on two distinct methodological orientations: the nomothetic and the idiographic.

The nomothetic approach seeks general, recurrent patterns and laws comparable to those found in the natural sciences. Its procedures include experimentation, verification and correlation, and its tools range from questionnaires, structured interviews and observations to controlled experiments and diagnostic tests.

By contrast, the idiographic approach aims to explain unique, context-dependent organisational phenomena by identifying the specific external forces that shape them. It relies heavily on case studies, documentary analysis, interviews, observations and projective methods (Chełpa, 2002). As Windelband and Rickert argued, the idiographic turn reflects the need to identify distinguishing features of complex social phenomena rather than impose universalising laws (Thomae, 1999).

While quantitative methods are often perceived as more rigorous, qualitative inquiry is indispensable when the nature of the research problem demands depth, contextual sensitivity or interpretative insight (Thomae, 1999). Quantitative research includes methods such as surveys, where hypotheses are tested through the statistical distribution of responses, whereas qualitative research encompasses fieldwork, anthropological interviews, participatory observation, focus groups, expert elicitation, panel studies and textual or discourse analysis (Thomae, 1999).

Importantly, quantitative and qualitative laws are not equivalent to quantitative and qualitative research methods. Quantitative laws are expressed via mathematical relationships and require clearly defined antecedent conditions, whereas qualitative laws articulate properties of classes of objects in natural language and often lack such precision (Such, 1987).

3.1.2. Empirical Design as a Challenge in Management Science

Management science is inherently interdisciplinary and lacks an autonomous methodological apparatus, drawing instead on economics, sociology, psychology, systems theory and other fields (Krzyżanowski, 1999). Consequently, researchers must independently construct the methodological architecture of their studies – articulating the research programme, defining the research problem and selecting appropriate methodological tools (Niemczyk, 2011). This requires substantial analytical competence and epistemological awareness.

Triangulation – combining multiple methods to increase the credibility of findings— is increasingly common, particularly in contemporary complex research domains. However, Niemczyk (2011) warns that triangulation carries methodological risks when researchers employ methods they do not fully understand. In such cases, triangulation may reduce rather than enhance the quality of research, contradicting its intended purpose. Dźwigoł (2018) therefore emphasises that rigorous scientific work requires deep understanding of methodological differences, scientific procedures and epistemological assumptions.

3.1.3. Skills Required for Empirical Inquiry

Mayer (1996) notes that researchers in economics and management frequently rely excessively on tools borrowed from the natural sciences, apply overly complex theories to simplistic problems or isolate their disciplines from broader social science debates. He argues that robust empirical research requires the integration of three intellectual qualities:

- skills, referring to methodological and analytical competence,
- imagination, enabling the formulation of meaningful and insightful research questions,
- insight, allowing the researcher to interpret complex organisational realities.

Ultimately, as Mayer (1996) stresses, the essence of empirical research lies not in the tools themselves, but in the search for an appropriate and credible solution to the problem under examination.

3.2. Literature Research

A fundamental principle of scientific inquiry is the continuity of knowledge development. As Czakon (2015) argues, any research endeavour must begin with an examination of the existing body of scholarship in order to identify established findings, inconsistencies and cognitive gaps. Literature research thus constitutes a prerequisite for developing scientifically grounded originality, as new insights can only be generated through a clear recognition of what is already known and where knowledge remains inconclusive (Czakon, 2015).

Nevertheless, the term literature research can be misleading, as its colloquial interpretation reduces the researcher to a passive reader engaged with books, monographs or encyclopaedic sources. In methodological terms, literature research refers not to passive reading but to a structured cognitive process whose aim is to reconstruct the state of knowledge, identify gaps and formulate research questions (Czakon, 2015). Every scientific article, research project or funding proposal is therefore expected to demonstrate awareness of the scholarly landscape, primarily through the analysis of peer-reviewed articles that collectively reflect the evolution of a research field (Czakon, 2011).

3.2.1. Traditional Literature Review and Its Pitfalls

Traditional literature review techniques draw on two pillars: bibliographic analysis and interpretative analysis conducted within the researcher's disciplinary community. Bibliographic analysis includes critical evaluation of scientific articles and monographs, which historically function as milestones in the academic life cycle—doctoral dissertations, habilitation monographs and professorial books. However, traditional literature reviews frequently exhibit methodological flaws, including:

- a tendency to discuss prior findings before articulating the research question, resulting in essayistic rather than rigorous argumentation,
- failure to identify all relevant literature, leading to fragmentation and incompleteness,

- vague criteria for inclusion or exclusion of publications, creating interpretative ambiguity,
- uncritical citation of studies without assessing their methodological quality, increasing the risk of selective or arbitrary interpretation (Czakon, 2015).

These shortcomings are compounded by inherent characteristics of scientific development:

- accrual (knowledge evolves unevenly, influenced by fashions and dominant paradigms),
- branching (the same phenomenon is studied from diverse perspectives),
- fragmentation (multiple small subfields with limited integration),
- methodicalness (the need to follow reproducible procedural steps) (Czakon, 2011, 2015; Combs, 2010).

To ensure methodological rigour in literature research, it is essential to recognise these characteristics and adopt procedures that reduce bias. Niemczyk (2009) emphasises that in management science, reliability is a function of rigour, defined through accuracy, clarity and transparency in methodological decisions.

3.2.2. Systematic Literature Review (SLR): A Response to Fragmentation

Growing concerns about methodological reliability have led to the increasing adoption of systematic literature review (SLR) methodologies. SLR follows a transparent, replicable and verifiable protocol comprising four phases and seven stages (Czakon, 2015):

- Phase I: defining the purpose of the review.
- Phase II:
  1. identifying primary literature,
  2. selecting relevant publications,
  3. building the database.
- Phase III:
  1. bibliometric analysis,
  2. content analysis.
- Phase IV: preparing the research report.

Digitisation and open access to electronic databases—EBSCO, ProQuest, Web of Science, Scopus and Google Scholar—have greatly expanded access to literature and enabled large-scale, data-driven evaluation. Yet, the abundance of digital sources also increases the difficulty of selection, making transparent inclusion criteria essential (Czakon, 2015).

A systematic review relies on descriptive bibliometric techniques (e.g., publication dynamics, citation analysis) and qualitative content analysis. The former allow researchers to assess the developmental stage of a research area—emergence, growth, maturity or decline—based on publication trends (Czakon, 2015). Citation analysis highlights seminal contributions and reveals how disciplinary communities construct knowledge around shared references (Jourdan et al., 2008).

Content analysis, in turn, must do more than identify thematic patterns. It requires assessing the methodological quality of publications based on criteria such as clarity of purpose, contextual relevance, sampling, robustness of data and generalisability. Only then can researchers identify cognitive gaps and determine the direction of future research (Czakon, 2015; Oliver, Ebers, 1998).

3.2.3. Bibliometrics and Scientometrics in Contemporary Management Research

Recent advances demonstrate a shift towards bibliometric and scientometric methods as tools for enhancing methodological rigour and overcoming the limitations of traditional narrative reviews. Bibliometric approaches enable transparent, replicable and quantitatively grounded mapping of research fields.

For instance, Kwilinski (2023) employs bibliometric analysis to reveal the intellectual structure connecting sustainable development and digital transformation, identifying emerging clusters, underexplored intersections and methodological gaps. Similarly, Kwilinski (2024b) conducts a comprehensive bibliometric analysis of global research on green energy and green investment, demonstrating how large-scale data analytics can illuminate dominant research fronts, thematic evolution and knowledge fragmentation. These examples illustrate how bibliometric techniques strengthen reliability, facilitate the detection of research gaps and support methodological clarity in interdisciplinary fields.

Moreover, the increasing importance of digital databases aligns with broader trends in management research, where methodological pluralism and interdisciplinarity create both opportunities and challenges. Scientometric techniques allow researchers to systematically navigate large volumes of dispersed literature and to construct structured, evidence-based foundations for further theorising.

3.2.4. Database Development, Keyword Strategies and Analytical Procedures

Constructing the primary literature database is one of the most critical stages of SLR. It requires defining the object of study—analogous to sampling in empirical research (Czakon, 2015). The initial search is typically conducted using author-supplied keywords (AKW) and index keywords (KW). However, the iterative nature of keyword refinement means that researchers must balance breadth and precision.

Czakon (2015) identifies four groups of keyword strategies:

- auxiliary concepts, used when the topic intersects multiple categories,
- variables, given that titles increasingly specify dependent and independent variables,
- methodological descriptors, useful but restrictive,
- empirical context, essential in fields such as sustainability, energy studies and digital transformation.

The database is subsequently cleaned using exclusion criteria, duplicate removal and abstract screening. Stratification of publications into: (1) directly relevant, (2) partially relevant, and (3) marginally relevant helps narrow the dataset to items that genuinely advance the research objective.

3.2.5. From Analysis to Synthesis

Bibliometric procedures provide quantitative characterisation—publication trends, citation patterns, thematic clusters—while content analysis delivers qualitative insights necessary for constructing theoretical synthesis. As Czakon (2015) and Jourdan et al. (2008) note, neither approach is sufficient in isolation; their integration is essential for identifying dominant perspectives, research gaps and methodological inconsistencies.

Finally, the reporting stage culminates in the synthesis of findings and their integration into a coherent narrative that can guide empirical inquiry or theoretical development.

3.3. Originality in Research

Originality constitutes a critical accelerator of scientific knowledge and a defining element of a researcher's competence and academic identity. Importantly, scientific originality must not be conflated with everyday notions of "being original", as the latter typically refers to unconventional behaviour or personal distinctiveness. Scientific originality functions differently: it pertains to the intellectual contribution made by the researcher and to the methodological and conceptual means through which this contribution is achieved (Strużyna, 2015).

In the social sciences, the pursuit of originality can be understood through three primary pathways (Strużyna, 2015):

1. The traditional scheme, in which the researcher situates the problem in the present and extends what is already known.
2. Problematisation, which involves questioning prevailing assumptions, challenging existing explanations and opening new analytical spaces.
3. The search for original obviousness, which entails returning to the fundamental origins of a problem and reinterpreting its primary assumptions.

Among these, the second pathway tends to generate the most influential contributions, receiving favourable evaluation from global scientific publishers and supporting the cumulative development of management theory (Strużyna, 2015). This approach aligns closely with Dubin's (1987) view that theoretical advancement emerges from proposing new answers to the foundational questions: what?, how?, and why?—each representing a distinct dimension of conceptual enrichment.

3.3.1. Forms and Criteria of Original Contribution

Within management sciences, the "what?" question holds particular significance but is especially difficult to satisfy due to the field's interdisciplinary and rapidly evolving character. Strużyna (2015) identifies five principal forms of original contribution:

1. Introducing new elements into existing constructs, such as incorporating emerging social phenomena or technological developments. To qualify as scientific originality, such additions must:

- modify the interpretative picture of the original construct (Czakon, 2005),
- clearly justify the necessity and relevance of the supplementation (Dooley, Van de Ven, 1999),
- engage with contemporary debates on the limitations of well-established theories,
- avoid blurring the conceptual boundaries of the original model,
- contribute more than subjective impressions of theoretical insufficiency.

2. Developing new concepts. Proposals can be regarded as original only if they:
   - enable comprehension by a wider scholarly community, not solely by the author,
   - simplify existing conceptual complexities,
   - or alternatively, introduce more sophisticated complexity that advances theoretical reasoning. Importantly, not every novel insight evolves into a coherent or meaningful theoretical construct.
3. Creating synergies between management knowledge and other disciplines, which requires a deep understanding of both fields and a clear demonstration of how interdisciplinary integration advances management theory.
4. Assessing the influence of management sub-disciplines on broader management theory, with originality becoming most evident when results extend, refine or reframe existing theoretical foundations rather than remaining confined to narrow subfields.
5. Building new management theory on the foundations of other theories. This can occur through:
   - developing a wholly new framework for management (rare in practice),
   - incremental theorising supported by leading academic institutions,
   - or adapting theories from other disciplines.

Researchers must therefore distinguish between mere compilation and the scientifically valuable practices of eclecticism and bricolage (Boxenbaum, Rouleau, 2011).

Notably, prioritising originality does not necessarily imply striving for entirely new theories. In many cases, designing a precise and meaningful extension of an existing theory offers far greater scientific value and a higher probability of scholarly acceptance (Strużyna, 2015).

3.3.2. Theoretical Foundations for Evaluating Originality

The search for originality requires acknowledging that a theory represents not simply a set of abstract concepts but a structured relationship between variables (Homans, 1964). Consequently, answering the "what?" must be complemented by coherent responses to the "how?" and the "why?". This triadic logic ensures the consistency, explanatory power and theoretical robustness of new contributions.

Strużyna (2015) proposes a structured procedure for producing original theoretical work:

1. Conducting in-depth analysis of existing theories, including interdisciplinary knowledge and practical insights.
2. Identifying a substantive knowledge gap.
3. Designing a concept aimed at filling that gap.
4. Evaluating the originality and significance of the proposed contribution.
5. Generalising findings and recognising their relations with other scientific fields.
6. Institutionalising original results through dissemination and theoretical consolidation.

3.3.3. Problematisation as a Method for Constructing Originality

Problematisation represents a deliberate, methodical and rational approach to constructing research questions. It operates not by following the natural evolution of ideas but by creating contrast between existing assumptions and alternative possibilities (Strużyna, 2015).

Alvesson and Sandberg (2011) warn, however, that excessive or unreflective problematisation can become dysfunctional, generating conceptual confusion or undermining the positive function of science. They therefore advocate embedding problematisation within a broader academic process that maintains equilibrium between novelty and convention.

A rigorous problematisation programme begins with two focal questions:

1. Which assumptions materially shape existing debates?
2. How can these assumptions be revealed, articulated and challenged to produce more compelling theories?

Assumptions can be clustered into five categories (Alvesson, Sandberg, 2011):

- internal assumptions,
- source metaphors,
- paradigmatic assumptions,
- ideological assumptions,
- field assumptions.

To operationalise problematisation, Strużyna (2015) proposes the following steps:

- identifying the relevant field of literature,
- identifying implicit assumptions within that field,
- evaluating their validity,
- developing alternative assumptions,
- analysing the alternatives against the expectations of their scientific audiences,
- evaluating the viability of the new assumptions.

Strużyna (2015) additionally emphasises the "social obviousness of the need"—the idea that problematisation must correspond to real research needs arising within the scientific community.

3.3.4. The Social Dimension of Originality

Weick (1989, 2005) argues that originality in the social sciences is inherently shaped by academic power structures. The acceptance of theoretical propositions depends not only on their logical coherence or empirical grounding but also on the social rules determining which contributions are considered credible, persuasive or interesting.

Thus, the advancement of theory occurs not simply through verification of truth but through the institutionalised reinforcement of new relations and ideas that scholars come to perceive as meaningful. Weick (1989, 2005) notes that academic discourse frequently relies on evaluative terms – such as "interesting", "obvious", "absurd" or "meaningless" – that reflect a blend of cognitive judgement and social negotiation.

4. Discussion

The findings of this conceptual analysis highlight a series of structural tensions and methodological challenges that continue to shape the development of management research. The first concerns the persistent debate between empirical and deductive approaches. Although contemporary management studies routinely employ empirical procedures – from incomplete induction to case-based analyses (Niemczyk, 2011) – theoretical reasoning remains indispensable for structuring hypotheses and giving meaning to empirical observations. The integration of introspective, experiential and observational insights characteristic of social-science inquiry further complicates this relationship (Nowak, 2007). As Wójcicki (1987) notes, empirical theories inevitably acquire deductive properties once their central assumptions are logically articulated. Thus, methodological effectiveness in management research depends not on privileging either empiricism or deduction, but on recognising that both approaches mutually constrain and enable one another.

A second tension arises from the coexistence of nomothetic and idiographic perspectives. While nomothetic designs emphasise experimentation, surveys and correlation to identify general patterns, idiographic approaches – particularly case studies informed by interpretative reasoning – provide insight into unique and complex organisational phenomena (Chełpa, 2002; Thomae, 1999). In management sciences, where problems are context-dependent and shaped by heterogeneous organisational conditions, both perspectives offer important but partial contributions. As Krzyżanowski (1999) observes, the interdisciplinary nature of management science prevents the field from relying on a unified methodological toolkit. Rather, the researcher must navigate competing epistemological logics to select a method that fits the research problem. This requirement reinforces the necessity of methodological reflexivity and the importance of aligning epistemological assumptions with the intended research outcome.

The growing popularity of triangulation reflects an attempt to overcome these limitations by employing multiple methodological procedures in a single inquiry. While triangulation increases the credibility and robustness of findings, Niemczyk (2011) warns that it also exposes researchers to significant risks, especially when methods are used without adequate competence. Misapplied triangulation may lead to methodological inconsistency, poor integration of results or superficial multi-method designs. The insight aligns with Dźwigoł's (2018) argument that methodological rigour requires precise knowledge of methodological differences, rather than merely expanding the number of methods employed.

A further methodological challenge concerns the quality of literature-based inquiry. The analysis demonstrates that traditional literature reviews are frequently compromised by fragmentation, incomplete sampling and unclear inclusion criteria (Czakon, 2011, 2015). Such weaknesses undermine transparency, hinder theory development and impede the identification of meaningful knowledge gaps. Although systematic literature reviews—characterised by staged procedures, sampling logic and quantitative descriptive techniques—address many of these concerns (Czakon, 2015), they also require advanced methodological competences, particularly in the selection of databases, the construction of search strategies and the evaluation of publication quality. The integration of bibliometric indicators with interpretative content analysis is therefore essential for avoiding superficial, metrics-driven reviews that fail to reflect substantive theoretical developments.

The analysis also reveals a structural gap relating to the conceptualisation and institutionalisation of originality in management studies. While originality is widely valued, its methodological grounding remains under-specified. Strużyna's (2015) typology of original contributions – ranging from new conceptual elements to interdisciplinary synergies – shows that originality is neither equivalent to novelty nor reducible to invention. Rather, it derives from the researcher's ability to meaningfully reframe existing constructs, articulate alternative assumptions and identify theoretically significant gaps. This perspective is reinforced by Dubin's (1987) assertion that originality emerges from new propositions addressing the core theoretical questions: what, how and why. However, Weick's (1989, 2005) observations regarding the social construction of scholarly credibility remind us that originality is evaluated within academic power structures. Hence, problematisation (Alvesson, Sandberg, 2011) becomes not only a methodological tool but also a social process through which assumptions are questioned, alternatives constructed and theoretical relevance negotiated.

Together, these tensions point to a broader implication: methodological rigour in management research cannot be secured by any single epistemological orientation, literature review technique or originality criterion. Instead, it requires a combination of three interdependent forms of reasoning:

1. Empirical reasoning, which provides evidence grounded in observation, induction and real-world organisational behaviour.
2. Literature-based reasoning, which locates research within existing knowledge, identifies conceptual gaps and ensures methodological transparency.
3. Originality-driven reasoning, which constructs new assumptions, reconfigures existing theories and advances the field.

The integration of these reasoning modes supports a more reflexive methodological culture – one that acknowledges the complexity of management phenomena and the evolving expectations of scholarly communities. This synthesis offers the strongest foundation for theory-building, allowing researchers to navigate epistemological plurality without sacrificing transparency, precision or credibility.

Although the present study offers a comprehensive conceptual examination of methodological issues in management research, several limitations should be acknowledged. First, due to its conceptual nature, the analysis does not aim to empirically test the identified methodological tensions. Rather, it synthesises insights from existing epistemological and methodological literature (e.g., Czakon, 2011, 2015; Dźwigoł, 2018; Strużyna, 2015). This reliance on secondary sources means that some nuances present in empirical studies—particularly those illustrating the practical consequences of methodological choices—may not be fully captured. Future empirical investigations could therefore validate and refine the conceptual propositions advanced here.

Second, the review draws primarily on theoretical and methodological contributions within European and Polish traditions of management science (e.g., Niemczyk, 2011; Krzyżanowski, 1999; Nowak, 2007). While these perspectives offer significant analytical value, they may reflect specific intellectual traditions, institutional norms and disciplinary assumptions. The inclusion of broader international methodological debates—especially those prevalent in Anglo-American, Scandinavian or Asian management scholarship—could further enrich the analysis and help identify additional patterns of methodological pluralism.

Third, although systematic literature review methodology is discussed extensively, this study does not perform a full systematic review itself. Instead, it evaluates the methodological principles and risks associated with traditional and systematic approaches. As Czakon (2015) notes, the effectiveness of systematic reviews depends on carefully structured procedures, database selection and search strategies. These components were intentionally not executed here, as the aim of the paper is conceptual rather than empirical. Nevertheless, future research might apply the full systematic review procedure to test the typologies and methodological claims developed in this study.

Fourth, the analysis of originality and problematisation relies on conceptual frameworks proposed by Strużyna (2015), Dubin (1987), Alvesson and Sandberg (2011), and Weick (1989, 2005). While these frameworks are intellectually robust, their application in management science varies significantly across subdisciplines. The practical processes through which

originality is socially constructed – shaped by academic hierarchies, reviewer expectations and disciplinary paradigms – require additional empirical inquiry, particularly through interviews with researchers, editorial board members or reviewers.

Finally, triangulation is identified as a valuable yet potentially risky methodological strategy (Niemczyk, 2011). However, this study does not evaluate specific triangulation designs or analyse cases where triangulation has succeeded or failed. Future work could map the use of triangulation across management research fields and assess the competencies, epistemological alignment and integration strategies that determine its success.

Overall, these limitations do not diminish the value of the study; rather, they clarify its conceptual scope and identify pathways for future empirical and methodological development.

5. Summary

Management science, situated within the broader domain of economic sciences, continues to navigate a distinctive methodological tension arising from its dual utilitarian and theoretical-normative orientation. As Niemczyk (2015) notes, the discipline must simultaneously accommodate nomothetic ambitions—deriving generalisations even from individual cases—and idiographic objectives aimed at understanding singular organisational phenomena in depth. This methodological duality reflects the epistemological plurality that characterises contemporary management research.

The findings of this study indicate that traditional methodological models are increasingly insufficient for addressing the challenges posed by interdisciplinary expansion, globalisation and the growing specialisation of management sciences. As Niemczyk (2015) and Czakon (2015) observe, the demand for methodological rigour now centres on transparency, replicability and analytically defendable procedures – qualities that are not always present in conventional narrative approaches. Systematic literature review techniques, bibliometric methods and hybrid research designs therefore emerge as valuable tools for enhancing methodological robustness, provided they are applied with epistemological awareness and procedural discipline.

Across the conceptual landscape discussed in this paper, one theme recurs consistently: the centrality of originality to scientific progress. Strużyna (2015) emphasises that originality is neither a stylistic flourish nor novelty for its own sake, but a structured process grounded in thorough engagement with existing knowledge. Whether originality is pursued through incremental elaboration of established constructs, through problematisation, or through the identification of "original obviousness", the initial step invariably involves a rigorous assessment of prior research. Reliability in recognising the existing state of knowledge enables

researchers to evaluate prior assessments, refine theoretical propositions and address cognitive gaps with clarity and conceptual precision.

Furthermore, the analysis confirms that originality in management science is inseparable from methodological reflexivity. The construction of novel theoretical contributions depends on consciously articulated assumptions, critical engagement with dominant paradigms and an awareness of the social processes shaping academic legitimacy (Strużyna, 2015; Alvesson, Sandberg, 2011; Weick, 1989, 2005). In this sense, methodological choices serve not only technical functions but also constitute a central mechanism for shaping the epistemic identity of the discipline.

Taken together, the study demonstrates that methodological rigour in management research cannot be reduced to the selection of a particular method, paradigm or analytical technique. Rather, it emerges from the deliberate alignment between epistemological assumptions, research objectives and methodological choices; from the transparent articulation of research procedures; and from the thoughtful integration of empirical insight, literature-based inquiry and originality. As the management sciences continue to evolve amid increasing complexity, methodological reflexivity and rigorous problematisation will play a decisive role in ensuring that research in the field remains relevant, credible and capable of generating meaningful theoretical contributions.

The analysis presented in this study points to several avenues for future research that may significantly advance methodological development in management sciences.

First, further inquiry is required into the epistemological integration of deductive, inductive and empirical approaches. As Niemczyk (2011) and Dźwigoł (2018) highlight, methodological fragmentation persists, and researchers frequently rely on one dominant paradigm while neglecting complementary perspectives. Future studies should therefore explore hybrid methodological frameworks capable of capturing the multidimensionality of organisational phenomena without sacrificing epistemological coherence.

Second, research is needed to enhance the methodological rigour of literature reviews. Although systematic review procedures have become increasingly recognised (Czakon, 2015), empirical evidence suggests that scholars still struggle with selection bias, insufficient transparency and inadequate quality assessment. Further work could examine how digitalisation, open-access databases and emerging bibliometric tools influence review quality, replicability and methodological clarity. Bibliometric mapping approaches (e.g., Kwilinski, 2023, 2024b) may be particularly promising for strengthening evidence-based literature synthesis and identifying emerging research fronts.

Third, there is considerable scope for developing more structured models of originality in management research. While Strużyna (2015), Dubin (1987), and Weick (1989, 2005) offer important foundations, the operationalisation of originality as a research construct remains under-theorised. Future studies could investigate how originality is institutionally assessed within academic communities, how problematisation (Alvesson, Sandberg, 2011) can be

systematically embedded into research programmes, and how interdisciplinary knowledge recombination contributes to theory advancement.

Fourth, the growing complexity of management practice calls for deeper examination of idiographic methods. Despite their recognised value for understanding singular organisational contexts (Chełpa, 2002; Thomae, 1999), idiographic approaches remain underutilised. Future research may evaluate how case studies, qualitative designs and interpretive methodologies can be integrated with quantitative and nomothetic procedures in a structured and methodologically defensible manner.

Finally, further investigations should address the risks associated with methodological triangulation. While triangulation is widely recommended for its potential to enhance credibility and completeness (Nowak, 2007; Niemczyk, 2011), inappropriate or unskilled application of multiple methods may introduce incoherence rather than strengthen findings. Future studies might develop guidance for competence-based triangulation, outlining the skills, epistemic awareness and procedural safeguards required to use triangulation effectively.

Collectively, these directions underscore the need for continued methodological innovation and reflexive research practice. Advancing methodological pluralism, improving review transparency and deepening conceptualisations of originality will be essential for strengthening the scientific foundations and societal relevance of management research.

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DETERMINANTS OF ORGANIZATIONAL CITIZENSHIP BEHAVIORS: AN ATTEMPT AT SYSTEMATIZATION AND A CONCEPTUAL MODEL

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Purpose: The main purpose of this article is to systematize knowledge about the determinants of Organizational Citizenship Behavior (OCB). The publication provides a synthetic overview of the main research streams on OCB antecedents, organizes the factors influencing these behaviors into three primary categories, and presents them in the form of a conceptual model.
Design/methodology/approach: To organize the existing knowledge on OCB determinants, a critical literature review was conducted. In searching for motivational mechanisms underlying OCB, the analysis draws on the following interpretative perspectives: social exchange theory, identification mechanism, impression management, and the concept of positive interpersonal relationships.
Findings: Based on the literature review, an original conceptual model of OCB determinants is proposed. The model integrates three groups of factors: (1) Personality factors – stable individual dispositions influencing the propensity for prosocial actions; (2) Work-related attitudes – cognitive–emotional evaluations of the organization, work, and supervisors; (3) Environmental factors – elements of the organizational context that create conditions conducive to citizenship behavior.
Practical implications: From a managerial perspective, the model of OCB determinants is highly valuable for designing HR policies and organizational culture. If citizenship behaviors result from the interaction of traits, attitudes, and context, this means organizations can actively shape environments that reinforce such behaviors. In practice, the model suggests that effective OCB management requires coordinated actions at three levels: (1) recruitment and selection (individual level), (2) motivation and appraisal (attitudinal level), (3) shaping organizational climate and leadership (environmental level).
Originality/value: The added value of this article has an integrative and organizing character. It not only reviews existing research but also proposes a new interpretative structure that may serve as a basis for future empirical studies. The analysis indicates that effectively explaining OCB requires considering multiple levels of antecedents simultaneously—individual dispositions, psychological processes, and organizational context—each of which may play a different role depending on the situation.
Keywords: Organizational Citizenship Behavior (OCB), OCB determinants, personality traits, work-related attitudes, work environment.
Category of the paper: Literature review.

1. Introduction

Organizational citizenship behavior (OCB) has for more than three decades been one of the key areas of interest within human resource management, organizational psychology, and organizational theory. Despite the vast number of publications and the growing practical importance of the phenomenon in management, the literature remains highly heterogeneous. This is particularly true for the determinants of citizenship behaviors, which are described in a fragmented, often inconsistent, and sometimes mutually contradictory manner (Organ, 1988; Podsakoff et al., 2000). Differences in how OCB is defined, the diversity of theoretical perspectives, and the absence of a clear classification of factors contribute to significant conceptual and methodological chaos in research on OCB antecedents.

Originally, the concept of OCB was introduced as an attempt to answer the question of why employees engage in activities that lie outside their formal job duties while simultaneously providing meaningful benefits to the organization. Organ (1988) defined OCB as voluntary activities not included in the formal reward system, yet conducive to the effective functioning of the organization. Over time, the scope of the concept expanded—from altruism and helping coworkers to organizational initiative, loyalty, and adherence to norms (Podsakoff et al., 2000). At the same time, alternative approaches emerged, such as the concept of "contextual performance" (Borman, Motowidlo, 1993), leading to further interpretative divergences.

The greatest challenge, however, concerns the determinants of OCB. The literature includes numerous studies emphasizing the role of personality traits (Chiaburu et al., 2011; Organ, Ryan, 1995), while others focus on the influence of the work environment, leadership style, or perceptions of fairness (Podsakoff et al., 2000; Walumbwa et al., 2008). Yet another stream highlights employee attitudes as the key explanatory mechanism for citizenship behaviors (Cropanzano et al., 2007; Kamdar, Van Dyne, 2007). As a result, the literature resembles a "patchwork" composed of many well-researched components that, however, are rarely integrated into coherent theoretical frameworks.

This lack of integration has tangible consequences: it hinders the comparison of research findings, complicates the interpretation of conflicting conclusions, and limits the possibility of building more general theories concerning OCB. Moreover, many studies focus on selected industries or specific samples, which further complicates the generalization of results. In response to these discrepancies, calls for organizing and synthesizing knowledge about the determinants of OCB have become increasingly common (Organ et al., 2006), encompassing individual, attitudinal, and contextual perspectives.

The aim of this article is to organize this fragmented literature by:

1. providing a synthetic overview of the main research streams on the determinants of OCB,
2. classifying the factors influencing OCB into three complementary groups: personality traits, work-related attitudes, and environmental factors,
3. presenting a conceptual model that frames OCB as the outcome of the co-occurrence of these three categories of determinants, taking into account their potential interrelations and interactions.

The added value of the article is primarily organizational in nature. The proposed systematization enables a coherent understanding of previously scattered findings, while the presented model offers an interpretative framework that can be used both in empirical research and organizational practice. The analysis indicates that effectively explaining OCB requires considering several levels of determinants simultaneously—individual dispositions, psychological processes, and the organizational context—each of which may play a different role depending on the situation.

The significance of this issue extends beyond the academic context. Contemporary organizations, operating under conditions of increasing complexity and competitive pressure, increasingly rely on employees' voluntary, informal behaviors that enhance adaptability, cooperation, and team effectiveness. Understanding the determinants of citizenship behaviors thus becomes crucial for effective human capital management. The structure of the article includes: an outline of the theoretical foundations, a synthetic review of OCB determinants, a proposed conceptual model, and a discussion of findings along with directions for future research.

2. Theoretical Foundations of Citizenship Behaviors

Organizational citizenship behavior is a multidimensional phenomenon that can be interpreted from various theoretical perspectives. The literature distinguishes four dominant interpretative approaches: social exchange theory, the identification mechanism, impression management, and the concept of positive interpersonal relationships. Each of these approaches emphasizes a different motivational mechanism leading to the display of citizenship behaviors.

The most frequently referenced theoretical approach to explaining OCB is Social Exchange Theory (Blau, 1964; Cropanzano, Mitchell, 2005). It assumes that the relationship between the employee and the organization is based on the principle of reciprocity. When employees perceive that the organization treats them fairly, supports their development, and appreciates their contributions, they develop a psychological obligation to reciprocate with behaviors that benefit the organization (Organ, 1988). In this way, OCB becomes a form of "social compensation" for the organizational support experienced (Eisenberger et al., 1986).

In practice, social exchange theory explains why factors such as perceived organizational justice, trust in supervisors, or perceived organizational support (POS) are strong predictors of citizenship behaviors. High levels of trust and fairness foster the belief that the individual's efforts will be appreciated, even if they are not directly rewarded (Cropanzano et al., 2007).

However, this theory is relational in nature—it assumes that citizenship behaviors are a reaction to the treatment employees receive from the organization, rather than merely the result of internal personality traits. Therefore, many scholars (Lavelle et al., 2007) argue that social exchange can have both an organizational dimension (employee–organization relationship) and an interpersonal dimension (employee–supervisor or employee–coworker relationship).

A second approach to explaining OCB is the organizational identification mechanism, which derives from social identity theory (Tajfel, Turner, 1979). It assumes that employees strive to build a positive self-image through belonging to a prestigious group. The more strongly an individual identifies with the organization, the more they perceive its successes as their own, and its failures as personal setbacks. Strong organizational identification promotes citizenship behaviors because employees view the organization's well-being as their own. A high level of identification leads to the internalization of organizational norms and values, resulting in the spontaneous undertaking of actions that benefit the team and the institution (Ashforth et al., 2008). From this perspective, OCB is not a reaction to social exchange but an outcome of internal identification with the organization. Such behaviors are therefore more stable and less dependent on immediate situational evaluations. Research indicates that organizational identification plays an especially important role in cultural contexts characterized by high collectivism (Van Der Vegt et al., 2003).

The third approach assumes that some citizenship behaviors are strategic in nature and serve to build a positive image of the employee in the eyes of others. According to Impression Management Theory (Bolino, 1999), employees may engage in OCB not only for altruistic reasons but also to gain recognition, promotions, or the trust of supervisors. From this perspective, OCB becomes an element of self-presentation. Employees who display high levels of citizenship behaviors may be perceived as more loyal, competent, and committed, which in the long term translates into personal benefits (Grant, Mayer, 2009).

This theory explains why OCB can also occur in environments where social relationships are weak or based on competition—in such contexts, citizenship behaviors become a way of building reputation. Although this approach is sometimes criticized for emphasizing egoistic motives, it constitutes an important complement to classical altruistic theories. In reality, motivation for OCB is often mixed, encompassing both prosocial and self-presentational components (Bolino et al., 2008).

The fourth approach is based on the assumption that citizenship behaviors result from positive interpersonal relationships in the workplace. According to the Positive Relationships Theory (Cameron et al., 2003; Clark, Mills, 1979), people have a natural need to form

relationships grounded in trust, reciprocity, and empathy. Strong bonds within a team foster knowledge sharing, cooperation, and helping others—behaviors that are typically associated with OCB. These relationships do not need to be formal; they may stem from everyday interactions that build a sense of community and belonging. Research indicates that in teams with high levels of trust and social support, the frequency of OCB is significantly higher (Bowler, Brass, 2006). Positive relationships play a particularly important role in collectivist cultures, where interdependence among individuals is a social norm. This approach focuses on the social context of OCB, in which citizenship behaviors are not so much a reaction to organizational conditions as a result of functioning within a network of trust-based and supportive relationships.

Although each of the above approaches focuses on a different motivational mechanism, in practice the phenomenon of OCB requires an integrative perspective. Social exchange theory explains the relational component of OCB, the identification mechanism explains the identity-based component, impression management highlights the strategic component, and positive relationships emphasize the social component. Only by jointly considering these four perspectives can one grasp the complexity of citizenship behaviors and understand why different factors may lead to similar outcomes.

The following section of the article presents a detailed analysis of the determinants of organizational citizenship behavior across three key categories: personality traits, work-related attitudes, and environmental factors.

3. Determinants of Citizenship Behaviors

Following the research directions outlined above, the article first describes personality traits that have been examined as potential foundations for engaging in citizenship behaviors. Next, work-related attitudes are analyzed. Finally, the article discusses the group of determinants rooted in the organization itself, that is, environmental factors.

3.1. Personality Traits

Several meta-analyses have been conducted in which authors examined the relationships between different human personality traits and OCB. However, these analyses most often differed in terms of how they were designed. In Borman and colleagues' meta-analysis (2001), an aggregated index of citizenship behavior was considered. Lapierre and Hackett (2007) adopted a similar approach. In some analyses, separate studies were conducted for OCB-I and OCB-O (Ilies et al., 2009; Lepine et al., 2002), while others examined only selected categories of OCB (Organ, Ryan, 1995). For individuals in managerial positions, many behaviors

classified as OCB naturally stem from their job responsibilities; therefore, the aforementioned meta-analyses primarily included non-managerial positions.

Previous research seeking the dispositional basis of citizenship behaviors has focused mainly on the Big Five model. Numerous studies have shown that conscientiousness correlates most strongly with OCB. Individuals high in conscientiousness are hardworking, responsible, dependable, disciplined, and skilled at organizing their work. Such an employee is consistent in their actions, sets demanding goals for themselves, and diligently strives to achieve them (Oleś, Drat-Ruszczak, 2008). Conscientious individuals are also more likely to follow organizational procedures and behavioral norms. Given this personality profile, it is reasonable to expect that highly conscientious employees are more inclined to exhibit citizenship behaviors (Baka, 2016). Organ and Ryan (1995) demonstrated that conscientiousness shows a positive and statistically significant relationship with OCB, especially with altruism and organizational compliance. Ilies et al. (2009), in addition to examining aggregated OCB, also analyzed links between personality traits and specific OCB dimensions. Their findings indicated that conscientiousness is most strongly associated with behaviors directed toward the organization (OCB-O), while agreeableness is most closely linked to behaviors directed toward individuals (OCB-P).

Agreeableness encompasses traits such as loyalty, warmth, politeness, and cooperativeness. A person high in agreeableness is caring, considerate, attentive to others' needs, and often displays empathy. In this sense, agreeable individuals are friendly, willing to help, and inclined to believe that others act similarly (Kraczla, 2017). People with high agreeableness enjoy being "socially useful". They tend to be well-liked, more compliant, and more willing to follow rules. They generally perform better in tasks where interpersonal relations matter (Barrick, Mount, 1993), and their attitude is far from competitive.

Since citizenship behaviors inherently involve support and a positive work environment, agreeable individuals may view OCB as a means of gaining acceptance and fostering positive workplace conditions. Empirical analyses confirm these relationships. High agreeableness correlates with aggregated OCB as well as with both OCB-O and OCB-P (Chiaburu et al., 2011). Neuman and Kickul (1998) also demonstrated relationships between agreeableness and various OCB categories—altruism, civic virtue, organizational compliance, courtesy, and conscientiousness—though these associations were weaker than those for conscientiousness.

The third component of the Big Five—extraversion—involves high levels of activity, positive energy, and the capacity to experience positive emotions. Extraverted individuals tend to enjoy life, are sociable, assertive, and communicative. Despite some evidence of positive relationships between extraversion and job performance, the link between extraversion and OCB remains insufficiently confirmed. Organ (1994) described the findings regarding extraversion as the most disappointing. However, isolated studies cited by Baka (2016) indicate weak but positive associations between OCB, extraversion, and positive affectivity—

understood as a component of extraversion. The role of positive affectivity in providing emotional support was demonstrated, among others, by Toegel, Anand, and Kilduff (2007). Encouragingly, Polish studies have shown positive correlations between OCB and extraversion, as well as its components—activity and assertiveness (Witkowski, Chwalibóg, 2010).

Neuroticism comprises traits such as sensitivity, anxiety, anger, nervousness, and fear. Individuals high in neuroticism are more prone to experiencing negative emotions, feel insecure, and are more psychologically reactive to stress. They may exhibit irrational behaviors, have difficulty controlling their emotions, and struggle with stress (Kraczla, 2017). According to Oleś and Drat-Ruszczak (2008), traits characteristic of neuroticism do not foster employee activity or engagement in helpful behaviors. Thus, one may infer a negative relationship between neuroticism and OCB. Baka (2016) identified several studies examining the relationship between one component of neuroticism—negative affectivity—and OCB. The results suggest negative associations between the constructs, both for aggregated OCB and for its individual dimensions (Hogan et al., 1998; McManus, Kelly, 1999).

The final component of the Big Five is openness to experience, which involves an individual's tendency to seek life experiences and evaluate them positively, cognitive curiosity, and acceptance of change. Individuals high in openness are creative, innovative, and eager to explore the world. They strive to continuously develop their competencies and knowledge, value autonomy, and seek variety in their work. One might expect that a tendency toward new experiences and creativity would correlate significantly with OCB. However, findings are inconsistent. Some studies show positive but weak relationships between openness and aggregated OCB, as well as between openness and both OCB dimensions (OCB-P and OCB-O) (Chiaburu et al., 2011). Other studies report no significant relationship between openness and OCB (Bourdage et al., 2012). Additionally, several authors suggest—and empirically confirm—that openness is an important predictor of OCB, especially in terms of fulfilling social expectations at work and promoting the organization's external image (Abu Elanain, 2007). The inconsistencies reflect primarily the limited amount of research on this trait.

The Big Five personality traits do not exhaust the catalogue of characteristics considered in predicting employee-initiated behaviors. In addition to the Five-Factor Model, researchers have also examined the relationships between OCB and traits such as locus of control, collectivism, and prosocial orientation.

The locus of control stems from the fact that people often have different interpretations and perspectives on the same events, whether they concern themselves or others. Julian Rotter (1966), the creator of the theory, argued that individuals fall into two categories: those who believe they control their own destiny, and those who think their lives are governed by external forces. For this reason, the locus of control can be divided into internal and external. People with an internal locus of control are more confident in their abilities and in their influence over the outcomes of their actions. They tend to be more engaged and more likely to take initiative.

One might therefore assume that such behaviors would largely support the undertaking of citizenship behaviors. However, research findings on this issue are not entirely consistent. Motowidlo and Van Scotter (1994) found positive relationships between internal locus of control and overall OCB. In contrast, Fundenberg and Levy (1997) confirmed a positive relationship between internal locus of control and altruism measured through self-reports, but a negative relationship when altruism was assessed by coworkers. As Baka (2016) notes, these inconsistencies may stem from the limited knowledge about the mechanisms through which locus of control influences OCB.

Another trait under examination is collectivism, understood as the opposite of individualism. Although debates exist as to whether collectivism should be treated as a personality trait, some researchers do approach it this way. Collectivism refers to communal orientation. Definitions of collectivism emphasize the importance of group belonging and placing group goals above one's own ambitions. Realo et al. (2008) argue that communal orientation treats the group as the primary unit of reality and requires individuals to commit themselves to the interests of the community. People with this trait tend to improve their skills for the benefit of the majority and value teamwork. These assumptions led researchers to explore the links between collectivism and OCB. Van Dyne et al. (2000), in an analysis of employees of a housing cooperative, showed that collectivism is associated with helpful behaviors. Lee and Allen (2002) found in their research on managerial staff that a high level of collectivism correlates with the amount of time managers spend mentoring employees. Positive relationships between collectivism and OCB were also observed by Borman et al. (2001).

Another trait—prosocial orientation—is linked to a system of moral norms and evaluations that emphasizes the importance of considering the well-being of others in one's own actions. The welfare of others, which must be respected, becomes the overriding value (Mariański, 2014). The pioneers of this concept and creators of a tool for measuring prosocial orientation were Penner, Fritzsche, Craiger, and Freifeld (1995). Their instrument measured seven personality characteristics referring to prosocial behaviors, thoughts, and emotions. An analysis by Midili and Penner (1995) revealed factors such as other-oriented empathy and helpfulness. Empathy correlated with all OCB categories, while helpfulness correlated with four.

The relationships between the eight personality traits listed above and citizenship behaviors indicate that the strongest connections occur for conscientiousness and agreeableness. A positive relationship—though based on a limited number of studies—can also be observed for collectivism and prosocial orientation. Extraversion, neuroticism, openness to experience, and locus of control do not play as significant a role in this relationship. However, it is important to note that the number of studies examining these traits is still insufficient. The results of analyses within the group of personality determinants of OCB are summarized in Table 1.

Table 1.
Results of Analyses on Personality Determinants of OCB

Personality Trait	Relationship with OCB	Determinant
Conscientiousness	positive	Conscientiousness
Agreeableness	positive	Agreeableness
Extraversion	weak positive / insufficient evidence	Extraversion
Neuroticism	negative	Neuroticism
Openness to experience	inconsistent results	Openness to experience
Locus of control	inconsistent results	Locus of control
Collectivism	positive	Collectivism
Prosocial orientation	positive	Prosocial orientation
Conscientiousness	positive	Conscientiousness

Note: "+" indicates that the trait is recognized as a determinant of OCB, "–" indicates it is not.

Source: own elaboration based on (Grego-Planer, 2023, p. 57).

It is worth noting that the vast majority of authors addressing this topic emphasize that the relationship between personality traits and citizenship behaviors is multifaceted in nature. Some researchers assume that personality traits may influence OCB directly. However, the dominant view suggests that this influence is indirect—occurring through the shaping of work attitudes or by moderating the relationship between how employees perceive their work environment and their actual behavior (2000). In recent years, growing attention has been given to Spector and Fox's (2005) stressor–emotion framework. According to this perspective, an interactional approach is crucial: personality traits become relevant for displaying OCB only when combined with environmental factors—that is, organizational or situational influences (Dalal, 2005).

3.2. Work-related attitudes

The second group of determinants of organizational citizenship behaviors consists of attitudes. These subjective (individual) factors—alongside personality traits—have been conceptually and empirically linked to OCB. In light of social exchange theory and the norm of reciprocity, a positive relationship is expected between employees' attitudes toward the organization and their citizenship behavior. As Dalal (2005) notes, if an organization provides employees with favorable working conditions, it may expect reciprocation in the form of engagement in OCB. Meta-analytic findings have confirmed these expectations (Lepine et al., 2002). Bolino et al. (2002) showed that the willingness to take on extra-role activities increases when employees are satisfied with their jobs or strongly attached to their organization. Podsakoff and colleagues (2000) reported similar conclusions, finding consistent support for the notion that positive work attitudes foster citizenship. Three key attitudes are most commonly emphasized in relation to OCB: job satisfaction, organizational commitment, and perceived organizational justice.

Hopkins (2002) defines job satisfaction as the fulfillment of specific needs related to performing a job. Traditionally, it encompasses relationships with coworkers, pay, working conditions, supervision, and benefits. According to Colquitt et al. (2019), job satisfaction reflects how employees feel about their work and how they evaluate it. Golbasi & Selma (2008) add that it is both an emotional and behavioral response to work, shaped by achievements, the work environment, and broader professional experiences. When an organization raises job satisfaction, employees—consistent with the logic of reciprocity—"repay" it by exhibiting OCB more frequently. Empirical evidence supporting this relationship was provided by, among others, Bateman and Organ (1983) and Organ and Konovsky (1989). Organ and Lingl (1995) found that overall job satisfaction increases altruistic behavior. Strong positive links between satisfaction and OCB are also reported in studies by Murphy et al. (2002), Foote et al. (2008), and more recent analyses by Setyowati et al. (2021) and Haji et al. (2021). The scale and consistency of findings confirm that job satisfaction is a robust antecedent of organizational citizenship.

Organizational commitment is the second attitude consistently identified as a determinant of OCB. It is defined as the relative strength of an individual's identification with and involvement in an organization (Mowday et al., 1982). In Meyer and Allen's (1997) three-component model, commitment is divided into affective, normative, and continuance commitment. The affective component refers to emotional attachment to the organization, the normative component reflects a sense of obligation to stay, and the continuance component concerns the perceived costs of leaving. Commitment is considered a factor promoting OCB because it reflects a readiness to support the organization even without direct rewards. Meyer et al. (2002) showed that employees who are emotionally attached to their organization engage more frequently in OCB, with the effect particularly strong for affective commitment (Meyer, Allen, 1997). This relationship is confirmed in more recent work (Siregar et al., 2019; Vasudevan, 2021). It is also worth noting that some scholars consider commitment—compared with satisfaction—to be a stronger antecedent of organizational outcomes, including OCB (Luthans, 1998).

Another key construct in the domain of individual determinants of citizenship is perceived organizational justice. In a social context, it refers to the extent to which employees perceive events and practices in an organization as aligned with their expectations (Herington et al., 2005). Moorman et al. (1993) argue that justice is associated with numerous positive organizational outcomes. Organ (1988) emphasized that the sense of justice is crucial: individuals who experience fair treatment are more likely to display positive attitudes toward their work, performance, and supervisors. Folger and Konovsky (1989) found strong links between perceived justice, organizational commitment, trust in supervisors, and pay satisfaction. Employees who view organizational processes as fair are more loyal and more willing to act in the organization's interest (Cropanzano et al., 2007). Importantly, Moorman et al. (1993) identified justice as an antecedent of OCB. Organ (1988) argued that fairness fosters

the building of faith and trust necessary for engaging in beneficial yet discretionary citizenship behaviors. Positive relationships between various OCB categories and perceived justice were confirmed, among others, by Konovsky and Folger (1989), Martin and Bies (1991), and Niehoff and Moorman (1993).

More recent studies have examined specific dimensions of justice: Nelson and Appel (2021), studying correctional officers in Israel, found that procedural justice is strongly linked to organizationally targeted OCB; Lim and Loosemore (2017) highlight the dominant role of interpersonal justice in shaping OCB. A lack of perceived justice clearly reduces such behaviors (Tziner, Sharoni, 2014).

3.3. Environmental Factors

Environmental factors constitute the final major group of determinants of citizenship behaviors. Undoubtedly, organizational conditions—and employees' perceptions of them—play an essential role in shaping OCB. The ways in which these determinants are grouped vary and often overlap. Podsakoff et al. (2000) attempted to systematize existing knowledge and identified three key categories: job characteristics, organizational characteristics, and leader behavior. Organ and colleagues (2006) proposed a different classification, distinguishing leadership behaviors (with emphasis on transformational and servant leadership), leader–member exchange (LMX), and employee participation. A second group of factors, according to these authors, concerns the work environment: satisfying tasks, group characteristics (cohesion, support, relationships), organizational features (e.g., formalization, perceived organizational support), and cultural context (especially the individualism–collectivism dimension). Spitzmuller and colleagues (2008) propose yet another division: individual antecedents, task characteristics, and social relationships with supervisors and coworkers.

Based on further analysis of the literature on OCB antecedents, the group of environmental factors—those shaped by the organization itself and closely tied to working conditions—can be understood to include primarily:

- organizational characteristics (including formalization, organizational climate, perceived organizational support),
- job/task characteristics,
- social relationships within the organization,
- leader behaviors.

Regarding organizational characteristics, the impact of formalization on OCB has been increasingly studied. Although excessive formalization and lack of flexibility may inhibit citizenship behaviors, organizational structure itself can influence their expression. In other words, the inclination to engage in OCB partly depends on one's position in the hierarchy. Yoshikawa and Hu (2017) indicate that at higher managerial levels, certain factors emerge that shape citizenship behaviors: informal role division among decision-makers, role identity,

and the relationship between hierarchical position and the tendency toward OCB—the higher the decision-making level, the stronger the tendency.

Engaging in activities beyond routine duties—i.e., beyond the narrowly defined role—requires a supportive work climate. Organizational climate is the shared perception of organizational events and practices—recurring patterns of attitudes and feelings (Griffin, Moorhead, 2014). When the organization is perceived as supportive, this fosters OCB. The most influential climate components include: supervisory support and voice (employee input), fair compensation (well-being), autonomy, and participation (Nwankwo et al., 2015; Randhawa, Kaur, 2015).

Perceived organizational support (POS) is the last construct within organizational characteristics. It reflects the extent to which employees feel that the organization values their contributions and cares about their well-being (Eisenberger et al., 1986). Although POS primarily influences individual-level variables, the perception of support may stem from organizational or relational factors (e.g., employee–supervisor interactions). These include job security, leader–member exchange (LMX) quality, and supervisor support (Gojny-Zbierowska, 2016). Numerous studies confirm strong links between POS and OCB (Ahmadi et al., 2010; Asgari et al., 2008; Kapela, Pohl, 2020).

The second category of environmental factors consists of job/task characteristics. Researchers consistently emphasize that tasks should be intrinsically satisfying, varied, and accompanied by leader feedback. Such characteristics are associated with higher levels of OCB. Empirical evidence shows that the strongest positive correlations with OCB occur for satisfying tasks and feedback, whereas routine, non-varied tasks are associated with lower levels of citizenship behaviors (Podsakoff et al., 2000).

Social relationships are another key area. The literature shows growing interest in the link between relationships and OCB. Bowler and Brass (2006) argue that without accounting for social relationships, one cannot fully understand citizenship behaviors. Dovidio et al. (2006) add that relationship quality can be a powerful predictor of human behavior. Relationships with coworkers have repeatedly been identified as antecedents of OCB—in the spirit of social exchange, good relationships are "reciprocated" through interpersonal citizenship behaviors. What matters is not only relationship quality but also group cohesion and cooperation norms (Ng, Van Dyne, 2005). Studies further suggest that coworker relationships are a key proximal antecedent of interpersonal OCB (Kamdar, Van Dyne, 2007).

Employee–supervisor relationships are of particular importance. Leader–Member Exchange (LMX) theory describes leadership based on relationships, emphasizing supportive, appreciative, consultative, and delegating behaviors (rather than strictly task-oriented ones) (Yukl et al., 2009). A meta-analysis by Ilies et al. (2007) indicates especially strong links between high-quality LMX and interpersonal citizenship. Kamdar and van Dyne (2007) also showed that employees "reciprocate" OCB directed specifically at the leader.

Leader behaviors constitute the final—and often considered the most important—category of environmental determinants of OCB. This area has generated an extensive body of empirical evidence. Beyond LMX, research has examined links between OCB and leadership practices such as: building acceptance of group goals, articulating vision, modeling desired behaviors, providing intellectual stimulation, shaping climates of trust and respect, and setting high expectations. All these elements show positive relationships with citizenship behaviors (Podsakoff et al., 2000). Additional studies demonstrate positive associations between OCB and leaders' rewarding behaviors, role clarity, and support (Podsakoff et al., 2000; Tran, Choi, 2019). Walumbwa et al. (2008) suggest that perceived leader integrity increases employees' tendency to engage in organizational goals and display OCB. Lapierre and Hackett (2007) argue that although conscientiousness may be innate, its expression requires a satisfactory relationship with the supervisor. According to their view, the link between leadership style and proactivity emerges when the leader–subordinate relationship reaches high quality. These conclusions are reinforced by findings by Lo et al. (2006), who determined that leader–member relationships play a crucial role in motivating OCB and examined how trust develops under fair leadership. They found that building high-quality relationships increases job satisfaction and trust, which likely translates into greater conscientiousness. Undeniably, leader behaviors should provide a role model and support for subordinates—this is one of the key dimensions shaping employee activity. The determinants of citizenship behaviors, divided into categories, are presented in Figure 1.

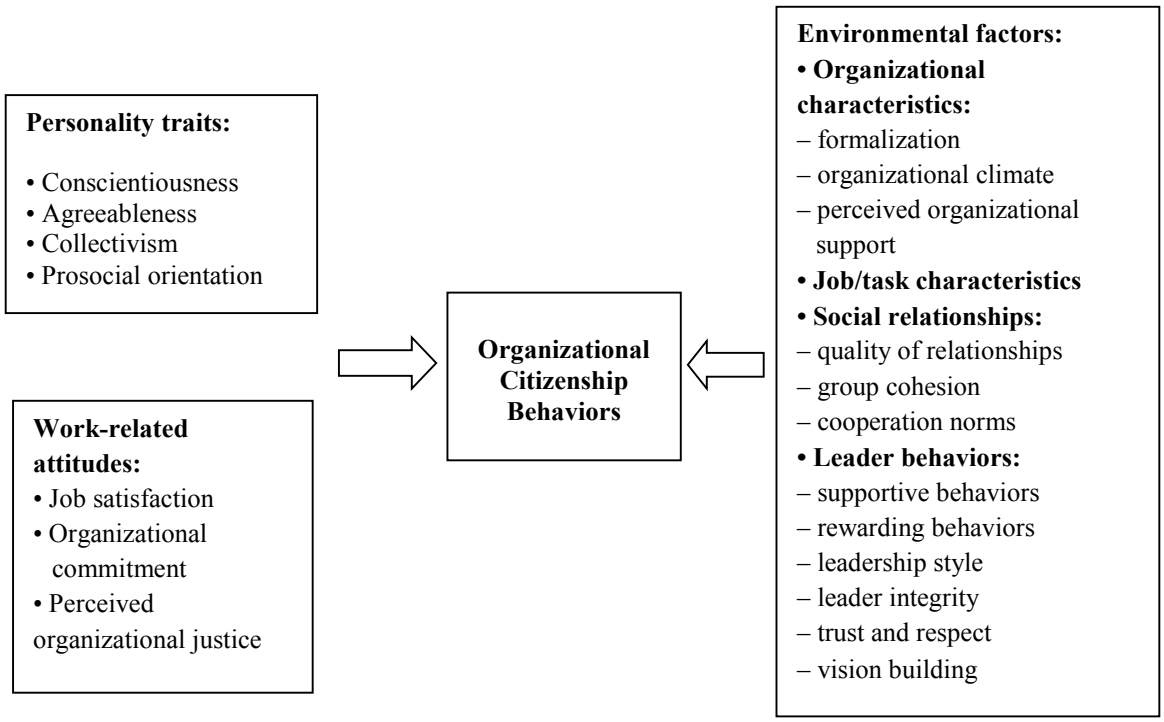


Figure 1. Determinants of Citizenship Behaviors.

Source: own elaboration based on (Grego-Planer, 2023, p. 67).

The classification of the determinants of citizenship behaviors presented in this section of the article certainly does not exhaust all the themes discussed in the literature. However, the authors hope that, drawing on the available sources, they have been able to offer a degree of structure to this issue in a synthetic and coherent manner.

4. Conceptual Model: An Interactionist and Layered Approach

Based on the literature review and the arguments presented earlier, a conceptual model is proposed that moves away from treating the three groups of determinants (personality traits, work-related attitudes, and environmental factors) as parallel and independent sources of OCB. Instead, this model (Figure 2) assumes that these determinants form a system of mutually interconnected mechanisms in which:

1. Personality traits influence OCB primarily indirectly—through shaping work-related attitudes and through the moderated effects of environmental factors.
2. Environmental factors provide the context that activates or suppresses the influence of personality traits and simultaneously shape attitudes, which in turn determine citizenship behaviors.
3. Work-related attitudes serve as a central mediator, transmitting the effects of both personality traits and the organizational environment onto OCB.

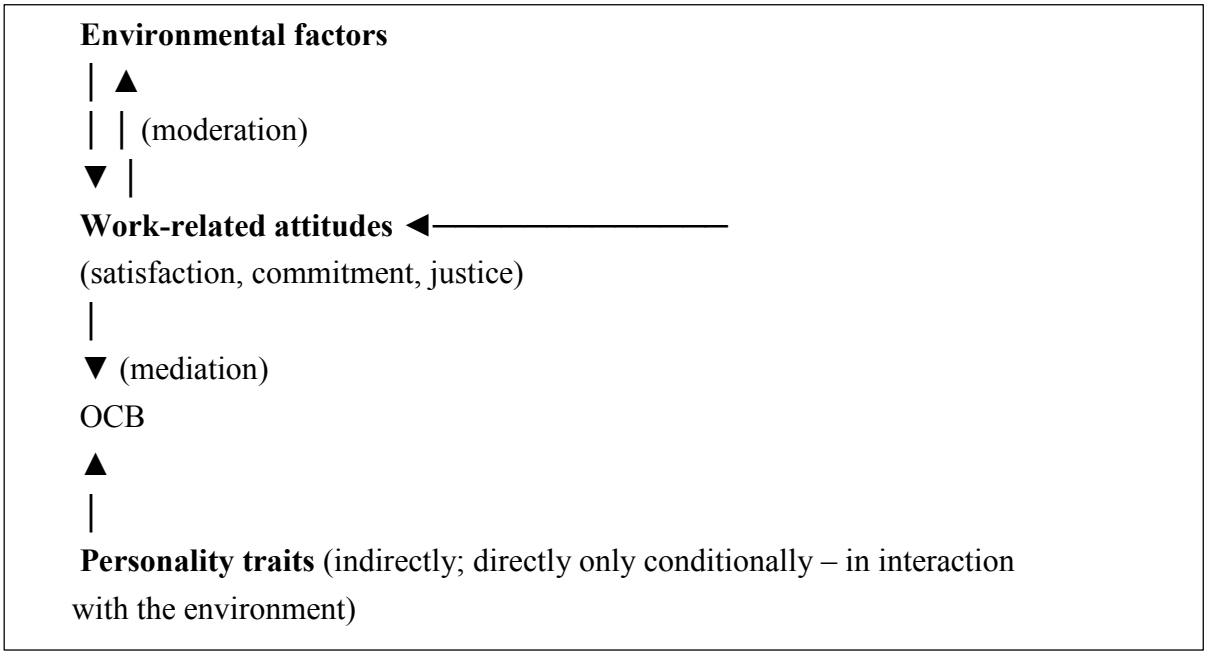


Figure 2. Conceptual model of OCB's determinants.

Source: own elaboration.

The model assumes three fundamental pathways:

(1) Personality → Work-related attitudes → OCB (mediation)
Personality traits rarely lead directly to OCB but instead influence how employees perceive their work, relationships with supervisors, fairness, climate, and satisfaction. These attitudes constitute the key mechanism through which psychological dispositions translate into behavior.

(2) Organizational environment → Work-related attitudes → OCB (full or partial mediation)
Environmental factors—such as climate, LMX, organizational justice, job design, or organizational culture—strongly and consistently influence attitudes toward work (Podsakoff et al., 2000). These attitudes partially mediate the impact of the environment on OCB; however, in many cases, the environment also exerts a direct effect on OCB (e.g., leadership style, relationship quality).

(3) Personality × Environment → Attitudes/OCB (moderation)
According to the interactionist perspective, personality traits manifest in citizenship behaviors only when the organizational environment allows their expression. This means that the influence of conscientiousness, agreeableness, or proactivity will be stronger when employees experience fairness, organizational support, or high-quality leader–member exchange (LMX).

The proposed model aligns more closely with contemporary scientific findings than classical linear approaches.

First, it acknowledges that research on personality traits yields mixed results, primarily because work environments are heterogeneous and differ in how much they enable employees to express their dispositions (Dalal, 2005).

Second, the model highlights the central role of work-related attitudes, which—according to meta-analyses—are the strongest and most consistent predictors of OCB (Lepine et al., 2002; Organ, 1990; Podsakoff et al., 2000).

Third, this approach helps explain why in some environments personality effects are weak or insignificant—because these dispositions cannot manifest without support and fairness.

5. Discussion and Theoretical Implications

The conducted literature review and the proposed conceptual model allow for the formulation of several key conclusions about the nature of organizational citizenship behavior (OCB). First, the review indicates that previous research on OCB antecedents has been marked by a lack of terminological consistency. Different classifications have coexisted in the literature, often overlapping, and in many cases the same variables were described using different

conceptual categories. As a result, drawing synthetic conclusions was difficult, and interpretations of existing findings were often ambiguous. Organizing these fragmented perspectives into three overarching groups—personality traits, work-related attitudes, and environmental factors—therefore constitutes a significant added value. This structure makes it possible to view OCB determinants through the lens of three classical levels of analysis in organizational behavior: individual dispositions, psychological states, and organizational context.

However, this organization serves not only a classificatory function. It also enables the identification and explanation of complex relationships linking these three groups of factors. In this regard, the interactionist perspective proposed in the article is particularly important, consistent with the stressor–emotion model (Spector, Fox, 2005) and Dalal's (2005) arguments. According to this approach, personality traits do not affect citizenship behaviors directly and uniformly, as classical dispositional models would suggest. Their influence is realized primarily through the shaping of work-related attitudes or only in situations where the organizational context supports the expression of prosocial dispositions. This means that personality "works" only under certain conditions—those that enable the manifestation of traits associated with altruism, conscientiousness, or agreeableness.

At the same time, the literature review confirms that environmental factors are not merely a backdrop but play an activating role. Organizational climate, the quality of relationships with supervisors, fairness, organizational support, and job characteristics are the factors that most strongly shape employees' attitudes, which subsequently translate into citizenship behaviors. These attitudes—including job satisfaction, organizational commitment, and perceived justice—thus constitute the central psychological mechanism linking both individual dispositions and the work environment with OCB. In light of meta-analyses (Lepine et al., 2002; Podsakoff et al., 2000), these variables consistently demonstrate the strongest and most stable predictive power.

The proposed interactionist model allows OCB to be viewed as a phenomenon emerging at the intersection of three spheres: employee dispositions, the organizational environment, and the attitudes formed through their interaction. This perspective not only explains the inconsistencies found in previous research more effectively but also offers a more realistic and useful analytical tool for organizational practitioners. The integration of dispositional, situational, and attitudinal approaches forms a coherent theoretical framework that supports further empirical research using mediated and moderated models.

To enhance the usefulness of the proposed model and provide a foundation for its empirical validation, it is important to indicate specific analytical strategies appropriate for the interactionist and layered approach. The model assumes the simultaneous presence of both mediation and moderation processes, which necessitates the use of advanced statistical methods.

First, suitable methodological approaches include mediation and partial mediation models, which allow for examining whether work-related attitudes indeed mediate the relationship between personality traits or environmental factors and OCB. In particular, structural equation modeling (SEM) enables the simultaneous testing of multiple paths and accounts for measurement error, which is crucial when analyzing psychological constructs.

Second, to verify the interactional role of the organizational environment assumed in the model, it is necessary to apply moderation analyses. These analyses make it possible to empirically determine whether the influence of personality traits on OCB becomes stronger under conditions of high organizational justice, perceived organizational support, or high-quality LMX relationships.

Third, given the simultaneous occurrence of mediation and moderation, the most appropriate empirical method is moderated mediation. This approach tests whether the strength of mediational pathways (e.g., personality → attitudes → OCB) depends on the level of environmental factors (e.g., organizational climate or leadership style). This is essential for the proposed theoretical framework, in which the environment not only shapes OCB directly but also conditions the extent to which individual dispositions can manifest.

Fourth, longitudinal studies may serve as a valuable complement to cross-sectional analyses, as they allow for testing the directionality of effects and determining whether the relationships described are stable over time. This is particularly important for attitudes and behaviors that may evolve with employees' experiences.

Fifth, model validation should ideally rely on multi-source data (e.g., self-reports combined with supervisor ratings), which helps reduce the risk of common method bias—a frequent concern in OCB research.

In sum, empirical validation of the proposed model requires the application of integrated analytical techniques, such as moderated mediation, SEM, or multilevel analyses, which account for the simultaneous influence of individual dispositions, attitudes, and environmental factors. These methods will not only confirm the model's adequacy but also deepen understanding of the psychological mechanisms underlying organizational citizenship behaviors.

6. Practical Implications

The conclusions drawn from the analysis have important implications for management practice and the design of the work environment. First, it is worth emphasizing that although organizational citizenship behaviors are associated in the literature with many different antecedents, effectively strengthening them requires understanding that personality traits, work-related attitudes, and organizational environmental factors operate simultaneously at different

levels of employee functioning. They do not represent separate, fully independent domains but rather areas that can complement one another in fostering or inhibiting OCB. In practice, this means that organizations aiming to build a culture supportive of citizenship behaviors should approach employee development holistically.

A key practical conclusion from the literature review is the role of the work environment as a space that can amplify or weaken the influence of both personality traits and attitudes. This implies that organizations should concentrate on creating conditions that promote a sense of fairness, trust, and psychological safety, because these elements enable the fuller expression of employees' prosocial dispositions. In practice, this includes transparent procedures, consistent leadership actions, adequate compensation systems, and reducing excessive formalization, which—according to research—does not promote engagement in discretionary behaviors.

The analysis also confirmed that work-related attitudes play an essential role in explaining citizenship behaviors. This leads to several practical recommendations: organizations should foster employee satisfaction, reduce barriers that undermine organizational commitment, and strengthen perceptions of procedural, distributive, and interpersonal justice. Because these attitudes reflect employees' overall assessment of their working conditions, improving them can substantially increase their willingness to engage in behaviors that go beyond formal job requirements.

From a management perspective, the role of leaders is particularly critical, as their behaviors and leadership style constitute one of the strongest predictors of OCB. Supportive and fair leadership, providing constructive feedback, openness to dialogue, and consistency in actions can influence employees' propensity to engage in organizationally beneficial initiatives—both directly and indirectly. For this reason, developing managerial competencies—especially in the areas of relationship-building, communication, and influence—should be a central element of HR policies aimed at fostering citizenship behaviors.

In summary, the model presented in this article and the developed categorization of the three main groups of OCB determinants lead to the conclusion that effectively supporting citizenship behaviors requires combining efforts across several complementary areas: ensuring favorable organizational conditions, strengthening positive work-related attitudes, and taking into account individual differences among employees.

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DETERMINANTS OF CONSUMER DEBT PROPENSITY IN THE ERA OF FINTECH EXPANSION AND THE RISE OF BUY NOW, PAY LATER (BNPL)

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Purpose: To identify and synthesize the determinants of consumers' propensity to incur debt, focusing on the impact of FinTech expansion and the rapid growth of buy-now-pay-later (BNPL) services.
Design/methodology/approach: Narrative literature review of over 30 peer-reviewed articles and reports (2010-2024) from international databases and Polish sources, integrating economic, socio-demographic, and psychological/behavioral perspectives.
Findings: Consumers' propensity to incur debt results from the interaction of three factor groups: economic (e.g. income, credit availability), socio-demographic (e.g. age, household composition, level of education), and especially psychological/behavioral (e.g. impulse-buying propensity, limited financial literacy, present bias, social norms). Buy Now, Pay Later (BNPL) services substantially elevate the risk of indebtedness by broadening access to credit, obscuring its true cost, leveraging cognitive biases, and promoting impulsive purchasing behavior, particularly among younger consumers.
Research limitations/implications: Narrative (not systematic) review; many BNPL studies are cross-sectional and context-specific. Longitudinal research combining transactional and psychological data is needed.
Practical implications: Urgent need for regulation of BNPL services (including affordability assessments and enhanced transparency), for responsible lending practices by FinTech companies and banks, and for strengthened financial literacy programs.
Societal implications: Risk of increasing over-indebtedness, exacerbation of financial inequality, and reinforcement of materialistic consumption is particularly pronounced among younger individuals and those with low financial literacy.
Originality/value: One of the first integrative reviews linking traditional and behavioral determinants of consumer indebtedness with the transformative role of BNPL and FinTech companies, with particular relevance for Central and Eastern European markets.
Keywords: consumer indebtedness, buy now pay later (BNPL), FinTech companies, behavioral finance, financial literacy.
Category of the paper: Literature review.

1. Introduction

Increasing consumer indebtedness represents a critical challenge for contemporary economies, as its level directly affects consumption, macroeconomic stability, and societal well-being. In 2023, U.S. credit card debt surpassed $1 trillion (Ackert et al., 2024), highlighting the magnitude of this phenomenon. Understanding the mechanisms that drive individuals' decisions to incur debt has thus become essential for promoting long-term economic stability (Waliszewski et al., 2024).

Prior research on household indebtedness has predominantly relied on rational economic frameworks, often overlooking the complexity of human behavior. Empirical studies—primarily from European countries, including Poland—have typically focused on economic determinants such as income, employment, education level, and credit policies. These studies frequently employ household resource-optimization models to explain debt-related decisions (Anioła, Gołaś, 2011; Wałęga, Wałęga, 2016; Sztaudynger, 2018). For example, macroeconomic analyses have highlighted the influence of unemployment and industrial production on credit risk, treating household indebtedness as a function of external economic indicators (Panciszko, 2016).

While the extant literature has meticulously catalogued the economic determinants of indebtedness through the lens of rational optimization models—most notably in the Life-Cycle Hypothesis (Modigliani, Brumberg, 1954) and the Permanent Income Hypothesis (Friedman, 1957)—and parallel research streams have examined psychological biases affecting financial decision-making (Kahneman, Tversky, 1979), a substantial theoretical gap persists in understanding how these domains interact within contemporary digital ecosystems.

The originality of this paper lies in its integrative analytical approach. In contrast to prior studies that tend to conceptualize economic constraints and psychological predispositions as orthogonal determinants, this review demonstrates how FinTech and Buy Now, Pay Later (BNPL) services leverage behavioral biases—such as present bias and mental accounting—to erode, circumvent, or recalibrate traditional economic constraints. By juxtaposing the rigid, resource-based constraints posited by neoclassical economic theory with the fluid, psychologically driven forms of accessibility characteristic of modern LendTech (Sng, Tan, 2022; Di Maggio et al., 2022), this study develops a novel, multidimensional framework for explaining individuals' propensity to incur debt.

Furthermore, this article is among the first to situate these global mechanisms within the distinct regulatory and economic context of Central and Eastern Europe, focusing specifically on Poland. It examines the unique complementarity between banking-sector stability and FinTech-driven innovation during periods of economic turbulence (Waliszewski et al., 2024), thereby offering an empirically grounded regional extension to predominantly Western-centric debates on digital indebtedness.

Based on the current literature, this review identifies three main groups of determinants influencing consumers' propensity to incur debt: economic, socio-demographic, and psychological-behavioral factors.

The remainder of the article is organized as follows: in the second part of the article, the most relevant economic theories underpinning the discussed topic are highlighted, and studies confirming the significance of the factors identified within these theories for consumer indebtedness are presented. The third part outlines the methodology employed in the literature review. The fourth part presents the conclusions drawn from a critical review of the literature on the determinants of indebtedness, along with the proposed key theoretical and practical implications. The fifth part of the article presents a discussion with the existing literature. Finally, the sixth part formulates the overall conclusions, identifies the limitations of the review, and suggests directions for future research.

2. Theoretical Foundations of Consumer Indebtedness Determinants

Understanding consumers' decisions to incur debt requires reference to several fundamental economic and psychological theories, which provide the framework for analyzing this phenomenon. The present article is grounded in the following theories:

- Life-cycle theory, the permanent income hypothesis, and rational choice theory – with regard to economic factors.
- Relative income hypothesis, social influence concepts, family life-cycle theory, and household economics – with regard to socio-demographic factors.
- Behavioral finance and prospect theory, self-control and self-regulation theories, and financial knowledge and competence models – with regard to psychological and behavioral factors.

The life-cycle theory, developed by Modigliani and Brumberg (1954), posits that individuals aim to smooth consumption over their lifetime. Consequently, households incur debt in the early stages of their working life, when incomes are low and needs are high (e.g., housing purchases, education), in order to repay it during peak earning periods (Strzelecka, Zawadzka, 2020a; Strzelecka et al., 2020b). Similarly, Friedman's (1957) permanent income hypothesis suggests that consumption depends not on current, but on expected future income, and that credit serves as a tool for consumption smoothing over time (Strzelecka, Zawadzka, 2020a). These models, based on the assumption of rationality, provide a starting point for analyzing the economic motives of indebtedness.

Duesenberry's (1949) relative income hypothesis indicates that the level of consumption (and thus the propensity to incur debt) depends not only on an individual's absolute income but also on the income and living standards of reference groups—such as family, neighbors,

or peers (Strzelecka, Zawadzka, 2020a). The "keeping up with the Joneses" phenomenon encourages borrowing to finance conspicuous consumption, aimed at social status and group identification (Cosma, Pattarin, 2011; Livingstone, Lunt, 1992). In this context, social norms—both empirical (what others do) and normative (what others consider appropriate)—are particularly significant. Research indicates that the perception of BNPL use as socially acceptable significantly reinforces consumers' propensity to adopt this form of financing (Ackert et al., 2024). At the same time, family life-cycle theory (Glick, 1947; Hill, 1986) and the new household economics approach (Becker, 1965) emphasize that financial needs and the propensity to incur debt change across different stages of household development (forming a couple, having children, children leaving home, retirement). During phases of intensive expenditure growth (e.g., housing purchases, children's education), households are more likely to borrow as a means of consumption smoothing, consistent both with Becker's (1965) classical time and resource allocation model and with empirically observed higher levels of indebtedness in multi-person households with dependent children (Strzelecka, Zawadzka, 2020a; Strzelecka et al., 2020b).

Classical economic theories, including rational choice theory (Becker, 1976), assume fully rational consumers maximizing utility. Behavioral finance and prospect theory challenge this assumption, highlighting systematic cognitive errors and emotional biases. Consumers exhibit myopia, excessive optimism regarding future repayment capacity, loss aversion, and a preference for immediate gratification over delayed benefits (Kahneman, Tversky, 1979; Ackert et al., 2024; Sng, Tan, 2022). BNPL products, which provide immediate satisfaction at a deferred and often underestimated cost, fully exploit these behavioral mechanisms (Ziemba, 2024). Another key factor is weak self-control and difficulties in self-regulation (Baumeister et al., 1998; Hoch, Loewenstein, 1991). The inability to resist purchasing impulses during moments of strong desire leads to excessive use of readily available credit forms, including BNPL (Ackert et al., 2024). Furthermore, low financial knowledge and literacy, measured through standard assessments (Lusardi, Mitchell, 2014), represent one of the best-documented risk factors for over-indebtedness. Consumers with low financial literacy are particularly susceptible to opaque credit product terms and marketing strategies emphasizing "no interest" or "pay later" schemes (Ackert et al., 2024; Ziemba, 2024).

Based on a review of the literature addressing determinants of consumers' propensity to incur debt, three main groups of factors were identified—economic, socio-demographic, and psychological/behavioral—and the key associated theories were mapped into the following classification (see Table 1).

Table 1.
Determinants of Consumers' Propensity to Incur Debt – Theoretical Foundations

Factor Category	Specific Determinants	Key Theoretical Frameworks
Economic	- Household income level. - Credit availability. - Cost of credit.	- Life-cycle hypothesis (Modigliani, Brumberg, 1954). - Permanent income hypothesis (Friedman, 1957). - Rational choice theory (Becker, 1976).
Socio-demographic	- Age and life-cycle stage. - Household structure. - Gender. - Education level. - Socio-economic characteristics of occupation.	- Relative income hypothesis (Duesenberry, 1949). - Conspicuous consumption (Veblen, 1899). - Social influence theory (Cialdini, 2001). - Family life-cycle theory (Glick, 1947; Hill, 1986). - New household economics (Becker, 1965, 1976).
Psychological and Behavioral	- Attitudes toward debt. - Locus of control. - Low financial literacy. - Impulsivity and consumerism. - Risk propensity.	- Behavioral finance, including prospect theory (Kahneman, Tversky, 1979). - Self-control and self-regulation theories (Baumeister et al., 1998; Thaler, Shefrin, 1981). - Financial literacy and competence frameworks (Lusardi, Mitchell, 2007, 2014).

Source: Authors' elaboration.

Among the economic factors influencing consumers' propensity to incur debt, the most significant are household income level (Strzelecka, Zawadzka, 2020a; Wałęga, Wałęga, 2016; Anioła, Gołaś, 2011), credit availability (Waliszewski et al., 2024; DiMaggio et al., 2022), and the overall cost of credit (Fišerová, 2018; Sng, Tan, 2022; Ziemba, 2024).

Income level and stability constitute fundamental determinants of creditworthiness and debt propensity. Empirical studies indicate a statistically significant relationship between average monthly household income and debt holding (Strzelecka, Zawadzka, 2020a). Higher-income households are more likely to take on mortgage debt, whereas lower-income households tend to rely on loans for day-to-day consumption (Strzelecka, Zawadzka, 2020a). Although banks remain the primary providers of credit despite the FinTech expansion, new FinTech actors (LendTech) have emerged, offering not only traditional loans but also innovative products such as Buy Now, Pay Later (BNPL) services. These new providers primarily target consumers with irregular incomes, such as gig-economy workers, who may be excluded from traditional banking systems (Sng, Tan, 2022). BNPL services have grown rapidly in e-commerce; in Poland, they have become the second most popular payment method after BLIK (Ziemba, 2024).

The rapid development of FinTech enterprises, including PayTech and LendTech firms, has significantly increased individuals' access to consumer credit. Digital platforms provide loans without stringent credit history requirements, using alternative data for risk assessment (Bian et al., 2023; Di Maggio et al., 2022). Market analyses in Poland indicate a complementarity effect: during crises ("black swan" events), when banks tighten credit policies, lending firms and BNPL services fill the gap, ensuring continued consumer access to financing (Waliszewski et al., 2024).

While high interest rates charged by non-bank lenders can be a deterrent, research shows that financially constrained consumers are willing to take out short-term, high-cost loans, especially immediately prior to personal bankruptcy (Fišerová, 2018). A key driver of BNPL popularity is marketing emphasizing the "interest-free" initial period, leading consumers to perceive BNPL more as a payment method than as a loan, and as a cheaper, lower-risk alternative to credit cards (Sng, Tan, 2022; Ziemba, 2024).

Among socio-demographic factors affecting debt propensity, the literature most frequently highlights age and life-cycle stage, household structure, educational attainment, and the socio-economic nature of employment.

Debt is strongly associated with consumer age. The highest debt levels are observed in the so-called productive age group (35-60 years), consistent with life-cycle theory (Strzelecka, Zawadzka, 2020a; Fišerová, 2018), with debt propensity declining thereafter (Strzelecka et al., 2020b). Younger generations, such as Millennials, demonstrate an aversion to traditional credit cards, making them the primary target group for BNPL services (Sng, Tan, 2022). In Poland, according to the Credit Information Bureau (BIK) data at the end of 2024, nearly 39% of BNPL users were under 34 years old, and an additional 32% were aged up to 44 (Cholewa, 2025).

Household size also affects indebtedness. Studies show that debt is more frequent and higher in multi-person households, especially those with dependent children. The household's life-cycle stage (e.g., young married couples with children) is one of the strongest predictors of debt holding (Strzelecka, Zawadzka, 2020a; Strzelecka et al., 2020b).

The effect of gender on debt propensity is ambiguous. BIK data (Cholewa, 2025) indicate that BNPL users are predominantly female (59.3%). Ackert et al. (2024) additionally show that women are more likely than men to take out loans. Conversely, Czech consumer bankruptcy data suggest that men tend to have higher average debt, albeit with higher repayment rates (Fišerová, 2018).

Education level is positively correlated with indebtedness. Individuals with higher education generally have higher income prospects and greater financial literacy, leading to more deliberate credit use (Strzelecka, Zawadzka, 2020a). In Poland, possessing economic education statistically increases the likelihood of holding debt (Strzelecka et al., 2020b).

Type of employment also influences debt. Self-employed individuals and farmers exhibit higher debt propensity than wage earners, likely due to investment needs associated with their activities. Pensioners and retirees are least likely to incur debt (Strzelecka, Zawadzka, 2020a; Strzelecka et al., 2020b).

The third group of determinants comprises psychological and behavioral factors. The literature most frequently identifies attitudes toward credit/debt, locus of control, financial illiteracy, impulsivity and consumerism, and risk propensity.

A key psychological determinant is attitude toward credit. Studies in Italy reveal that consumer loan holders have significantly more positive attitudes toward indebtedness than non-borrowers (Cosma, Pattarin, 2011). This attitude can be decomposed into three components:

cognitive (beliefs and knowledge), affective (emotions and feelings), and behavioral (intentions and preferred actions). Conversely, the main reasons for rejecting student loans in Poland are reluctance to incur debt and fear of non-repayment (Misterek, 2017).

Locus of control describes the extent to which individuals believe they can influence events in their lives. Findings are mixed: some studies indicate that individuals with an external locus of control (believing their fate depends on external factors) are more indebted. However, an Italian study found the opposite for deliberate use of consumer credit: individuals with an internal locus of control (believing in personal agency) more often use credit as a tool to achieve goals (Cosma, Pattarin, 2011).

Financial illiteracy is a well-documented risk factor for excessive indebtedness. Consumers with low financial knowledge are more vulnerable to complex and opaque credit conditions, a vulnerability exploited by credit providers, including BNPL services (Ackert et al., 2024).

The ease of financing purchases via BNPL fosters impulsive buying and promotes consumerism, driven by immediate gratification and deferred payment obligations (Ziemba, 2024; PIE, 2021).

Finally, risk propensity is associated with debt behavior. A U.S. study found that individuals more willing to take financial risks to achieve higher returns are also more likely to finance purchases through credit (Ackert et al., 2024).

3. Methodology of the Literature Review

The present narrative literature review is based on over thirty peer-reviewed articles and research reports published between 2010 and 2024, selected for their direct relevance to the determinants of consumer and household indebtedness, particularly in the context of FinTech and BNPL services.

Sources were identified through systematic searches of major academic databases and repositories, including Scopus, Web of Science, ScienceDirect, NBER Working Papers, SSRN, and RePEc, as well as authoritative industry and central-bank reports. The search strategy employed a set of primary keywords in both English and Polish, including: "consumer debt", "household debt", "household indebtedness", "buy now pay later (BNPL)", "deferred payment", "FinTech lending", "LendTech", "digital credit", "psychological factors", "behavioral finance", "financial literacy", "impulse buying", "self-control", "social norms", and "locus of control", along with their Polish equivalents (e.g., "zadłużenie konsumentów", "zadłużenie gospodarstw domowych", "kup teraz, zapłać później").

The review incorporated empirical articles, theoretical studies, and analytical reports, primarily from the last decade, in order to capture recent trends in the digitalization of financial services. Publications in both Polish and English from various countries and regions

(e.g., Poland, Czech Republic, China, Singapore, Italy, and the United States) were included, allowing for the identification of both universal and culturally specific determinants of consumers' propensity to incur debt.

The most frequently applied research methods in the reviewed studies included secondary data analysis, surveys, and interviews. Specific research tools employed were:

- Online and telephone surveys, often targeting specific demographic groups (e.g., households, students, indebted individuals).
- Structured questionnaires containing closed-ended questions and demographic information.
- Narrative and biographical interviews, enabling the collection of detailed information on respondents' experiences.
- Statistical data from public institutions (e.g., Central Statistical Office [GUS], National Bank of Poland [NBP], European Central Bank, OECD, Ministry of Finance).
- Transactional data analysis using e-wallet and BNPL provider data.
- Horvitz-Thompson estimator – a statistical method applied to data analysis.
- Legislative analyses and international case studies, incorporating legal and regulatory aspects.
- Demographic studies and economic models, examining relationships between indebtedness and other social factors.
- Household budget surveys, including the "Social Diagnosis" study.
- Data from debtor registers, such as BIG InfoMonitor, BIK, and the National Debt Register.

Table 2 provides a summary of the methodology applied in the literature review.

Table 2.
Summary of Literature Review Methodology

Criterion	Specification
Keywords	- "consumer debt", - "household debt", - "household indebtedness", - "buy now pay later", - "BNPL", - "FinTech lending", - "LendTech", - "psychological factors", - "behavioral finance", - "financial literacy", - "social norms", - "locus of control" (and Polish equivalents).
Languages of source material	- English, - Polish.

Cont. table 2.

Countries represented in the reviewed studies	- Poland, - Czech Republic, - China, - Singapore, - Italy, - United States.
Primary research methods employed in the reviewed studies	- secondary data analysis, - survey methods, - in-depth interviews.
Main data sources and research tools used in the reviewed studies	- Online and telephone surveys. - Structured questionnaires with socio-demographic sections. - Narrative and biographical interviews. - Official statistics (Statistics Poland – GUS, National Bank of Poland – NBP, ECB, OECD). - Transactional data from e-wallet and BNPL providers. - Horvitz–Thompson estimator. - Legislative and regulatory analyses, international case studies. - Econometric and demographic modelling. - Household budget surveys (incl. "Social Diagnosis" panel). - Credit bureau and debtor register data (BIK, BIG InfoMonitor, KRD).

Source: Authors' elaboration.

The analytical approach adopted in this article is based on a thematic synthesis of research findings. The determinants of consumers' propensity to incur debt were categorized into three main groups: economic, socio-demographic, and psychological-behavioral factors. This structure enabled a comprehensive and systematically organized presentation of the conditions influencing consumer borrowing behavior.

Addressing the heterogeneous character of the source material—which encompasses rigorous econometric analyses of household budgets (e.g., Strzelecka, Zawadzka, 2020a) as well as qualitative psychological studies and industry reports (e.g., PIE, 2021; Cholewa, 2025)—this review adopts a structured approach to evidentiary weighting. While systematic reviews often exclude qualitative data, a narrative approach was deemed essential to capture the nascent and rapidly evolving nature of the BNPL phenomenon, where longitudinal quantitative data is still scarce.

The analysis adopts a triangulated hierarchy of evidence comprising three complementary tiers:

1. **Theoretical Foundation (Primary Weight).** Causal mechanisms derived from peer-reviewed economic models—such as the Life-Cycle Hypothesis—and from established behavioral finance theories, including Prospect Theory, constitute the structural core of the analytical framework (Ackert et al., 2024; Friedman, 1957).
2. **Empirical Corroboration (Secondary Weight):** Statistical data from credit bureaus (BIK, BIG InfoMonitor) and national statistical offices (GUS, NBP) are used to validate the prevalence of theoretical mechanisms in the actual market population (Cholewa, 2025).

3. **Contextual Insight (Tertiary Weight).** Industry reports and qualitative survey evidence are used to interpret nuances of consumer sentiment and patterns of technological adoption, thereby offering contextual depth that purely quantitative approaches may overlook (Ziemba, 2024).

This hierarchical configuration enables a nuanced synthesis in which "hard" economic data delineate the scope and distribution of indebtedness, whereas "soft" behavioral insights explain the psychological mechanisms through which debt accumulates in the digital environment.

4. Key Findings and Implications from the Literature Review

The synthesis of research findings from various countries allows for the formulation of several key observations regarding contemporary determinants of consumer indebtedness.

Decisions to incur debt rarely result from a single factor. Rather, they reflect the complex interaction of economic conditions, demographic characteristics, and the psychological profile of the consumer. For instance, a young individual (demographic factor) with low but stable income (economic factor), a positive attitude toward credit, and strong peer influence (psychological factors), coupled with easy access to BNPL services (technological-economic factor), represents an archetypal candidate for regular utilization of deferred payment options.

Among the most significant phenomena shaping the consumer credit market in recent years, and substantially influencing consumers' propensity to incur debt, are the expansion of FinTech enterprises (including PayTech and LendTech) and, in particular, the growth of BNPL services. These developments have contributed to:

- Democratization of credit access: Credit has become available to previously financially excluded groups, such as individuals with no credit history, irregular incomes, or the youngest consumer cohorts (Bian et al., 2023; Sng, Tan, 2022).
- Shifts in the perception of credit: BNPL is often perceived not as a form of credit but as a payment method, reducing the psychological barrier to borrowing. The ease and speed of transactions embedded in the purchasing process encourage impulsive decisions (Ziemba, 2024).
- Complementarity with traditional banking: Non-bank financial providers, particularly LendTech firms, complement the banking sector. Evidence from the Polish market indicates that during periods of economic instability, when banks tighten credit policies, LendTech fills gaps in consumer financing, stabilizing the market. In stable periods, the two sectors serve distinct customer segments—banks focus on larger loans and older clients, while LendTech targets smaller loans and younger cohorts (Waliszewski et al., 2024).

The impact of BNPL on consumer finances appears highly context- and culture-dependent. In the Chinese market, where BNPL services are integrated into super-app platforms, increased access to credit leads to higher consumption, but users—especially those excluded from traditional banking—manage their debt cautiously when interest applies. In this model, BNPL does not necessarily increase overall indebtedness (Bian et al., 2023). Conversely, in developed countries such as the USA and the UK, concerns exist that BNPL may negatively affect consumers' financial health, as debt from BNPL is often rolled over onto high-interest credit cards (deHaan et al., 2024; Guttman-Kenney et al., 2023).

The literature review unequivocally indicates that neglecting the psychological aspects of indebtedness results in an incomplete understanding of the phenomenon. Behavioral and social factors—such as attitudes, social norms, and cognitive biases—play a critical role in borrowing decisions. Non-transparent conditions offered by some BNPL providers and marketing targeting uninformed consumers highlight the need for regulatory intervention (Ackert et al., 2024). The lack of unified regulations governing BNPL services in many countries, including Poland and across the European Union, poses risks to consumers and constitutes a legal gap requiring urgent legislative action to enhance borrower protection (Sng, Tan, 2022; Ziemba, 2024).

The literature review yields important theoretical and practical implications. From a theoretical perspective, the dynamic growth of BNPL services provides a fertile ground for testing and advancing behavioral finance theories. It demonstrates how cognitive biases (e.g., the present-bias effect) can be leveraged in the design and deployment of financial products, challenging assumptions of consumer rationality and underscoring the need to integrate economic models with psychological frameworks.

From a practical perspective, implications can be categorized into three main groups:

- For regulators and policymakers: It is essential to establish regulatory frameworks for the BNPL market that ensure transparency, mandate creditworthiness assessments, and provide adequate consumer protection. Promoting financial literacy is also crucial to enhance awareness of the risks associated with "easy credit".
- For financial institutions: Traditional banks face competition from flexible PayTech and FinTech enterprises. They must adapt business models, invest in technology, and better understand the needs and psychological profiles of younger clients. PayTech and LendTech firms, particularly those offering BNPL, should implement responsible lending mechanisms to prevent over-indebtedness, which could undermine trust in the sector in the long term.
- For consumers: Greater awareness is needed that BNPL services constitute a form of credit and that their excessive or imprudent use can lead to a debt spiral. Developing household budget management skills and critically evaluating financial offers are therefore key competencies in today's financial environment.Addressing the regulatory deficits identified by Sng and Tan (2022), as well as the practical need for a coherent policy framework, this study proposes a three-tier typology of regulatory interventions tailored to the specific risk architecture of the BNPL model.

Table 3.
Typology of Regulatory Interventions for BNPL and FinTech Services

Regulatory Tier	Mechanism / Tool	Theoretical Target	Implementation Context
Tier 1: Informational *(Soft Paternalism)*	**Standardized Disclosure (APR):** Mandating the conversion of "fees" into Annual Percentage Rate. **Friction Injection:** "Cool-off" warnings at checkout.	**Cognitive Bias / Mental Accounting:** Counteracts the framing of BNPL as "free" (Thaler, 1999) and interrupts impulsive "hot-state" decision-making (Baumeister et al., 1998).	Implementation of "Schumer Box" disclosures on mobile interfaces (Ackert et al., 2024).
Tier 2: Structural *(Market Conduct)*	**Affordability Checks:** Mandating income verification for all deferred-payment transactions. **Credit Register Reporting:** Full integration with bureaus (e.g., BIK).	**Rational Choice / Budget Constraint:** Enforces the alignment of borrowing with repayment capacity. **Asymmetric Information:** Prevents "debt stacking" across opaque or unreported BNPL lenders	Closing the "reporting loophole" that allows small consumer loans to bypass credit-bureau systems (Cholewa, 2025; Sng, Tan, 2022).
Tier 3: Prudential *(Systemic Stability)*	**Capital Adequacy:** Aligning LendTech reserves obligations with banking standards.	**Systemic Risk:** Mitigates insolvency risks and liquidity pressures during macroeconomic downturns.	Safeguarding the stability of the complementary role played by FinTechs within the broader financial ecosystem (Waliszewski et al., 2024).

Source: Authors' elaboration.

The proposed typology of regulatory interventions implies the need to reorient regulatory responses to the development of BNPL and FinTech companies. At present, regulatory efforts concentrate predominantly on Tier 1 interventions, emphasizing transparency and consumer information. However, the findings of this review indicate that such informational remedies are insufficient given the behavioral nature of BNPL i.e. where consumers often incur liabilities knowingly, driven by present bias and other behavioral distortions. Consequently, a regulatory shift toward Tier 2 structural mechanisms is warranted. In particular, the mandatory reporting of BNPL obligations to national credit registries (e.g., BIK) emerges as the single most critical factor in preventing consumer over-indebtedness and enhancing market discipline.

5. Discussion

The findings of this review necessitate a fundamental re-evaluation of the Life-Cycle Hypothesis (LCH) in the context of digital lending ecosystems. Traditionally, LCH posits that indebtedness constitutes a rational mechanism for intertemporal consumption smoothing: households borrow against anticipated future income to finance essential, utility-enhancing assets such as housing or education (Modigliani, Brumberg, 1954; Strzelecka, Zawadzka, 2020a). The rapid diffusion of BNPL services, however, challenges the assumption of rational debt allocation. Evidence presented in this review indicates that FinTech-enabled liabilities are

increasingly decoupled from strategic asset accumulation and instead facilitate impulsive consumption of low-durability goods.

This shift signals a transition from strategic indebtedness—consistent with Friedman's Permanent Income Hypothesis—to behavioral indebtedness. The underlying mechanism is the technologically induced attenuation of the "pain of paying" (Ziemba, 2024). By fragmenting payments and deferring immediate cash outflows, BNPL architectures artificially inflate perceived purchasing power, thereby circumventing the cognitive and budgetary checks typically constraining consumption (Ackert et al., 2024). As a consequence, the rational, utility-maximizing consumer of Becker (1976) is supplanted by a myopic decision-maker whose intertemporal preferences are systematically distorted by the gratification-oriented design of FinTech applications.

A distinct demographic pattern further illustrates this behavioral transformation. Whereas traditional bank loans in Poland remain concentrated among individuals in the "productive age" cohort (35-60 years), consistent with Family Life-Cycle Theory (Glick, 1947), the FinTech sector disproportionately attracts the youngest consumers. Data from BIK indicate that nearly 70% of BNPL users are under 44 years of age (Cholewa, 2025), mirroring global adoption trends documented in the United States and Singapore, where Millennials and Generation Z dominate the user base (Sng, Tan, 2022).

The motivational structure underlying this indebtedness reveals a digital reformulation of Duesenberry's (1949) Relative Income Hypothesis. The "demonstration effect"—traditionally anchored in physical social comparison—has been amplified by social media ecosystems and embedded e-commerce platforms. In this environment, the "FinTech effect" effectively democratizes access to conspicuous consumption for demographic groups previously constrained by insufficient creditworthiness (Ackert et al., 2024).

A particularly salient finding emerges in the Polish context. Contrary to patterns observed in several Western markets, where FinTech providers often cannibalize the market share of incumbent banks, LendTech firms in Poland frequently function as a stabilizing "safety valve" during credit contractions and macroeconomic disruptions (so-called "black swan" events). This complementarity effect (Waliszewski et al., 2024) indicates that while the behavioral drivers of digital indebtedness—impulsivity, social comparison, and present bias—are broadly universal, the systemic role of FinTech credit in Poland exhibits a structurally distinctive, countercyclical character.

Overall, the integrative review confirms the implicit hypothesis that psychological determinants have become the dominant predictors of debt propensity within digital financial channels, outweighing traditional economic indicators. While income stability remains a necessary determinant for access to long-term credit instruments such as mortgages (Strzelecka, Zawadzka, 2020a), it is the psychological profile—specifically locus of control and susceptibility to framing effects—that most strongly predicts engagement with BNPL services (Cosma, Pattarin, 2011; Ziemba, 2024). These findings reinforce the conclusion that FinTech

expansion does not merely satisfy pre-existing demand for credit; rather, it actively manufactures such demand by strategically exploiting cognitive biases, including present bias and over-optimism (Kahneman, Tversky, 1979).

6. Conclusions

Consumer propensity to incur debt is a complex phenomenon, determined by a broad spectrum of economic, socio-demographic, psychological, and behavioral factors. The literature review indicates that none of these categories alone can fully explain credit behavior; understanding this phenomenon requires analyzing the interactions among them.

A key finding highlights the significant role of modern financial technologies in facilitating access to credit. Services such as Buy Now, Pay Later (BNPL) have revolutionized credit accessibility, making it more convenient, faster, and increasingly integrated into consumers' daily lives. While these services contribute to greater financial inclusion, they also introduce new risks associated with over-indebtedness, stemming from increased impulsive consumption and cognitive biases.

Among the principal determinants of consumer debt propensity in contemporary contexts are:

- Economic stability and credit accessibility: The level and regularity of income remain the most important determinants of indebtedness. However, the growing availability of loans provided by FinTech companies enables individuals without traditional creditworthiness to obtain credit.
- Life-cycle and demographic factors: Empirical studies indicate that age, household composition, and the presence of children significantly influence consumers' likelihood of incurring debt.
- Psychological profile and social context: Individual attitudes toward debt, self-control, and prevailing social norms can be decisive in shaping borrowing behavior, particularly when financial products are readily accessible.

Key limitations of the present review include its narrative nature, which is inherently more subjective than a full meta-analysis. Moreover, many cited studies, especially those concerning BNPL services, are cross-sectional and describe an economic phenomenon in its early stage of development. The long-term consequences of using such services have not yet been fully examined. Research findings are often context-dependent, reflecting specific cultural and regulatory environments, which complicates the formulation of universal conclusions.

Future research on consumer borrowing behavior could focus on:

- Examining the long-term relationship between BNPL usage and debt levels to assess the real impact of such services on consumers' financial stability, credit history, and overall indebtedness.
- Conducting in-depth comparative analyses of BNPL providers' business models and their influence on consumer behavior, including debt propensity, across different economic and cultural systems.
- Integrating transaction data analysis with quantitative survey-based research on consumers' psychological profiles and attitudes to better understand underlying decision-making mechanisms.
- Analyzing regulatory approaches to BNPL services in terms of their effectiveness in protecting consumers.

On the basis of the limitations identified in this review, future research should prioritize three strategic directions aimed at advancing theoretical understanding and enhancing the evidence base for consumer protection in digital credit markets:

- Longitudinal Panel Studies: Future work should move beyond cross-sectional analyses and employ longitudinal panel designs to track cohorts of BNPL users across multiple life stages. Such designs are essential for empirically testing the "gateway" hypothesis—that early engagement with BNPL services predicts elevated default risk or diminished creditworthiness in later adulthood, particularly with respect to mortgages and other long-term credit instruments (deHaan et al., 2024).
- Experimental UI/UX Analysis: Experimental economics and controlled interface testing should be used to quantify the causal influence of specific UI/UX design features—such as "one-click" purchasing versus multi-step verification—on debt uptake. This approach would allow researchers to isolate the impact of digital "friction" on self-control mechanisms, thereby testing theoretical claims regarding impulsivity and hot-state decision-making (Baumeister et al., 1998).
- Cross-Cultural Comparative Analysis: Comparative studies should contrast the Polish "complementarity model" (Waliszewski et al., 2024) with financial systems in which FinTech innovation functions primarily as a disruptive force (e.g., the United States or the United Kingdom). Such cross-national analyses would clarify the extent to which institutional characteristics—particularly banking-sector structure and regulatory depth—buffer consumers from FinTech-induced over-indebtedness.

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ESG DISCLOSURE PRACTICES IN VIETNAM

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Purpose: This study examines ESG disclosure practices among 673 listed companies on Vietnam's two stock exchanges (HNX and HOSE) from 2015 to 2024. It addresses the gap in understanding ESG reporting evolution in emerging ASEAN markets by analysing disclosure trends, standards, sectoral variations, and the influence of regulatory frameworks.
Design/methodology/approach: The study employs descriptive and trend analysis methods to examine 673 listed companies (296 on HNX and 377 on HOSE) over the period 2015-2024. Data were collected from sustainability reports, annual reports, integrated reports, and publicly available corporate information. The analysis focuses on disclosure trends, reporting frameworks adopted, industry variations, third-party verification levels, regulatory influences, and the use of quantitative versus qualitative reporting.
Findings: ESG report disclosure has increased significantly since the government's issuance of Circular 155/2015/TT-BTC and Circular 96/2020/TT-BTC. The GRI standards and the Sustainable Development Goals (SDGs) are the most widely adopted frameworks, while the State Securities Commission (SSC) guidelines remain the main reference. Reporting practices are concentrated in a few sectors, including Finance, Consumer Staples, Materials, Industrials and Real Estate. However, reports still have limited third-party assurance and independent sustainability reports are not yet widely implemented by many businesses. The shift from qualitative to quantitative reporting shows that transparency and measurement capabilities are improving.
Research limitations/implications: This analysis is based on publicly disclosed reports, which differ in quality across companies. Future research may include unlisted firms and examine the impact of ESG disclosure on corporate financial performance.
Practical implications: For regulators, the study provides insights into sectoral variations that can guide targeted policy interventions. Corporate practitioners can benchmark their ESG disclosure practices against industry standards and identify opportunities to enhance reporting quality and transparency. International investors gain an understanding of Vietnam's ESG maturity level and reporting reliability when making investment decisions.
Originality/value: This study provides a comprehensive analysis of ESG disclosure practices among Vietnamese listed companies over a decade-long period. It fills a critical gap in emerging market ESG research, particularly in the ASEAN context, by empirically documenting the transition from voluntary to mandatory ESG disclosure and the role of regulatory frameworks in shaping corporate sustainability reporting practices. The findings contribute to understanding how institutional factors influence ESG disclosure in emerging economies with developing capital markets.

Keywords: ESG disclosure, sustainability reporting, Vietnam, emerging markets, ASEAN.
Category of the paper: Research paper.

1. Introduction

ESG reporting has become a key mechanism for enhancing transparency regarding non-financial issues that impact corporate operations and value (Markota Vukić et al., 2017), strengthening corporate social responsibility while promoting transparency (Karwowski, Raulinajtys-Grzybek, 2021). As a mainstream trend and essential component of corporate operations (Andrey, 2023), transparent ESG reporting enhances corporate reputation (Flammer, 2018), reduces financing costs, attracts investors (Ghanbarpour, Gustafsson, 2022), and supports long-term sustainable development (Meng-tao et al., 2023). Globally, ESG reporting is progressively shaping a unified disclosure system (Gurung et al., 2025), particularly as governments intensify mandatory requirements for environmental and social transparency (Krueger et al., 2024). Under increasing pressure from investors, regulators, and the public, ESG disclosure is transitioning from voluntary commitment to mandatory, data-driven, and independently verified practice (Moharram et al., 2024).

The regulatory landscape varies significantly across regions. The European Union leads through the Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD), creating global ripple effects (Sinnig, Zetzsche, 2024), while U.S. regulations remain fragmented (Nchako, Benjamin, 2025). Asia-Pacific markets are adopting ESG frameworks at varying rates, aligning with international standards while adapting to local priorities (PwC Vietnam, 2025). In Africa and Latin America, ESG adoption is growing through investor pressure and international trade requirements, though enforcement remains uneven (Chawarura et al., 2025; PwC Vietnam, 2025). Within ASEAN, ESG awareness is growing rapidly with notable implementation differences among countries (Han et al., 2022). While Singapore and Malaysia mandate ESG disclosure for all businesses (Li, 2025; Mohammad, Wasiuzzaman, 2021), and Indonesia, Thailand, and the Philippines have established clear regulatory frameworks, other countries are actively strengthening environmental protection and promoting sustainable finance instruments (Yean, 2022; ASEAN-Korea Centre, 2020).

Vietnam, with one of the fastest-growing economies and significant capital market development (Can, Nguyen, 2021), has maintained positive economic growth despite global challenges, achieving GDP growth rates of 5.07% and 7.09% during 2023-2024 (State Securities Commission of Vietnam, 2024). However, the financial system faces challenges including limited market transparency, underdeveloped credit rating systems, and market irregularities that undermine investor confidence (Phuoc Tai, 2024; Phuc et al., 2024).

ESG is shifting from awareness to action, with listed firms in finance, energy, and real estate sectors publishing integrated ESG reports (Hien, Ngoc, 2025), supported by government policies related to ESG disclosure (Nguyen, Hoang, 2025). Vietnamese companies increasingly recognise that sustainable development and future viability are closely linked (KPMG Asia Pacific, 2023). However, disclosure quality remains inconsistent due to the absence of mandatory mechanisms. Survey results from 100 businesses reveal that although 87% have sustainability reports, 90% have not published carbon targets, 93% have not mentioned environmental risks, and 86% have not addressed social or governance risks. While business leaders emphasise governance importance (PricewaterhouseCoopers, 2022), a majority (71%) lack knowledge and resources for ESG reporting. Despite high ESG commitment - 89% of Vietnamese businesses have implemented or plan to implement ESG goals within 2-4 years - primary motivations remain regulatory compliance (70%), stakeholder pressure (40%), and leadership directives (39%) (PwC Vietnam, 2025).

Although the sustainability reporting literature has grown significantly and mandatory ESG disclosure trends are increasing globally, the understanding of development trends remains limited (Bosi et al., 2022), with few studies reviewing ESG research (Li et al., 2021), particularly in Vietnam. As the SDGs 2030 approach, examining corporate compliance with ESG disclosure is essential. This study addresses this gap by analysing current ESG disclosure practices by listed firms in Vietnam through six research questions:

1. What is the trend of ESG reporting disclosure by Vietnamese companies?
2. What is the level and standards of ESG disclosure?
3. How does ESG disclosure vary by industry?
4. What is the level of third-party verification or assurance?
5. What role does government regulation play in the development of ESG disclosure?
6. Do Vietnamese enterprises use quantitative or qualitative information in sustainability reports?

The structure of this paper is organised as follows: following this introduction, Section 2 establishes the theoretical framework and reviews relevant literature on ESG reporting practices; Section 3 details the research design and methodological approach; Section 4 reports the empirical findings from the analysis of Vietnamese listed companies; Section 5 interprets these findings within the broader context of emerging market ESG disclosure; and Section 6 concludes by summarising key contributions, acknowledging limitations, and identifying avenues for future research.

2. Literature Review and Theoretical Framework

2.1. Theoretical Perspectives on ESG Disclosure

ESG disclosure practices can be understood through multiple theoretical lenses, with agency theory and legitimacy theory providing complementary explanations for corporate disclosure behaviour.

Agency Theory Perspective

From agency theory (Meckling, Jensen, 1976), by prioritizing stakeholder interests, companies can reduce their environmental impact, enhance performance, and contribute to achievement the SDGs. Raman et al. (2023) assumed that ESG disclosure can help balance the interests of managers and shareholders by reducing information asymmetry, thereby limiting conflicts of interest between the two parties. In this oversight mechanism, the board plays a role in ensuring the accuracy and transparency of ESG reporting (Islam et al., 2022). According to Nuhu & Alam (2024) the Board characteristics are important determinants of ESG disclosure in emerging Asian economies. Specifically, board independence, diversity of expertise, and commitment to sustainability are key factors influencing the scope and quality of ESG reporting. Abu Afifa et al (2025) shows that corporate governance and social responsibility strategies have a positive impact on the ESG disclosure quality (ESGDQ) of enterprises in the ASEAN region, including Vietnam, Thailand, Malaysia, Indonesia, and the Philippines. Similarly, Suttipun (2021) emphasizes that board composition and structure are key factors influencing the level of ESG disclosure by companies in Thailand.

Legitimacy Theory Perspective

From the perspective of legal theory, Suchman (1995) argues that organizations need to continually demonstrate that their actions are "legitimate", that is, socially accepted and seen as consistent with shared values, norms, and expectations. Based on this view, Rahman & Alsayegh (2021), believed that in Asian countries, large-scale enterprises tend to pay more attention to their reputation and corporate image. Therefore, they tend to disclose ESG information at a higher level to strengthen their legitimacy, maintain public trust and meet close supervision from stakeholders. Kansal et al (2014) also found that firm size and industry characteristics have a significant impact on corporate social disclosure and reputation in India. Similarly, firm size is positively related to ESG reporting capability (Nguyen, Hoang, 2025), and the level of social responsibility disclosure among Vietnamese enterprises (Nguyen et al., 2021). Overall, the literature indicates that ESG disclosure in emerging Asian economies is shaped by a combination of key factors, including the evolving legal and institutional framework, as well as the characteristics of corporate boards and firms. These factors collectively influence both the current state and the future trajectory of ESG reporting practices in the region.

2.2. ESG Reporting in Emerging Markets

The differences in ESG performance and practices between developed and emerging markets are largely explained by significant variations in social, cultural, and institutional governance contexts (Griesse, 2007). Firms in emerging markets are often influenced by inefficient institutions, government intervention, challenging business environments, weak corporate governance practices and cultural barriers (Peng et al., 2008; Horváthová, 2010; Benites, Polo, 2013; Bagai, 2025). According to the report by (IFC, 2016), although emerging economies are striving to improve their ESG reporting standards, a significant gap remains due to limitations in infrastructure, legal frameworks, and managerial capacity. In contrast, developed markets tend to implement more advanced ESG reporting practices, driven by stricter regulations, higher social awareness, and more effective corporate governance structures (Bagai, 2025).

Long & Johnstone (2023) note that, compared to Western countries with strict regulations on reporting and social–environmental responsibility, many Asian nations still maintain more lenient standards in areas such as carbon emissions, environmental protection, and employee welfare. In an intensely competitive environment, many Asian enterprises prioritize rapid growth over long-term sustainable development. Studies conducted in China indicate that the level of awareness regarding ESG remains limited (Mio, Lu, 2019), while the regulatory and enforcement systems remain ineffective (Zhao, 2019), ESG is not yet a key factor in corporate evaluation.

The study by Aymen Karoui (2024) indicates that the gap in the scope and transparency of ESG disclosure between markets is gradually narrowing, primarily due to the strengthening of regulatory frameworks and increasing pressure from stakeholders. Zhou & Nian (2024) also finds that Chinese firms tend to focus on disclosing information related to environmental and governance aspects, while social information remains relatively neglected. Furthermore, a study Ng et al., (2023) and Hong et al., (2025) demonstrates that institutional ownership, as well as foreign or internationally listed firms, has a positive impact on the quality of ESG reporting in emerging markets. Notably, the COVID-19 pandemic further highlighted these differences, with companies in emerging markets performing better in environmental aspects, while those in developed markets showed stronger performance in social dimensions (Amosh, Khatib, 2023). A synthesis of the existing literature suggests that, although emerging markets have made substantial progress in promoting and reporting ESG, a considerable gap remains with developed markets. This disparity primarily stems from differences in institutional maturity, legal frameworks, stakeholder engagement, and stages of economic development, all of which could influence the quality, scope, and impact of ESG disclosure across the two groups of markets.

ESG Reporting Trends in Asian Emerging Markets

Khamisu & Paluri (2024) argued that many countries, including emerging economies, have enacted regulations related to ESG disclosure. However, the required content of these regulations varies significantly depending on the institutional and regional context, leading to heterogeneity in ESG disclosure practices across countries. This difference directly affects the transparency and comprehensiveness of ESG disclosure in enterprises operating in different markets.

In the ASEAN region, ESG awareness is growing rapidly, with notable differences in the level of implementation among countries (Han et al., 2022). Singapore and Malaysia mandating ESG disclosure for all businesses (Li, 2025; Mohammad, Wasiuzzaman, 2021), while Indonesia, Thailand, and the Philippines have also established clear regulatory frameworks for public ESG reporting. Other countries like Thailand, Cambodia, Laos, Brunei, and Myanmar are actively strengthening environmental protection and promoting sustainable finance instruments like green bonds and solar energy (Yean, 2022; ASEAN-Korea Centre, 2020).

In Asian countries, ESG reporting largely remains voluntary, leading to limited clarity about the determinants of ESG disclosure levels (Abdul Rahman, Alsayegh, 2021). Sharma et al (2020) noted that in developing countries like India, the voluntary disclosure related to social responsibility and corporate governance remains relatively low. However, the increasing trend of ESG reporting in this context reflects the efforts of businesses to address stakeholder concerns about transparency, responsibility, and sustainable development.

Determinants of ESG Disclosure in Emerging Markets

Research has identified several key determinants that influence ESG disclosure practices in emerging market contexts, particularly in Asia.

According to Nuhu & Alam (2024), the board characteristics are important determinants of ESG disclosure in emerging Asian economies. Specifically, board independence, diversity of expertise, and commitment to sustainability are key factors influencing the scope and quality of ESG reporting. Abu Afifa et al (2025) show that corporate governance and social responsibility strategies have a positive impact on the ESG disclosure quality (ESGDQ) of enterprises in the ASEAN region, including Vietnam, Thailand, Malaysia, Indonesia, and the Philippines. Similarly, Suttipun (2021) emphasises that board composition and structure are key factors influencing the level of ESG disclosure by companies in Thailand.

Based on legitimacy theory, Abdul Rahman & Alsayegh (2021), believed that in Asian countries, large-scale enterprises tend to pay more attention to their reputation and corporate image. Therefore, they tend to disclose ESG information at a higher level to strengthen their legitimacy, maintain public trust and meet close supervision from stakeholders. Kansal et al (2014) also found that firm size and industry characteristics have a significant impact on corporate social disclosure and reputation in India. Similarly, firm size is positively related to ESG reporting capability (Nguyen, Hoang, 2025), and the level of social responsibility disclosure among Vietnamese enterprises (Nguyen et al., 2021).

Furthermore, a study Ng et al. (2023) and Hong et al. (2025) demonstrated that institutional ownership, as well as foreign or internationally listed firms, has a positive impact on the quality of ESG reporting in emerging markets.

2.3. ESG reporting development in Vietnam

Vietnam's Sustainability Commitments

Vietnam has demonstrated political will and international cooperation in pursuing sustainable development and addressing climate change. Over the past decade, Vietnam has aligned its national policies with global sustainable development frameworks, including the United Nations 2030 Agenda for Sustainable Development (SDGs), the Paris Agreement, and commitments at the COP26 Climate Change Summit. These commitments form the foundation for Vietnam's ESG roadmap, reflecting the transition to a low-carbon, inclusive, and resilient economy. Table 1 summarises Vietnam's key national and international commitments, along with key targets and implementation timelines.

Table 1.
Vietnam's Commitments

Commitment	Description	Targets and Timeline
United Nations 2030 Agenda for Sustainable Development (SDGs – 2015)	Decision No. 841/ QD-TTg, issued by the Prime Minister, promulgates Vietnam's Roadmap for the Implementation of the Sustainable Development Goals (SDGs) to 2030 (Vietnam.vn, 2023).	The roadmap to 2030 includes 117 detailed indicators. Among these indicators, several are directly related to ESG dimensions. - The proportion of renewable energy is targeted to reach 15-20% by 2030. - The multidimensional poverty rate is expected to be reduced by 1-1.5% annually; the proportion of working-age people covered by social insurance is to reach 60%. - The unemployment rate is to remain below 3%, the proportion of citizens satisfied with public services should reach 90%. - The proportion of people paying informal fees when accessing public services should be kept below 10%.
Paris Agreement	Vietnam commits to reducing greenhouse gas emissions and enhancing climate resilience (State Securities Commission, 2024).	Climate action targets by 2030: - Forest coverage maintained at 42-43%. - Share of renewable energy in total primary energy supply: 15-20%. - 100% of facilities emitting over 2000 tons of CO_2 equivalent/year must develop and implement GHG reduction plans. - GHG emission intensity per GDP reduced by at least 15% compared to 2014.
COP26 Commitments	Vietnam commits to achieving net-zero emissions by 2050 (International Union for Conservation of Nature, 2022).	- 2020: Vietnam was among 12 countries that completed updates to its Nationally Determined Contribution (NDC). - 2030: Reduce total GHG emissions by 9% through domestic resources and 27% with international support. - 2030: End deforestation. - 2040: Phase out coal-fired power generation. - 2050: Achieve net-zero emissions.

Source: Authors' compilation.

Regulatory Framework for ESG Disclosure in Vietnam

The implementation of reporting by listed companies is based on the legal basis and changes in regulations of the Ministry of Finance of Vietnam over time. Specifically, Circular 155/2015/TT-BTC for the first time requires listed companies to disclose information on sustainable development in their annual reports. According to the requirements of Circular 155, public companies must disclose information related to sustainable development in order to comply with international practices and enhance the company's responsibility to the environment and society. This content is included in the Annual Report Form or prepared separately as a Sustainable Development Report.

Currently, the implementation of the Sustainable Development Report is regulated in Circular 96/2020/TT-BTC, guiding information disclosure on the stock market (Circular 155/2015/TT-BTC was adjusted). According to current regulations, enterprises are permitted to separate content related to environmental and social impacts in their Annual Report to prepare an independent Sustainable Development Report. Enterprises operating in the financial services sector, such as banking, securities, and insurance, are not required to report content related to environmental impacts, raw materials, or energy consumption. Circular 96/2020/TT-BTC also encourages enterprises to apply international reporting standards in the preparation of Sustainable Development Reports, thereby enhancing the transparency and comparability of information.

Thus, in Vietnam, currently, only public companies and enterprises listed on the stock market are required to disclose information on sustainable development annually. This regulation requires enterprises to report on content related to the environment, society, and corporate governance (see Table 2). For other types of enterprises, there is currently no legal document stipulating mandatory obligations regarding the disclosure of information on sustainable development. Other enterprises only need to submit a number of periodic reports to state management agencies, with specific scopes and requirements depending on each case, not including sustainable development content. These reporting regulations are mentioned in many different legal documents in areas such as environment, labour and corporate governance.

Table 2.
Regulations on ESG information disclosure under Circular No. 96/2020/TT-BTC

No.	Topic	Content to report
1	Environmental Impact	Overall greenhouse gas emissions and the initiatives implemented to mitigate and reduce them.
2	Management of Material Resources	Total materials used in production and services, percentage of recycled materials used.
3	Energy Consumption	Total energy consumed, energy saved, reports result on initiatives.
4	Water Consumption	Sources of water supply and total water usage, percentage of water reused or recycled.
5	Compliance with Environmental Laws	Total number of violations and total fines related to non-compliance with environmental protection laws.
6	Labour-Related Policies	Number of employees; labour policies including wages, training activities, health and safety assurance for employees.
7	Community and Local Responsibility	Investments and activities contributing to community and local development.

Source: Regulations from Circular No.96/2020/TT-BTC.

Figure 1 illustrates the evolution of ESG disclosure requirements in Vietnam, showing the progression from voluntary to mandatory reporting for listed companies. Currently, ESG reporting in Vietnam is mainly encouraged. Only listed companies are required to disclose ESG information. It is expected that stricter regulations will be implemented and will be extended to all businesses in the near future (Climate Disclosure Standards Board, 2021).

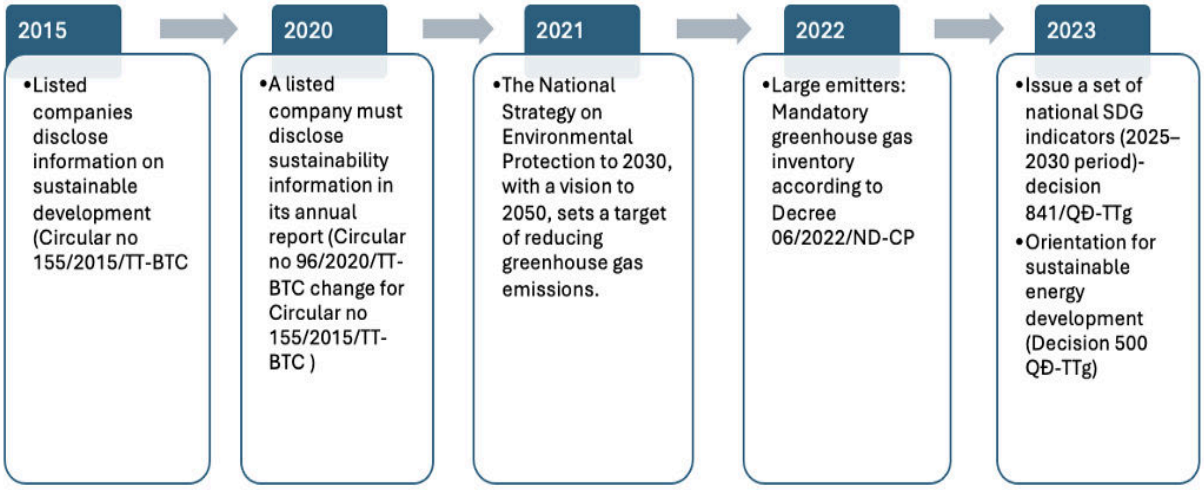


Figure 1. Timeline of mandatory and voluntary disclosure requirements.

Soure: Author's compilation.

To meet current market demands, many non-listed companies are also becoming interested in incorporating ESG practices into their production and business activities (Nguyen et al., 2024).

ESG Reporting Guidelines and Support Mechanisms in Vietnam

To support Vietnamese enterprises in implementing ESG disclosure, the State Securities Commission (SSC), in collaboration with international organisations, has developed several comprehensive guidelines.

- *Sustainability Reporting Handbook (2013)*

The State Securities Commission (SSC), in collaboration with the International Finance Corporation (IFC), issued a guideline focusing on environmental and social aspects of business operations (SSC, IFC, 2013). The guide recommends globally recognised frameworks, including GRI, CDP, United Nations Global Compact, IFC Sustainable Development Framework, IIRC, AA1000 AccountAbility Principles, ISO 26000:2010, and GIIRS. It outlines a 10-step process for report preparation, from defining sustainability vision to ensuring credibility through independent verification and continuous improvement. The report should present the enterprise's sustainability strategy, major environmental and social impacts, and key performance indicators.

- *Environment Social diclosure guide (2016)*

The SSC, in collaboration with IFC, issued the Environmental and Social (E&S) Disclosure Guide for listed companies (SSC, IIFC, 2015). Based on the GRI G4 Reporting Framework, this guide emphasises four key principles: Stakeholder Inclusiveness, Sustainability Context, Materiality, and Completeness. The reporting process comprises four steps: defining scope, calculating and collecting data, reviewing and verifying information, and disclosing results. This framework enables Vietnamese listed companies to improve consistency, transparency, and comparability of E&S disclosures in alignment with international practices.

- *Little Book of GHG Emissions Reporting (2023)*

The SSC, in collaboration with IFC, SECO, and BSI, issued comprehensive guidance for greenhouse gas measurement and reporting (SSC, IFC, SECO, BSCI, 2023). The guide emphasises internationally recognised frameworks, including ISO 14064, the Greenhouse Gas Protocol, UNFCCC, IPCC guidelines, PCAF, and TCFD, alongside domestic legal documents such as Decree No. 06/2022/ND-CP, Decision No. 01/2022/QD-TTg, Circular No. 96/2020/TT-BTC, Decision No. 2626/2022/BTNMT, and national standard TCVN ISO 14064-1/2/3. The reporting process includes six steps: defining scope, establishing a base year, conducting GHG inventory, developing an Inventory Management Plan, preparing the report, and verification.

- *ESG Disclosure Implementation Handbook (2024)*

The SSC issued the ESG Disclosure Implementation Handbook to provide comprehensive guidance for integrating ESG factors into strategic and operational management (SSC, 2024). The handbook recommends internationally recognised frameworks, including GRI, SASB standards, TCFD framework, and ISSB/IFRS S1 & S2 standards. It outlines a six-step process: establishing resources and responsibilities, developing transformation plans, defining content and scope, evaluating information systems and controls, compiling the ESG report, and planning improvements. The proposed report structure comprises eight sections: compliance statement, scope, materiality assessment, governance, strategy, risk management, indicators and targets, and reporting basis. The handbook emphasises integrating strategic, economic, environmental, and social aspects while ensuring accuracy, comparability, and credible verification.

2.4. Factors influencing ESG disclosure in Vietnam

ESG disclosure in Vietnam mainly applies to listed firms, while most other businesses only follow basic legal compliance reports and have not yet integrated sustainability into their management practices. The regulatory framework and support mechanisms provide the foundation for ESG disclosure. However, some other factors influence the actual implementation and quality of ESG reporting by Vietnamese enterprises.

Market and Investor Pressure

According to (PricewaterhouseCoopers, 2022), the factors that motivate Vietnamese enterprises to disclose ESG information mainly come from market pressure, investor requirements and internal development goals. Specifically, 82% of enterprises participating in the survey said that they implement ESG to enhance brand image and reputation, while 68% consider this an important measure to maintain competitiveness in the market. Additionally, 44% of enterprises consider attracting and retaining employees as the primary driver for ESG initiatives. Additionally, 40% of enterprises are under pressure from investors and stakeholders, and 37% noted that the impact of state management agencies is a factor directly affecting their ESG commitments. In addition, about half of global consumers say ESG factors influence their purchasing behaviour, and in Vietnam, governance (59%) and social (51%) aspects are rated more important than environmental factors (46%).

On the investor side, nearly 80% said ESG is an important factor in the investment decision-making process, while about 50% are willing to withdraw capital from businesses that do not take specific actions on ESG. These figures show that ESG disclosure in Vietnam is not only governed by government regulations, but also by pressure from the capital market, consumers and workforce, making ESG a strategic competitive tool in the current period of sustainable integration.

Stock Exchange Requirements

The Securities Law 2019, together with Circular 96/2020/TT-BTC, stipulates that listed companies must disclose information related to sustainable development in their annual reports. The report contents include energy and water use, emissions, biodiversity conservation, as well as labour policies, welfare and social responsibility. In addition, the State Securities Commission (SSC) has issued guidelines on Sustainability Reporting for listed companies based on the GRI (Global Reporting Initiative) Standards. To date, the SSC has continued to encourage and require public companies to integrate ESG (Environmental, Social, and Governance) content into their annual reports, thereby enhancing transparency and accountability in information disclosure activities.

Industry-Specific Characteristics

According to PwC's survey (PricewaterhouseCoopers, 2022), the motivation for ESG implementation among industries in Vietnam has significant differences. Financial institutions often react more strongly to pressure from investors and regulators, as these stakeholders increasingly view ESG performance as a key factor in assessing the stability and long-term value of enterprises. In contrast, enterprises in the manufacturing and retail sectors often implement ESG activities with the aim of strengthening brand image, enhancing customer confidence and attracting high-quality human resources. This difference reflects the specific priorities and market dynamics of each industry, as financial enterprises focus more on regulatory compliance and investor relations, while manufacturing and service enterprises emphasise image building and workforce engagement.

3. Research Methodology

This study employs descriptive and trend analysis to examine the current state and evolution of ESG disclosure practices among Vietnamese listed companies. The research analyses data from 673 companies (296 on HNX and 377 on HOSE) over the period 2015-2024, using secondary data from sustainability reports, annual reports, integrated reports, and publicly available information on company websites.

Descriptive Analysis

The descriptive analysis synthesises the current state of sustainability disclosure among listed companies. The methodology involves: (1) identifying enterprises that published ESG reports or ESG-related content and documenting disclosure forms and content; (2) classifying adopted reporting standards and frameworks, including GRI, SDG and SSC guidelines; (3) analysing industry-level ESG reporting patterns; and (4) assessing the extent of third-party verification and assurance by independent organisations to evaluate transparency and reliability.

Trend Analysis

Trend analysis assesses changes and development in ESG disclosure practices by comparing data across years to identify increasing, decreasing, or stable patterns. This method determines growth or decline in ESG disclosure activities over time and evaluates the impact of new policies, regulations, or changes in disclosure requirements. The study also analyses trends in qualitative versus quantitative reporting methods, examining the presentation content and indicators to determine the level of data measurement versus commitment descriptions, thereby reflecting the depth, ability to quantify ESG impacts, and maturity in sustainability reporting practices.

Research Questions

The study addresses six research questions to provide a comprehensive understanding of ESG disclosure practices in Vietnam:

- *RQ1: What is the trend of ESG reporting disclosure by Vietnamese companies?* This question examines the development and frequency of ESG reporting over time, highlighting progress and adoption rates.
- *RQ2: What is the level and standard of ESG disclosure?* This assesses the extent to which Vietnamese listed companies comply with international ESG reporting standards.
- *RQ3: How does ESG disclosure vary by industry?* This examines industry groups that actively implement ESG information disclosure among listed companies, determining which industries lead in compliance and the level of sectoral differences.

- *RQ4: What is the level of third-party verification or assurance?* This examines whether sustainability reports are independently assured by third parties, a crucial factor in determining reliability and transparency that enhances stakeholder trust.
- *RQ5: What role does government regulation play in the development of ESG disclosure?* This investigates the influence of policies, legal frameworks, and regulatory guidelines in shaping corporate ESG disclosure practices in Vietnam.
- *RQ6: Do Vietnamese enterprises use quantitative or qualitative information in sustainability reports?* This assesses whether information presentation is quantitative (specific, measured) or qualitative (goals and commitments), helping identify how Vietnamese enterprises communicate their sustainable development commitments, outcomes, and orientations.

These research questions provide a comprehensive framework for examining ESG disclosure practices in Vietnam from multiple perspectives - temporal trends, standards, sectoral variations, verification mechanisms, regulatory influences, and reporting methodologies. This multi-faceted approach enables a thorough assessment of both the current state and evolutionary trajectory of sustainability reporting among Vietnamese listed companies. The subsequent section presents the empirical findings obtained through this analytical framework.

4. Results

To answer *RQ1*, the detailed findings are shown in Figure 2. This research reviewed the annual and sustainability reports of 296 listed companies on the Hanoi Stock Exchange (HNX) to determine the trend of ESG information disclosure during 2015-2024. The results show that 2015 marked the initial stage when several companies began mentioning environmental and social responsibility aspects in their annual reports, although no separate sustainability reports were issued. Only four enterprises (1.35% of the sample) integrated sustainability content into their annual reports, mainly describing environmental and social impacts, while most others only referred to general sustainable development goals or corporate social responsibility (CSR) commitments. From 2016 onward, ESG disclosure improved significantly, as reflected in the steady increase in the number of enterprises reporting sustainability content, from eight in 2016 and eleven in 2017 to seventy-one by 2024. Notably, during 2021-2024, only one company Thang Long Investment Group (TIG), published a sustainability report reviewed and referenced under the international GRI Standards, including GRI 101 (Reporting Principles), GRI 102 (General Disclosures), GRI 103 (Management Approach), and the three topic-specific standards: GRI 200 (Economic), GRI 300 (Environmental), and GRI 400 (Social). Overall, enterprises listed on HNX have not yet issued independent sustainability reports; instead, they mainly integrate ESG content into their annual reports.

According to data compiled from 377 firms listed on the Ho Chi Minh City Stock Exchange (HOSE). In 2015, fourteen firms integrated sustainability content in their annual reports, and four companies (1.06%) prepared independent sustainability reports including Bao Viet Group (BVH), PAN Group (PAN), Century Synthetic Fiber Corporation (STK), and Vietnam Dairy Products (Vinamilk, VNM). Since 2016, there has been a steady rise in the number of companies issuing sustainability reports, reaching 107 companies (28.38%) in 2024, of which 26 issued independent reports aligned with international standards.

To answer *RQ5*, Figure 2 illustrates that regulations of state management agencies play a crucial role in promoting and supporting ESG disclosure practices in Vietnam. Circular 155/2015/TT-BTC is considered an initial milestone, when it first required listed companies to report on environmental and social issues in their annual reports. Then, Circular 96/2020/TT-BTC was issued to supplement, expand and clarify requirements related to ESG disclosure. Along with that, guidelines from the State Securities Commission (SSC) and the Ho Chi Minh City Stock Exchange (HOSE) on the application of GRI Standards have contributed to standardizing the content, methods and structure of reports, helping businesses access international practices more easily. As a result, the legal framework and ESG reporting guidelines in Vietnam are continually improving, with regulations that require businesses to comply, while also encouraging them to enhance transparency and accountability. The strengthening of the regulatory system has had a clear impact: the number of independent sustainability reports on the Vietnamese stock market has gradually increased, from four reports (1.1%) in 2015 to twenty-six reports (6.8%) in 2024. This figure reflects, in addition to businesses' efforts to meet investor expectations and capital market requirements, that the legal environment also plays an important role in promoting ESG disclosure practices more widely.

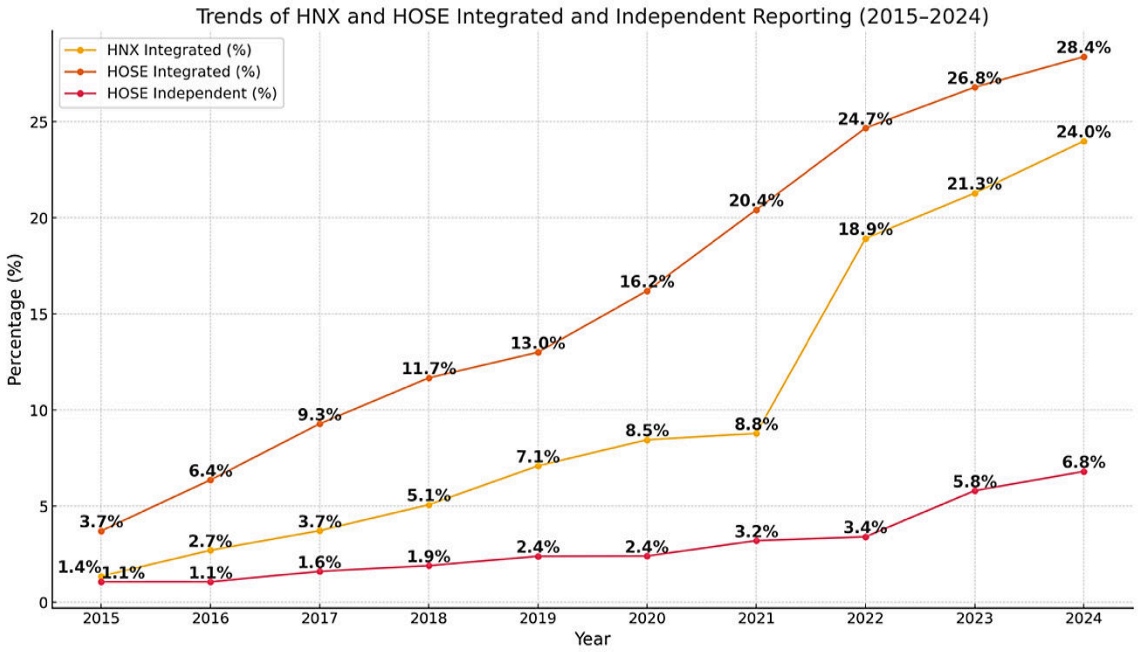


Figure 2. Percentage of enterprises mentioning sustainability reporting (2015-2024).

Source: Vietstock Finance annual and sustainability report database. https://finance.vietstock.vn/tai-lieu/bao-cao-thuong-nien.htm

To answer *RQ2*, the results (Table 3) show that, during the period 2015-2024, Vietnamese enterprises primarily prepared sustainability reports (including integrated and standalone reports) in accordance with the guidance of the SSC. Additionally, the most widely used ESG reporting frameworks today are the Global Reporting Initiative (GRI) and the United Nations Sustainable Development Goals (SDGs) Framework. Specifically, the rate of enterprises implementing the GRI model ranges from 19.23% to 25%, the rate of enterprises referencing or reporting according to SDGs Framework reaches 8.0% in 2022 and increases slightly to 12.7% in 2024.

Table 3.
Frameworks related to sustainability reporting in Vietnam

Year	GRI (%)	SDG (%)	SSC guideline (%)
2015	22,73	18.2	59.07
2016	25,00	11.1	63.9
2017	19,23	11.5	69.27
2018	22,73	11.1	66.17
2019	22,78	11.4	65.82
2020	22,11	9.5	68.39
2021	23,68	10.5	65.82
2022	20,37	8.0	71.63
2023	22,04	11.8	66.16
2024	22,55	12.7	64.75

Note: the proportion of enterprises that prepare independent and integrated sustainability reports annually

Source: Vietstock Finance annual and sustainability report database. https://finance.vietstock.vn/tai-lieu/bao-cao-thuong-nien.htm

To answer *RQ3***,** the results are presented in Figure 3, which shows that the high rate of ESG-independent reporting enterprises is primarily concentrated in the financial, consumer staples, and real estate sectors. Specifically, the number of ESG reporting enterprises in the Finance sector increased from 1 enterprise in 2015 (25%) to 11 enterprises in 2024 (42.3%), the consumer staples sector maintained the second position with a rate of 15.4% when increasing from 2 to 4 enterprises in 2024. The real estate sector increased from 0 to 3 enterprises in 2024 (11.6%). From 2017 onwards, several industries, including healthcare, industry, materials, information technology, and utilities, began to report on ESG.

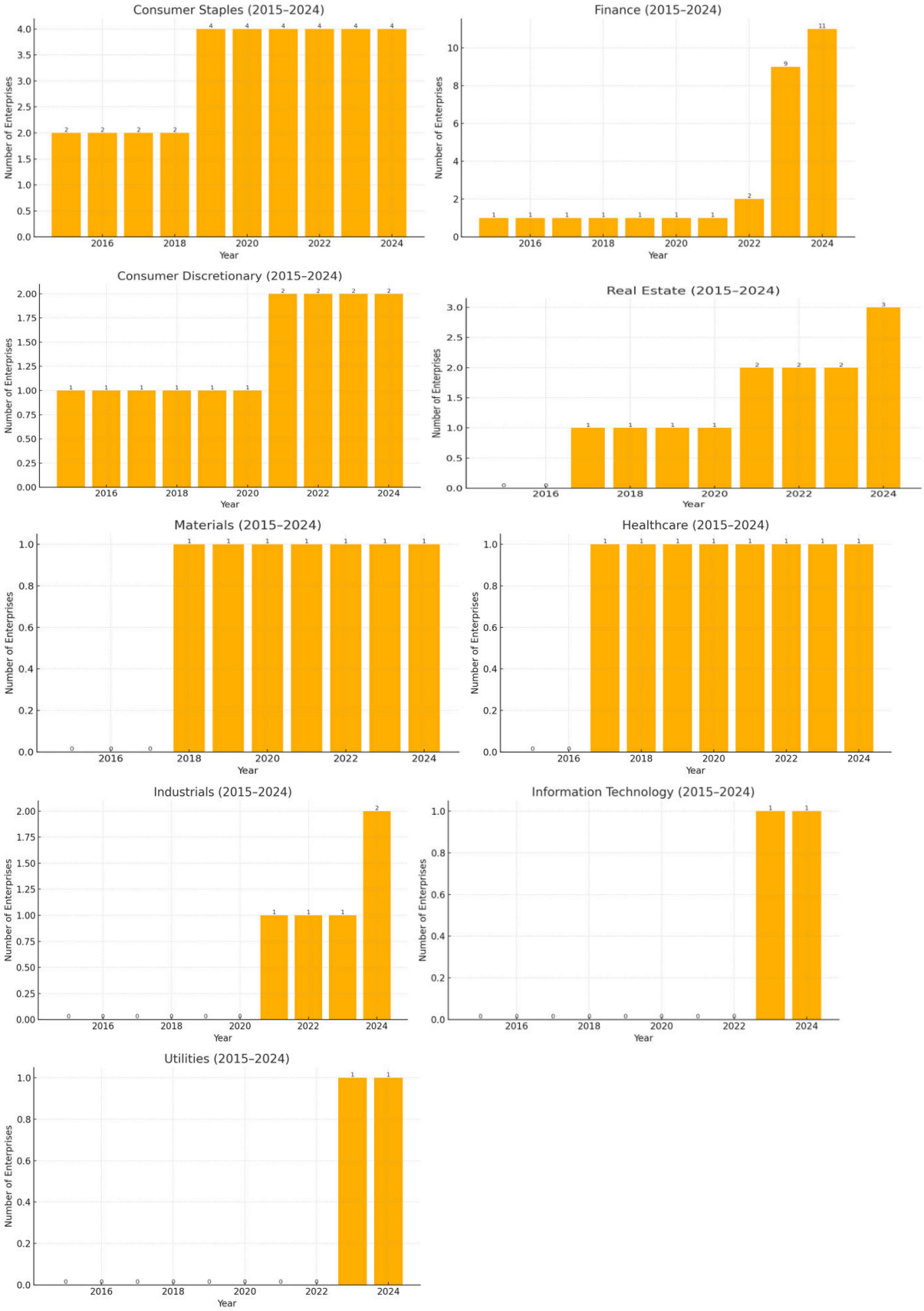


Figure 3. Number of enterprises in sectors with independent sustainability reports.

Source: Vietstock Finance annual and sustainability report database. https://finance.vietstock.vn/tai-lieu/bao-cao-thuong-nien.htm.

Figure 4 shows the difference between industries in the level of participation in integrated sustainability reporting. The three leading industries are Materials, Real Estate and Industry, with the number of enterprises reporting by 2024 being 33 (19%), 32 (18%) and 32 (18%) respectively. This reflects the nature of activities with a large impact on the environment and society, making enterprises in these industries under higher pressure to disclose information and have a stronger motivation to implement sustainability reporting. The Finance industry also recorded a steady growth trend, from only 3 enterprises publishing reports in 2015 to 12 enterprises in 2024, showing increasing awareness of the role of ESG transparency in risk management and responsibility to investors. Similarly, the Consumer Goods group also saw a significant expansion in the level of participation in reporting; In which, the Essential Consumer Goods sector will reach 20 enterprises (11%) and the Non-Essential Consumer Goods sector will reach 19 enterprises (11%) by 2024, reflecting the need to build trust and strengthen brand image in the eyes of consumers. Notably, the Communications Services, Energy and Technology sectors show slower changes in awareness than traditional sectors as they only started participating in integrated reporting after 2019.

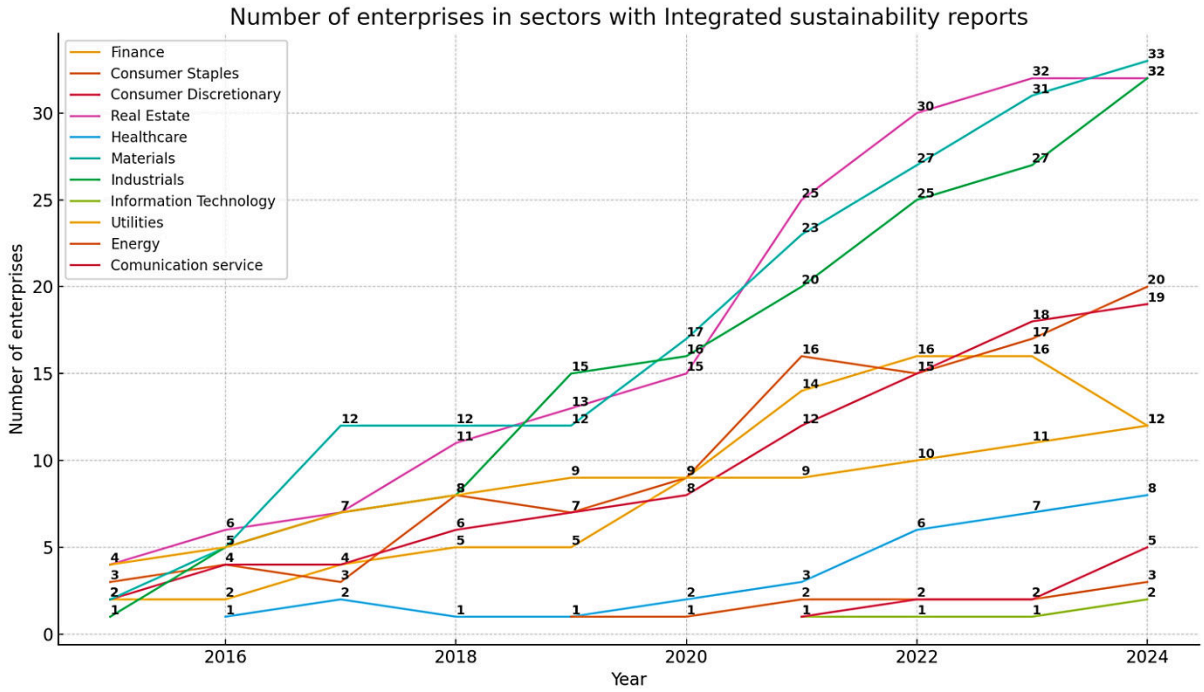


Figure 4. Number of enterprises in sectors with independent sustainability reports.

Source: Vietstock and sustainability report database. https://finance.vietstock.vn/tai-lieu/bao-cao-thuong-nien.htm

To answer *RQ4*, results from enterprises with independent sustainability reports indicate that most ESG reports of Vietnamese enterprises are currently not verified by a third party. Most reports are only verified internally through the enterprise's audit or risk management department, rather than being guaranteed by independent external organisations. For enterprises that integrate sustainability reports into their annual reports, the financial statements are often audited by an independent unit; however, the content on sustainable development has not been

confirmed for accuracy and reliability. Notably, only 2 enterprises out of 22 enterprises (in 2024) have independent sustainability reports, such as Asia Commercial Joint Stock Bank (ACB); Vietnam Dairy Products Joint Stock Company (VNM), guaranteed by third parties such as PWC and KPMC.

To answer *RQ6*, the results from enterprises with independent sustainability reports for all these enterprises conduct quantitative reporting, with specific, measurable indicators. In contrast, enterprises conducting integrated sustainability reports mainly use qualitative reports (Figure 5), focusing on demonstrating commitment, social and environmental responsibility, as well as sustainable development goals in the overall strategy.

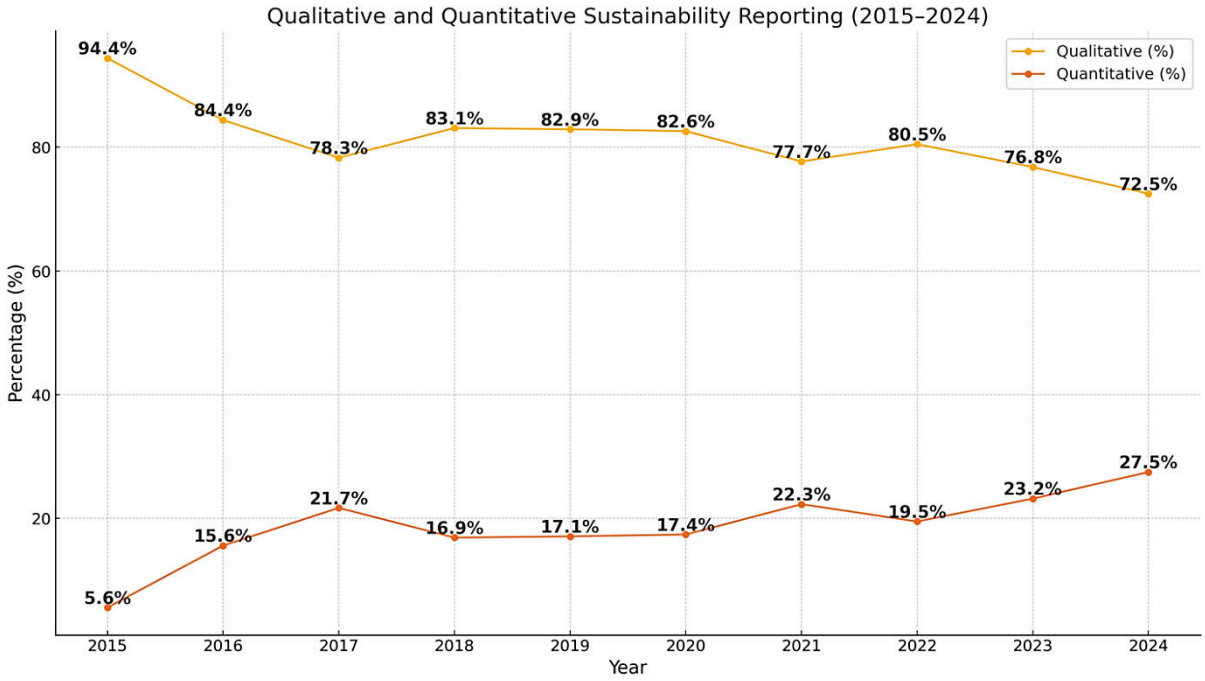


Figure 5. Percentage of enterprises conducting qualitative and quantitative reporting.

Source: Vietstock Finance annual and sustainability report database. https://finance.vietstock.vn/tai-lieu/bao-cao-thuong-nien.htm

The proporti on of enterprises using qualitative reporting methods has generally declined, moving from 94.4% in 2015 to 72.5% in 2024. Conversely, the proportion of enterprises employing quantitative reporting methods has risen, increasing from 5.6% to 27.5% over the same period. This shows that enterprises are increasingly shifting from qualitative to quantitative reporting.

5. Conclusion

This study examined ESG disclosure practices among 673 listed companies on the HNX and HOSE during 2015-2024, revealing significant progress in Vietnam's sustainability reporting. The number of firms publishing sustainability reports has increased steadily, driven by regulatory compliance pressure and growing corporate awareness, with widespread adoption of GRI Standards, SDGs, and the SSE Initiative.

Three key findings emerge. First, whilst large enterprises in finance, banking, insurance, and essential consumer goods have adopted international standards, most companies integrate ESG content only within annual reports rather than producing independent verified reports. Second, sectoral variations are evident: finance and essential consumer goods lead in independent ESG reporting, whilst real estate, industrial, and information technology sectors strengthened participation only after 2020. Materials, industrial, and real estate sectors dominate integrated sustainability reporting. Third, companies publishing independent reports prefer quantitative reporting with measurable indicators, whereas integrated reports primarily utilise qualitative disclosures emphasising commitments and strategic goals.

Circular 155/2015/TT-BTC and subsequent SSC guidelines marked a turning point, prompting sharp increases in ESG disclosure. Circular 96/2020/TT-BTC, the National Green Growth Strategy 2021–2030, and the COP26 commitments have created clear legal foundations and standardised reporting structures. However, impact remains concentrated among large enterprises, with SMEs achieving only formal compliance.

Several barriers persist. Independent third-party verification remains limited, with most reports relying on self-disclosure, constraining transparency and reliability. The absence of mandatory sanctions has led to predominantly formal compliance. Standardisation, verification, and enforcement monitoring remain the main barriers to ESG reporting development in Vietnam.

These findings confirm that mandatory mechanisms play a key role in promoting transparency in emerging markets, consistent with Krueger et al. (2024) and Moharram et al. (2024). The concentration of reports in high-impact industries and the proactive application of GRI and SDGs strengthen legitimacy theory's argument that industry specificity is decisive in emerging markets, aligning with Abdul Rahman & Alsayegh (2021) and Hien & Ngoc (2025). Whilst progress in quantitative indicator disclosure is evident, the lack of independent verification and formal compliance among SMEs highlight the institutional reforms necessary to transition Vietnam's ESG disclosure framework towards international best practice.

Limitations

The analysis is primarily based on annual reports and publicly disclosed sustainability reports of 673 listed firms, potentially missing ESG information that is not disclosed or reported only internally. Additionally, the level of detail and quality of reporting varies across companies and industries, making comparison and quantitative assessment challenging.

Future Research Directions

Research can be expanded in several directions: quantitative analysis of relationships between ESG disclosure levels and financial outcomes, capital attraction, or risk management; expanded scope to unlisted enterprises and SMEs to reflect ESG practices more comprehensively; and comparative studies between Vietnam and other ASEAN countries to determine integration levels and identify regional gaps in ESG practices.

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INPUT-OUTPUT MODELING OF ECONOMIC SENSITIVITY TO ENERGY COMMODITY PRICE CHANGES, 2005-2020

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Purpose: This study provides a comprehensive analysis and assessment of changes in the Polish economy from 2005-2020 and its sensitivity to energy commodity price fluctuations. It focuses on resource use, import dependence, and the processes shaping economic resilience, with particular attention to crude oil and natural gas volatility given Poland's high import reliance.

Design/methodology/approach: The research applies input-output analysis to measure intersectoral linkages and multipliers. Using statistical data for Poland from 2005-2020, the study calculates material and import intensity, labor input, production and price multipliers, and develops a price model. The approach is quantitative and comparative, emphasizing long-term trends rather than short-term fluctuations.

Findings: The study reveals significant structural changes in the Polish economy from 2005-2020 and its varying sensitivity to energy price fluctuations. Coal and electricity sectors showed low, unstable price multipliers, while crude oil and gas exerted stronger impacts earlier but weakened over time. Chemical, metallurgical, and electromechanical industries displayed the highest multipliers, transmitting shocks across the economy due to high import dependence. Coal mining remained the most labor-intensive sector, while services grew increasingly sensitive to energy costs. Overall, vulnerability shifted from traditional energy commodities toward energy-intensive industries and services, highlighting broader exposure to energy price volatility.

Research limitations/implications: The input-output model is static, based on aggregated data, and ends in 2020, excluding recent shocks and energy transition policies. Delays in publishing input-output data by GUS reduce timeliness. Future research should extend the period, include international comparisons, and integrate micro-level data.

Practical implications: The results identify the sectors most sensitive to energy prices, providing a basis for risk management, strategic planning, and supporting the energy transition process.

Social implications: The research shows that rising energy prices can affect households through higher living costs. Labor-intensive sectors like coal mining remain vulnerable, while wage pressures in services and high-tech industries underscore the need for workforce adaptation.

Originality/value: This paper presents the latest study on Poland's economic sensitivity to energy commodity price changes, covering a long period. Its value lies in providing an up to date, comprehensive view, making it relevant for researchers, policymakers, and businesses.
Keywords: input-output analysis, energy resources prices, labor costs, systemic analysis.
Category of the paper: Research paper.

1. Introduction

The energy system is, in a broad sense, an extremely important element in the national economy, shaping economic growth of the country, human welfare and living standards, international exchange and communication, environmental quality and at the same time significantly affecting economic development, the stability of the country, its sovereignty and self-sufficiency. Energy and energy raw materials have been the most important trade commodity for many years, and subsequently source of unrest and discussions – as we have seen in recent years with regard to Russia's military actions. Prices of raw materials and energy are particularly important for proper functioning of the state, as they show strong correlation with the rate of economic growth – sharp soaring prices of raw materials and energy translate into increasing costs of production, which leads to reduction in aggregate supply ultimately affecting inflation. Moreover, noticeable climate change encourages intensified efforts to decarbonize the energy sector by increasing renewable energy share in the energy mix. Thus, on the one hand, the economic use of energy is being promoted, drawing attention to factors like energy intensity, environmental protection and promotion of 'green energy', while on the other hand, Western lifestyles and the advances of civilization are stimulating an increase in energy consumption.

Due to its globally significant solid fuel resources Poland's energy sector is mainly based on coal. Unfortunately, Poland does not have significant natural gas and oil resources – their extraction is not able to supply the current demand, which necessitates import. Figure 1 shows the structure of primary energy production in Poland in 2005-2023 and illustrates a clear and steady transition in Poland's primary energy production over nearly two decades. During the reviewed period the primary energy production in Poland decreased by 30% (from 78 Mtoe to 54 Mtoe). In 2005, the energy mix was overwhelmingly dominated by solid fossil fuels and peat, accounting for nearly 88% of total production. By 2023, this share had dropped to 65%, reflecting a significant 23 percentage point decline. Meanwhile, renewables and biofuels saw a remarkable rise – from just 5.8% in 2005 to 25.6% in 2023 – a more than fourfold increase. This shift highlights Poland's growing commitment to decarbonization and energy diversification, especially in response to EU climate targets and domestic air quality concerns. Natural gas remained relatively stable throughout the period, hovering around 5-6%, indicating limited domestic production and continued reliance on imports.

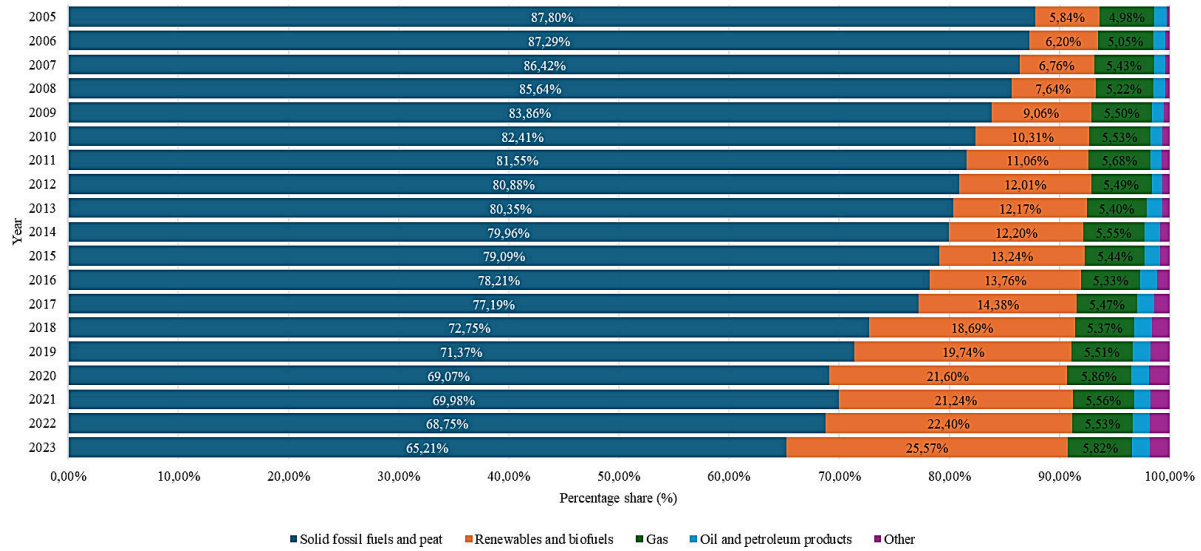


Figure 1. Primary energy production in Poland (2005-2023) – share by source [%].

Source: Eurostat. Database 2025. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 28 October 2025)

In contrast to primary energy production, the structure of Poland's gross inland consumption in 2005-2023 shows a similar decline in the share of solid fossil fuels, accompanied by a steady rise in renewables and biofuels, though the overall level of consumption decreased less sharply than production. Figure 2 illustrates the evolution of Poland's gross inland energy consumption over this period, broken down by energy source. It reveals a gradual but significant shift in the country's energy structure.

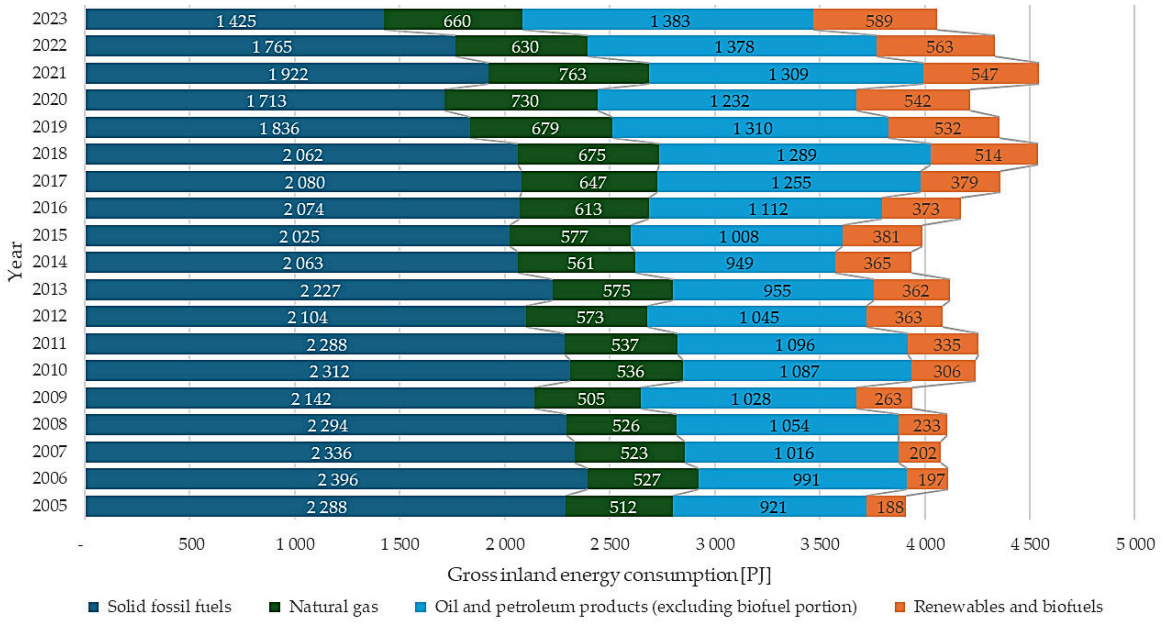


Figure 2. Gross inland consumption in Poland (2005–2023) [PJ].

Source: Eurostat. Database 2025. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 28 October 2025)

The structure of energy consumption in Poland is different from that of highly developed European Union member states, mainly due to the preponderance of coal, the low share of hydrocarbon fuels and deficiency of nuclear power.

Gross inland consumption, defined as the total energy supplied to the domestic market in Poland between 2005 and 2023, remained relatively stable at around 4000-4600 PJ (Figure 2). The consumption of solid fuels in the reviewed period decreased by 38%, with simultaneous increase of consumption of oil (by 50%), natural gas (by 29%) and energy from renewable sources and biofuels (by 214%).

Thanks to its internationally considerable reserves of solid fuels, Poland is the largest coal producer in the European Union (Report Energy, 2022) and the tenth largest in the world (International Index of energy security risk, 2020), and its energy sector is based mainly on coal. It should be noted that despite taking a number of measures to achieve energy balance over the past decade, there are no doubts that, with significant resource reserves and existing mining infrastructure, coal will continue to play a key role in Poland's energy system (Nyga-Łukaszewska, Aruga, Stala-Szlugaj, 2020; Bórawski, Bełdycka-Bórawska, Holden, 2023; Rybak, Aurelia., Rybak, Aleksandra, Joostberens, 2023). Dominant share of domestic solid fuels both in the structure of primary energy consumption and electricity production ensures high and stable level of energy security and limits, as far as possible, the burden on the trade balance by the cost of imports of energy carriers. However, appropriate measures are needed to be taken to provide sound management of deposits and to reduce the intensity of the use of fossil fuels, in particular hard coal and lignite, in electricity generation. Reducing or even phasing out the extraction and combustion of hard coal and lignite in Poland has been recognised by experts participating in the Poland Energy Foresight project as the most important element of energy transformation of the country (Dębkowska et al., 2021). At the same time, it is essential that any modification or transformation process also considers the social dimension of such decisions, as emphasized in a study on residents of the Silesian region's perceptions of Poland's sustainable energy transition (Włodarczyk, Herczakowska, 2025).

In view of the above, a systemic study of the Polish energy market becomes indispensable. The application of the input-output model provides a valuable analytical tool that makes it possible to capture the complex interdependencies between supply, demand, and economic development.

2. Methods

Input-output tables, also known as input-output matrices, are an analytical tool used in economics to show the value or volume of transactions that have taken place within a given economic system over a specific period of time. These transactions are grouped according to the type of products or industries to which they relate (Przybyliński, 2012). The first such table, the socalled economic table, was constructed by François Quesnay (Quesnay, 1928), while the author of the currently used form is Wassily Leontief (Leontief, 1936), who in the 1930s developed an interindustry flow table for the United States economy based on data from 1919 and 1929 (Gruszczyński, Kuszewski, Podgórska, 2009). More on input-output methods and directions of their development can be found in the literature (e.g., Boratyński, Przybyliński, Świeczewska, 2015; Xie et al., 2018). At present, input-output methods are used to build various simulation models, to conduct research on environmental protection (Prandecki, 2016), energy intensity (Mrówczyńska-Kamińska, Mańkowski, Bajan, 2024; Szymańska, Mroczek, 2023), or labor intensity (Parteka, 2018), as well as to assess the environmental impacts of electricity generation, where they form the basis for emission footprint analyses and comparisons of energy technologies (Henriques, Sousa, 2020). Thanks to data on exports and imports, it is also possible to evaluate foreign trade and include these resources in analyses.

Input-output analysis constitutes one of the key tools for examining interdependencies within the national economy. It enables the identification of interindustry flows, the assessment of production structures, and the determination of the role of individual sectors in generating value added. In the case of Poland, whose economy over the past two decades has undergone intensive processes of transformation and integration with the European market, the application of the input-output model makes it possible to capture both changes in the structure of demand and supply as well as the consequences for the energy balance and the development of key industries.

The systemic approach offered by this method is particularly valuable in the analysis of the energy market, where the interdependencies between production, consumption, and imports have a direct impact on the country's economic stability and energy security. The use of input-output tables enables both the description of the current situation and the forecasting of energy and economic policy impacts. The Central Statistical Office (Główny Urząd Statystyczny) publishes input-output tables cyclically, at five‑year intervals, though with a significant delay. The most recent compilation, covering data for the year 2020, was released only in June 2024, which continues the trend observed in earlier editions. These tables present the structure of the flow of goods and services between sectors of the Polish economy, distinguishing between resources originating from domestic production and from imports, and they also illustrate their use in production and consumption processes.

For the analysis and assessment of trends and the impact of changes occurring in the energy resources market on other branches of the economy, data from the input-output balance were used, which were presented in the input-output balance at current basic prices (the so-called table without separation of imports), in the input-output balance at current basic prices for domestic production (the so-called table with separation of imports), and in the table concerning the use of imported goods and services (the so-called import table).

2.1. Input-output table – general form

The number of sectors in the considered economic system is denoted by n, and their indices by $i, j = 1,2, \ldots, n$. The individual quantities, expressed in monetary units, denote:
x_{ij} – the flow from sector i to j, i.e., the value of production generated in sector i, and consumed in sector j,
X – the total (global) production of the entire economy,
Y_i – the final demand of sector i,
Z_i – the intermediate consumption of sector i,
K_j – material costs, i.e., the sum of the value of production consumed in sector j,
D_j – the value added of sector j (net production), defined as the difference between the value of total production and material costs.

The applied sectoral division is exhaustive, which means that the sum of the production values of all sectors X_i equals the total production value of the entire economy:

$$X = \sum_{i=1}^{n} X_i \tag{1}$$

The general form of the input-output table is presented in Figure 3.

		Branches / Directions of Use				Intermediate Consumption $Z_i = \sum_{j=1}^{n} x_{ij}$	Final Demand Y	Total Output (Global Production) X
		1	2	…	n			
Branches / Products	1	x_{11}	x_{12}	…	x_{1n}	Z_1	Y_1	X_1
	2	x_{21}	x_{22}	…	…	Z_2	Y_2	X_2
	…	…	…	…	…	…	…	…
	n	x_{n1}	x_{n2}	…	x_{nn}	Z_n	Y_n	X_n
Material Costs $K_j = \sum_{i=1}^{n} x_{ij}$		K_1	K_2	…	K_n	$Z = \sum_{i=1}^{n} Z_i = K = \sum_{j=1}^{n} K_j$	$Y = \sum_{i=1}^{n} Y_i$	$X = \sum_{i=1}^{n} X_i = Y + Z$
Value Added		D_1	D_2	…	D_n	$D = \sum_{j=1}^{n} D_j$		
Total Output (Global Production)		X_1	X_2	…	X_n	$X = \sum_{j=1}^{n} X_j = K + D$		

Figure 3. Input-output Table: Basic Structure.

Source: author's own work.

The decomposition of total production can be expressed in the form of a system of production balance equations, also referred to as distribution equations:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + Y_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + Y_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + Y_n = X_n \end{cases} \tag{2}$$

which is equivalent to:

$$X_i = \sum_{j=1}^{n} x_{ij} + Y_i \tag{3}$$

The above system is a multi-equation, linear, static, deterministic model, whose matrix notation is as follows:

$$\mathbf{X\,i + y = x} \tag{4}$$

where:

X – the input-output flow matrix with elements x_{ij},

i – the summation vector of matrix **X**, of dimensions n x 1,

y – the final demand vector of dimensions n x 1 with elements Y_i,

x – the total production vector of dimensions n x 1 with elements X_i.

Analogously, the value of total production can be expressed from the perspective of its creation, in the form of the following system of equations:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + D_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + D_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + D_n = X_n \end{cases} \tag{5}$$

where: D_i – the value added in sector i,
or, in matrix notation:

$$\mathbf{X^T i + d = x} \tag{6}$$

where **d** is the vector of value added with elements D_i.

The systems of equations presented above constitute models, from which the following relationships result:

$$Z + Y = X \tag{7}$$

The sum of intermediate consumption Z and final demand Y equals total production X.

$$K + D = X \tag{8}$$

The sum of material costs K and value added D equals total production X.

$$K = Z \tag{9}$$

Material costs K are equal to intermediate consumption Z.

$$D = Y \tag{10}$$

The inputs of production factors are transformed into final product, which means that value added D is equal to final demand Y.

2.2. Input-output table without separation of imports

The input-output table without separation of imports presents the total value of both domestic and imported flows. The difference compared to the general form lies in the introduction of an additional row containing data on the volume of imports of products in a given sector, as well as in the refinement of the components of the cost equation:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + D_1 = X_1^K \\ x_{21} + x_{22} + \cdots + x_{2n} + D_2 = X_2^K \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + D_n = X_n^K \end{cases} \tag{11}$$

where:

x_{ij} – inter-industry flows of domestic and imported products,

Y_i – value of final demand for domestic and imported products of sector i,

X_i^K – total (global) production of sector i,

M_i – imports of products of sector i,

X_i – total supply (total use), i.e., the sum of the global production of sector i (X_i^K) and the imports of products of that sector (M_i).

Balancing the table without separation of imports, which in matrix notation can be expressed as:

$$\mathbf{X\,i + y = x} \tag{12}$$

$$\mathbf{X^T + d + m = x^K + m = x} \tag{13}$$

where **m** is the import vector with elements M_i.

Balancing the table without separation of imports consists of summing global production and imports to obtain total supply (total use), thereby ensuring consistency between sectoral outputs and the overall economic equilibrium.

2.3. Input-output table with separation of imports

The input-output table with separation of imports consists of reducing inter-industry flows and final demand by the value of imported products:

$$x_{ij}^K = x_{ij} - x_{ij}^M \tag{14}$$

$$Y_i^K = Y_i - Y_i^M \tag{15}$$

The index K refers to domestic products, while M refers to imported ones. As a result, the table describes flows exclusively of domestic goods, with the costs of imported materials included in additional rows.

The balancing variable of the domestic input-output table is total production:

$$\mathbf{X^K\,i + y^K = x^K} \tag{16}$$

$$\mathbf{(X^K)^T\,i + (X^M)^T\,i + d = x^K} \tag{17}$$

where: $\mathbf{X^M}$ **–** the matrix of intermediate product flows originating from imports.

The macroeconomic relations take the following form:

$$Z^K + Y^K = X^K \tag{18}$$

$$K^K + K^M + D = X^K \tag{19}$$

Since:

$$Z = K \tag{20}$$

then:

$$K^M + D = Y^K \tag{21}$$

By combining the tables of domestic product flows and imported product flows, we obtain a complete and accurate picture of the economy.

2.4. Cost coefficients

Input-output tables make it possible to describe production processes in individual sectors using input-output relations (Gruszczyński, Kuszewski, Podgórska, 2009). The relationship between the inputs of sector j and production outputs is defined by the cost coefficients of that sector, denoted by a_{ij}, and defined as:

$$a_{ij} = \frac{x_{ij}}{X_j} \qquad i, j = 1,2,\dots,n \tag{22}$$

where:

x_{ij} – the flow from sector i to sector j, i.e., the value of production generated in sector i and consumed in sector j,

X_j – the total (global) production of sector j.

The cost coefficients for all sectors are recorded in the form of a matrix:

$$\mathbf{A} = [a_{ij}] \tag{23}$$

called the cost structure matrix. The elements a_{ij} are non-negative, and the sum of the elements forming the j-th column equals the material intensity coefficient of that sector.

Depending on the type of table, cost coefficients may take the following forms:

– for tables with separation of imports, they express the share of domestic raw material and input costs in the production costs of goods manufactured domestically:

$$a_{ij}^K = \frac{x_{ij}^K}{X_j^K} \tag{24}$$

$$\mathbf{A^K} = [a_{ij}^K] \tag{25}$$

These are referred to as direct product intensity coefficients of domestic production.

– for tables presenting the breakdown of imported products, the import intensity of production can be determined using direct import intensity coefficients:

$$a_{ij}^M = \frac{x_{ij}^M}{X_j^K} \tag{26}$$

$$\mathbf{A^M} = [a_{ij}^M] \tag{27}$$

Cost coefficients form the basis of the mathematical model in the form of a system of linear equations or a linear matrix equation, describing the relationships between total and final production across all sectors.

2.5. Leontief model

The general form of the distribution equations is given by:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + Y_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + Y_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + Y_n = X_n \end{cases} \tag{28}$$

Transforming the cost coefficient formula, we obtain the relation:

$$x_{ij} = a_{ij} X_j \tag{29}$$

which allows the distribution equations to be written as:

$$\begin{cases} a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n + Y_1 = X_1 \\ a_{21}X_1 + a_{22}X_2 + \cdots + a_{2n}X_n + Y_2 = X_2 \\ \vdots \\ a_{n1}X_1 + a_{n2}X_1 + \cdots + a_{nn}X_n + Y_n = X_n \end{cases} \tag{30}$$

which is equivalent to:

$$\mathbf{Ax} + \mathbf{y} = \mathbf{x} \tag{31}$$

After rearrangement, we obtain:

$$\left(\begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & \cdots & a_{1\mathrm{n}} \\ \vdots & \ddots & \vdots \\ a_{\mathrm{n}1} & \cdots & a_{\mathrm{nn}} \end{bmatrix}\right)\begin{bmatrix} X_1 \\ \vdots \\ X_{\mathrm{n}} \end{bmatrix} = \begin{bmatrix} Y_1 \\ \vdots \\ Y_{\mathrm{n}} \end{bmatrix} \tag{32}$$

which is:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{y} \tag{33}$$

This matrix equation describes the relationship between total and final production, where the matrix $(\mathbf{I} - \mathbf{A})$ is called the Leontief matrix or the production structure matrix.

It can also be written as:

$$\mathbf{Lx} = \mathbf{y} \tag{34}$$

using the following notation:

$\mathbf{x} = [X_i]$ – an n-dimensional column vector of total production,

$\mathbf{y} = [Y_i]$ – an n-dimensional column vector of final production,

$\mathbf{L} = \mathbf{I} - \mathbf{A}$ – an $n \times n$ matrix, where $\mathbf{A}$ is the cost structure matrix and $\mathbf{I}$ is the identity matrix of order n.

This equation constitutes the Leontief model of the considered n-sector economic system, describing the relationships between total and final production across all sectors. The parameters of the model are the cost coefficients given by the cost structure matrix $\mathbf{A}$.

The parameters α_{ij} of the inverse Leontief matrix, i.e. $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ express the amount of total production of sector i required to satisfy a unit of final demand for products of sector j. The elements of this matrix are called coefficients of total product intensity, showing how final demand for products of type j changes under the influence of a change in production of goods of type i by α_{ij}:

$$\mathbf{x^K} = (\mathbf{I} - \mathbf{A^K})^{-1}\mathbf{y^K} = \mathbf{L^K}\mathbf{y^K} \tag{35}$$

while the sums of its columns are called production multipliers or input-output multipliers:

$$\alpha_j = \sum_{i=1}^{j} \alpha_{ij} \tag{36}$$

which indicate the increase in production in the entire economic system resulting from a unit increase in final demand for products of type j.

Similarly, based on the direct import intensity coefficients, we can determine the coefficients of total import intensity as:

$$\mathbf{L^M} = \mathbf{A^M}\mathbf{L^K} \tag{37}$$

Since multipliers are the derivative of an endogenous variable with respect to an exogenous variable, their determination in the case of linear models poses no difficulty, as they are constants. In the case of nonlinear models, however, their determination may be more complex. Therefore, in practice, multiplier analysis is reduced to conducting simulations and examining the reactions of endogenous variables to the occurrence of disturbances.

2.6. Coefficients describing production and imports of individual sectors

The determination of coefficients characterizing the production and imports of individual sectors requires the calculation of the appropriate cost coefficient matrices A and AK, as well as the matrix AM of direct import intensity coefficients of production. Since the cost coefficients a_{ij}, recorded in matrix **A** represent the share of total intermediate costs of type i – both domestic and imported – in the supply of domestic and imported products of sector j, the interpretation of the model in the form without separation of imports may raise doubts from an economic perspective, due to the assignment of costs incurred domestically simultaneously to domestic production and imports (Przybyliński, 2012). Therefore, when determining matrix **A**, it was taken into account that the costs given in the numerator serve exclusively to generate domestic production, not imported products, and the following relation was used:

$$a_{ij} = \frac{x_{ij}}{X_j^K} \tag{38}$$

At the same time, the following condition is satisfied:

$$a_{ij} = a_{ij}^K + a_{ij}^M \tag{39}$$

The sum of the elements forming the j-th column is equal to the material intensity coefficient of that sector:

$$\sum_{i=1}^{n} a_{ij} = \frac{\sum_{i=1}^{n} x_{ij}}{X_j} = \alpha_j \tag{40}$$

This formulation ensures that the coefficients reflect the true material intensity of each sector, linking intermediate inputs directly to the scale of domestic production.

2.7. Labor inputs

Input-output tables also allow for the analysis of employment costs, which, together with taxes, depreciation of fixed assets, and operating surplus, constitute the gross value added of production. The relationship between the employment costs of sector j and production outputs is defined by the labor intensity coefficients of that sector, denoted by w_j and defined as:

$$c_j = \frac{C_j}{X_j^K} \qquad i, j = 1,2,\dots,n \tag{41}$$

where:

C_j – employment costs in sector j,

X_j^K – domestic total production of sector j.

The analysis of labor inputs was carried out on the basis of the input-output table with separation of imports, since employment costs relate exclusively to domestic production. The coefficients c_j are defined analogously to the coefficients of direct material inputs, and the total value of factor inputs is expressed by the vector equation:

$$\mathbf{C} = \mathbf{c}^{\mathbf{T}}\mathbf{x}^{\mathbf{K}} = \hat{\mathbf{c}}\,\mathbf{x}^{\mathbf{K}} \tag{42}$$

where:

$\mathbf{C}$ – vector with elements C_j,

c – vector of direct factor input coefficients (production results),

$\hat{\mathbf{c}}$ – diagonal matrix derived from vector c with elements c_j,

$\mathbf{x}^{\mathbf{K}}$ – vector of domestic total production of sector j.

Substituting into the equation:

$$\mathbf{x}^{\mathbf{K}} = (\mathbf{I} - \mathbf{A}^{\mathbf{K}})^{-\mathbf{1}}\,\mathbf{y}^{\mathbf{K}} \tag{43}$$

we obtain:

$$\mathbf{C} = [\hat{\mathbf{c}}(\mathbf{I} - \mathbf{A}^{\mathbf{K}})^{-\mathbf{1}}]\mathbf{y}^{\mathbf{K}} \tag{44}$$

In the above formula, the magnitude of employment-related inputs depends on the level of final demand.

2.8. Price model

Input-output tables also make it possible to conduct simulations of the economy's sensitivity to changes in the prices of imported products, based on the price model (Miller, Blair, 2009), According to this model, the scale of the impact of import prices on domestic prices results from the import intensity of individual sectors and the mutual raw-material – product linkages between them. The foundation of the price model is the cost equation:

$$\hat{\mathbf{x}}\mathbf{A}^{\mathbf{T}}\mathbf{i} + \mathbf{d} = \mathbf{x} \tag{45}$$

where:

$\mathbf{x}$ – vector of total production,

$\hat{\mathbf{x}}$ – diagonal matrix derived from vector $\mathbf{x}$,

$\mathbf{A}^{\mathbf{T}}$ – transposed cost coefficient matrix,

$\mathbf{d}$ – value added of production.

Applying the transformations described in the works, (Przybyliński, 2012; Herczakowska, 2016, 2020) the final price equation for an open economy takes the form:

$$\mathbf{p}^{\mathbf{K}} = \mathbf{\Pi}^{\mathbf{M}}\mathbf{p}^{\mathbf{M}} + (\mathbf{L}^{\mathbf{K}})^{\mathbf{T}}\mathbf{v} \tag{46}$$

where:
$\mathbf{p^K}$ – vector of domestic prices,
$\mathbf{p^M}$ – vector of import prices,
$\mathbf{\Pi^M p^M} + (\mathbf{L^K})^{\mathbf{T}}\mathbf{v}$ – multiplier matrix expressing changes in domestic prices under the influence of changes in import prices,
$\mathbf{\Pi^M} = (\mathbf{L^K})^{\mathbf{T}} \cdot (\mathbf{A^M})^{\mathbf{T}} = \left[\pi_{ij}^{M}\right]$ – matrix expressing the magnitude of the change in the domestic price of sector *i* resulting from a unit change in the price of imported products of sector j.

From the input-output tables, we can also read the initial share of imports m in total supply for product group i:

$$S_i = \frac{m}{x^K + m} \tag{47}$$

where:
S_i – share of imports in supply for product group *i*,
m – volume of imports for product group *i*,
x^K – domestic total production of sector *i*.

Furthermore, by including production volume in the price equation in the form of vector $\dot{\mathbf{x}}^{\mathbf{K}}$:

$$\dot{x}_i^K = \frac{x_i^K}{\sum_{i=1}^{n} x_i^K} \tag{48}$$

we obtain the equation:

$$\boldsymbol{\pi}^{\mathbf{M}} = (\mathbf{\Pi^M})^{\mathbf{T}}\dot{\mathbf{x}}^{\mathbf{K}} \tag{49}$$

which allows simulations of how an increase in the price of a given product group will affect domestic prices. Domestic price multipliers indicate which product group changes the economy is particularly sensitive to.

2.9. Materials

The basis for the analyses conducted in this publication were the Input-Output Balances in current basic prices published by the Central Statistical Office (GUS, 2009, 2014, 2019, 2024). In the analyzed period, covering the years 2005, 2010, 2015, and 2020, for which input-output tables were prepared, changes occurred in the PKD and PKWiU classifications. As a result, the 2009 balance presented the Polish economy divided into 55 sectors, while in subsequent balances this number increased to 77. Consequently, it was necessary to systematize the data to enable a consistent comparative analysis.

Given the scope of the research, the data were aggregated into ten sectors listed below, while retaining, in disaggregated form, those sectors of particular interest for this publication (Hard coal and lignite; peat, as well as Crude oil and natural gas, metal ores, and other mining products):

1. Agricultural and hunting products, forestry, fishing, and aquaculture.
2. Hard coal and lignite; peat.
3. Crude oil and natural gas, metal ores, other mining products.
4. Light industry.
5. Chemical industry.
6. Metallurgical industry.
7. Electromechanical and high-technology industry.
8. Electricity, gas, steam, and hot water.
9. Construction and water collection, treatment, and distribution.
10. Service activities.

The tables obtained through aggregation and calculations became the basis for further analyses, covering both the structure of the economy and the impact of changes in energy resource prices on other sectors. Due to their extensive form, a full presentation of the matrices in this work is not possible; instead, the main stages of model construction and the most important results of the conducted research are presented.

3. Results

Based on the conducted research and the calculations of coefficients characterizing the Polish economy, the directions of their changes in the years 2005-2020 were determined. Particular attention was devoted to assessing the impact of energy resource prices on the structure of the economy and the mechanisms of its functioning. The analysis covered material intensity coefficients, import intensity coefficients, and production multipliers, which make it possible to determine the degree of resource utilization and dependence on foreign supplies. The share of imports in the structure of inputs was also taken into account, enabling an assessment of the economy's sensitivity to external factors. Another area of research concerned labor inputs, indicating the intensity of human resource utilization in individual sectors. A key element of the study was the price multipliers, showing how changes in the prices of energy and other raw materials affect the entire economy. The analysis is complemented by the price model, which serves as a tool for evaluating inter-industry mechanisms of price formation under the influence of fluctuations in energy markets.

3.1. Material intensity of the Polish economy

The analysis of the material intensity of the Polish economy can be carried out using the material intensity coefficient, which in input-output analysis defines how many material resources (raw materials, energy, semi-finished products) must be consumed in order to produce one unit of output in a given sector of the economy. The higher the value of the coefficient, the greater the sector's dependence on material inputs.

Thus, material intensity is the relationship between the quantity (or value) of materials consumed and the value of production. In the input-output model, this coefficient reflects the material inputs per unit of total production and enables an assessment of resource use efficiency, while also identifying sectors that are highly dependent on raw materials and those with lower material intensity. Moreover, it highlights potential risks associated with rising raw material prices – the higher the material intensity, the greater the economy's sensitivity to changes in energy or raw material prices.

Table 1.
Changes in material intensity coefficients in the Polish economy, 2005-2020

Industrial branch	Material intensity coefficient value			
	2005	2010	2015	2020
agricultural, hunting, forestry and fishing products	0.520	0.540	0.590	0.585
hard coal, lignite, and peat	0.340	0.340	0.400	0.437
crude oil, natural gas, metal ores, and other mining raw materials	0.380	0.490	0.510	0.489
light industry (textiles, apparel, consumer goods)	0.750	0.740	0.730	0.748
chemical industry	0.750	0.750	0.730	0.715
metallurgical industry (ferrous and non-ferrous metals)	0.700	0.730	0.690	0.674
electromechanical and high-technology industries	0.750	0.770	0.720	0.726
electricity, gas, steam, and hot water supply	0.630	0.560	0.560	0.478
construction, water abstraction, treatment, and distribution	0.620	0.620	0.590	0.624
service activities	0.400	0.410	0.410	0.410

Source: author's own work.

Table 1 presents changes in the material intensity coefficient over the analyzed period, while Figure 4 illustrates the trends by focusing on the extreme years.

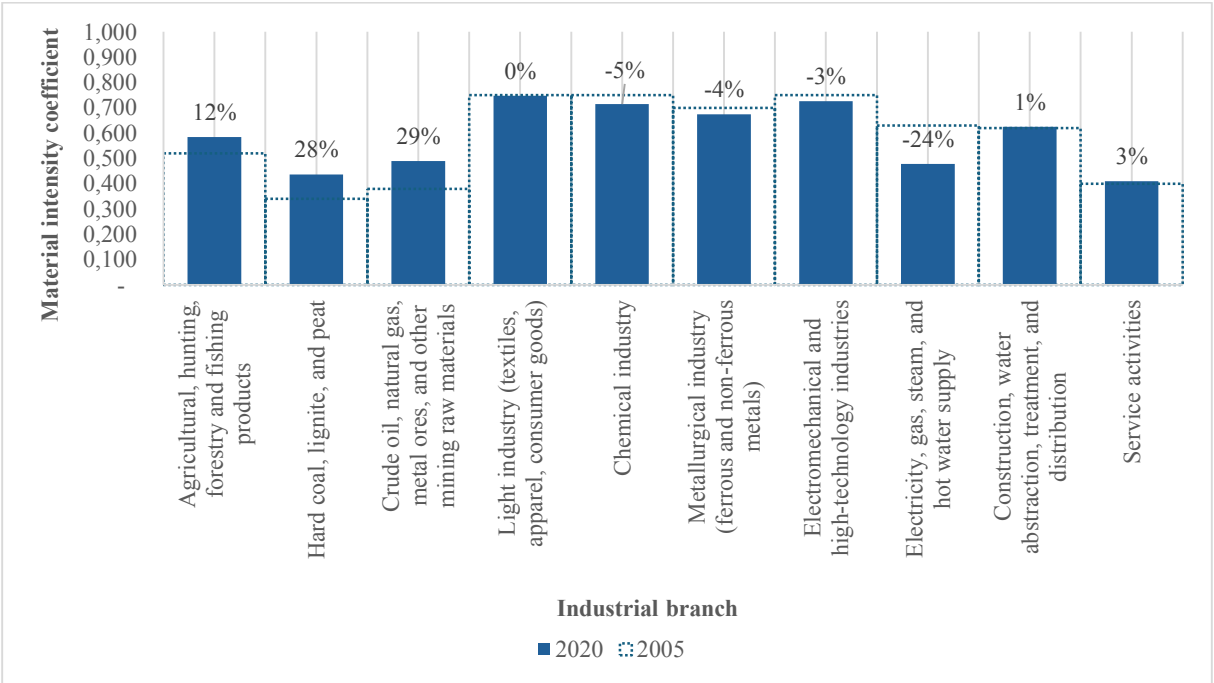


Figure 4. Material intensity coefficient and its changes in the Polish economy in 2005 and 2020.
Source: author's own work.

Based on the presented results, several characteristic trends can be observed across individual sectors:

- Agriculture, forestry, and fisheries – the coefficient increased from 0.520 in 2005 to 0.590 in 2015, then slightly declined to 0.585 in 2020. This indicates a gradual rise in resource use intensity, with slight stabilization in recent years.
- Hard coal, lignite, and peat – values increased systematically (from 0.340 to 0.437), pointing to higher material intensity in the mining sector.
- Crude oil, natural gas, and metal ores – the coefficient rose to 0.510 in 2015, then fell to 0.489 in 2020, suggesting improved efficiency or changes in production structure.
- Light industry – values remained stable (around 0.74-0.75), reflecting a consistent level of material use.
- Chemical industry – a slight decrease of about 5%, indicating improved material efficiency.
- Metallurgical industry – minor fluctuations with a downward trend (from 0.700 to 0.674), possibly reflecting modernization of production processes.
- Electromechanical and high technology industry – values oscillated between 0.72-0.77, with no clear trend, suggesting stable material intensity.
- Energy sector (power plants, gas, steam, hot water) – a marked decline from 0.630 in 2005 to 0.478 in 2020, indicating improved efficiency and technological changes in the sector.
- Construction and water management – values remained stable, with a slight increase in 2020 (0.624), reflecting rising material inputs in infrastructure.
- Services – the coefficient remained virtually unchanged (0.400-0.410), confirming the low material intensity of this sector.

In summary, the most material intensive sectors remain the chemical, electromechanical, and light industries, though signs of stabilization or decline are visible. The energy sector stands out for its significant efficiency improvements, while services maintain a low level of material intensity. In contrast, the coal mining sector shows increasing material burdens, which is particularly important in the context of the economy's sensitivity to changes in energy resource prices.

3.2. Import intensity of the Polish economy

The import intensity coefficient is a measure showing the extent to which production in a given sector of the economy, or in the economy as a whole, relies on goods and services originating from imports. A high value of the coefficient indicates strong dependence on foreign supplies, while a low value points to greater self-sufficiency and reliance on domestic resources.

In the input-output model, import intensity is defined as the share of imported goods and services in the total production inputs of a sector. This indicator makes it possible to determine the degree of the economy's dependence on external sources of supply and to identify the sectors most vulnerable to external shocks, such as increases in raw material prices on global markets or disruptions in supply chains.

It is of particular importance in studies on energy and resource security, as it highlights the branches of the economy that cannot function without imports. The interpretation of the coefficient is relatively straightforward: high import intensity means that a significant share of production inputs comes from abroad, while low import intensity indicates the dominance of domestic resources.

Table 2.
Changes in import intensity coefficients in the Polish economy, 2005-2020

Industrial branch	Import intensity coefficient value			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	4%	6%	9%	9%
Hard coal, lignite, and peat	3%	5%	7%	5%
Crude oil, natural gas, metal ores, and other mining raw materials	3%	9%	13%	8%
Light industry (textiles, apparel, consumer goods)	15%	17%	17%	17%
Chemical industry	34%	38%	34%	32%
Metallurgical industry (ferrous and non-ferrous metals)	22%	23%	23%	24%
Electromechanical and high-technology industries	33%	31%	29%	31%
Electricity, gas, steam, and hot water supply	12%	13%	12%	12%
Construction, water abstraction, treatment, and distribution	9%	8%	10%	10%
Service activities	4%	6%	6%	7%

Source: author's own work.

As before, changes in the import intensity coefficient throughout the entire analyzed period are presented in Table 2, while the graphical presentation of the data (Figure 5) illustrates the trends between 2005 and 2020.

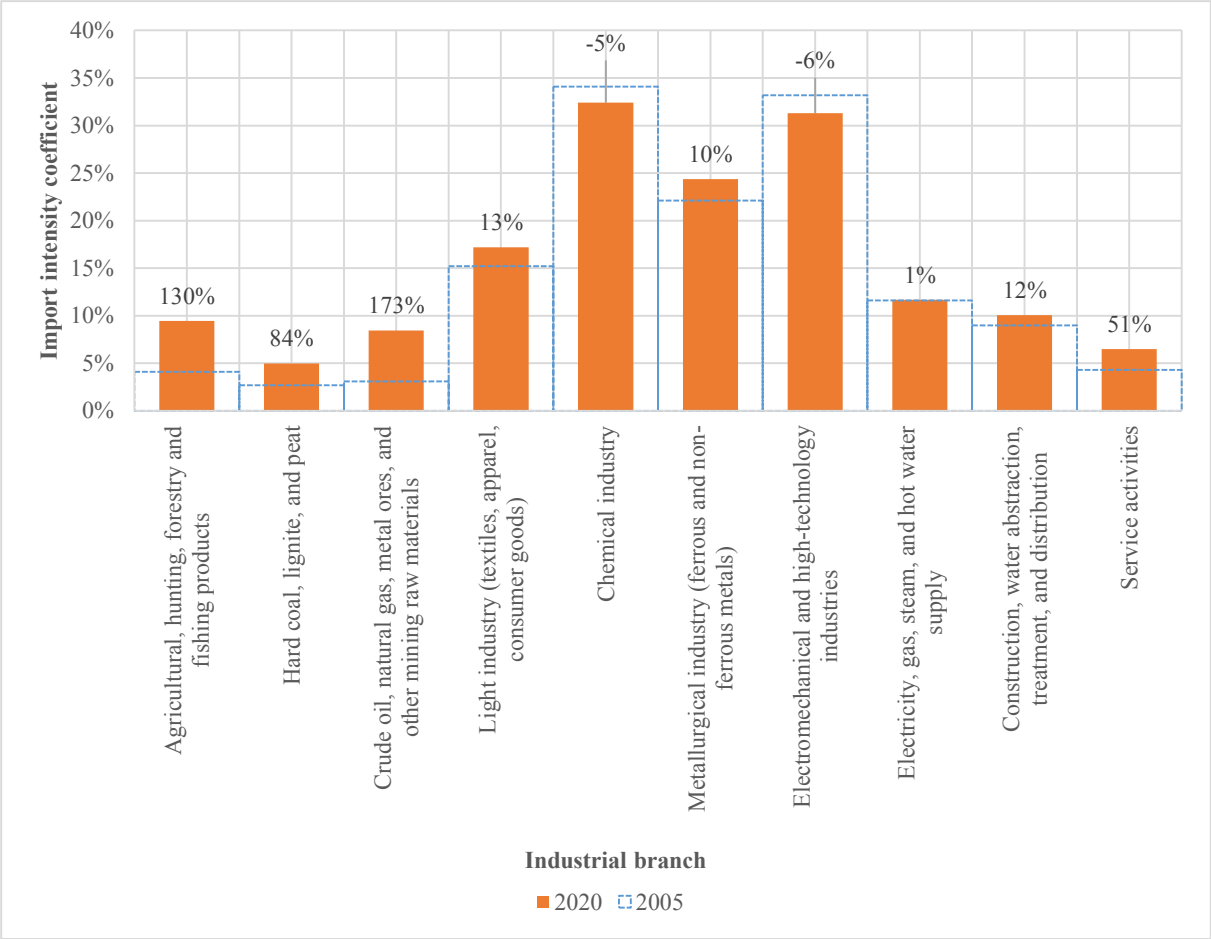


Figure 5. Import intensity coefficient and its changes in the Polish economy in 2005 and 2020.
Source: author's own work.

The analysis of changes in import intensity in the Polish economy between 2005 and 2020 reveals several key tendencies across individual sectors:

- Agriculture, forestry, and fisheries – the coefficient rose from 4% in 2005 to 9% in 2015, and then remained at this level. This indicates the growing importance of imported inputs in a sector traditionally based on domestic resources.
- Hard coal, lignite, and peat – values increased until 2015 (7%), then declined to 5% in 2020, which may suggest reduced imports and greater reliance on domestic resources.
- Crude oil, natural gas, and metal ores – the coefficient reached its peak in 2015 (13%), then fell to 8% in 2020. This trend reflects the variable dependence on imported energy and metallic raw materials.
- Light industry – values remained stable (15-17%), indicating a persistent reliance on imported materials and semi finished products.
- Chemical industry – the highest coefficients in the entire economy (32-38%), confirming strong dependence on imported petroleum based raw materials and chemicals.

- Metallurgical industry – stable values (22-24%) at a high level, indicating lasting dependence on imported ores and metals.
- Electromechanical and high technology industry – a slight decline from 33% in 2005 to 29% in 2015, followed by a return to 31% in 2020. This shows a consistently high, though somewhat variable, reliance on imported components.
- Energy sector (power plants, gas, steam, hot water) – stable values (12-13%), pointing to a moderate but steady dependence on imports.
- Construction and water management – minor fluctuations (8-10%), suggesting a limited role of imports in this sector.
- Services – the coefficient increased from 4% to 7%, but remained at a low level, confirming the dominance of domestic resources and limited exposure to imports.

In summary, the most import intensive sectors remain the chemical, electromechanical, and metallurgical industries, which rely heavily on foreign raw materials and components. Agriculture and services, despite traditionally low dependence on imports, show a gradual increase in the coefficient, which may indicate growing integration with international markets. Meanwhile, the energy and construction sectors maintain a moderate, stable dependence on imports.

3.3. Production multipliers – the impact of individual sectors on the economy

The total output multiplier is an indicator that shows how much total production in the economy will increase in response to a unit increase in final demand in a given sector. In other words, it measures the strength of one sector's impact on other branches of the economy through inter‑industry linkages.

The mechanism of the multiplier effect is based on indirect and induced effects. An increase in demand in one sector leads to higher production in that sector, which in turn requires the purchase of additional goods and services from other sectors. These sectors also raise their production levels to supply the necessary inputs, triggering further rounds of the multiplier effect. As a result, the initial impulse in one sector spreads throughout the economy, generating a total increase in production greater than the original stimulus (Miller, Blair, 2009). The interpretation of the multiplier's value is as follows: if its value equals 1, this indicates no indirect effects – production increases only in the analyzed sector. Values greater than 1 show that the sector generates additional impulses in other branches of the economy. The higher the multiplier, the stronger the inter-industry linkages and the greater the importance of the given sector for the development of the entire economy.

Total output multipliers make it possible to identify key sectors with the greatest impact on the economy, highlight areas where investments or support may yield the largest multiplier effects, and enable analysis of the economy's sensitivity to changes in final demand – whether stemming from exports, consumption, or investment.

Table 3.
Changes in total output multipliers in the Polish economy, 2005–2020

Industrial branch	Total output multiplier value			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	2.240	2.300	2.460	2.417
Hard coal, lignite, and peat	1.810	1.820	1.920	1.967
Crude oil, natural gas, metal ores, and other mining raw materials	1.850	2.120	2.120	2.068
Light industry (textiles, apparel, consumer goods)	2.780	2.770	2.770	2.802
Chemical industry	2.690	2.760	2.720	2.656
Metallurgical industry (ferrous and non-ferrous metals)	2.750	2.900	2.700	2.638
Electromechanical and high-technology industries	2.940	3.070	2.840	2.838
Electricity, gas, steam, and hot water supply	2.290	2.200	2.230	2.043
Construction, water abstraction, treatment, and distribution	2.520	2.540	2.450	2.530
Service activities	1.870	1.900	1.870	1.862

Source: author's own work.

Changes in production multipliers during 2005-2020 are shown in Table 3, with Figure 6 highlighting the trends between 2005 and 2020.

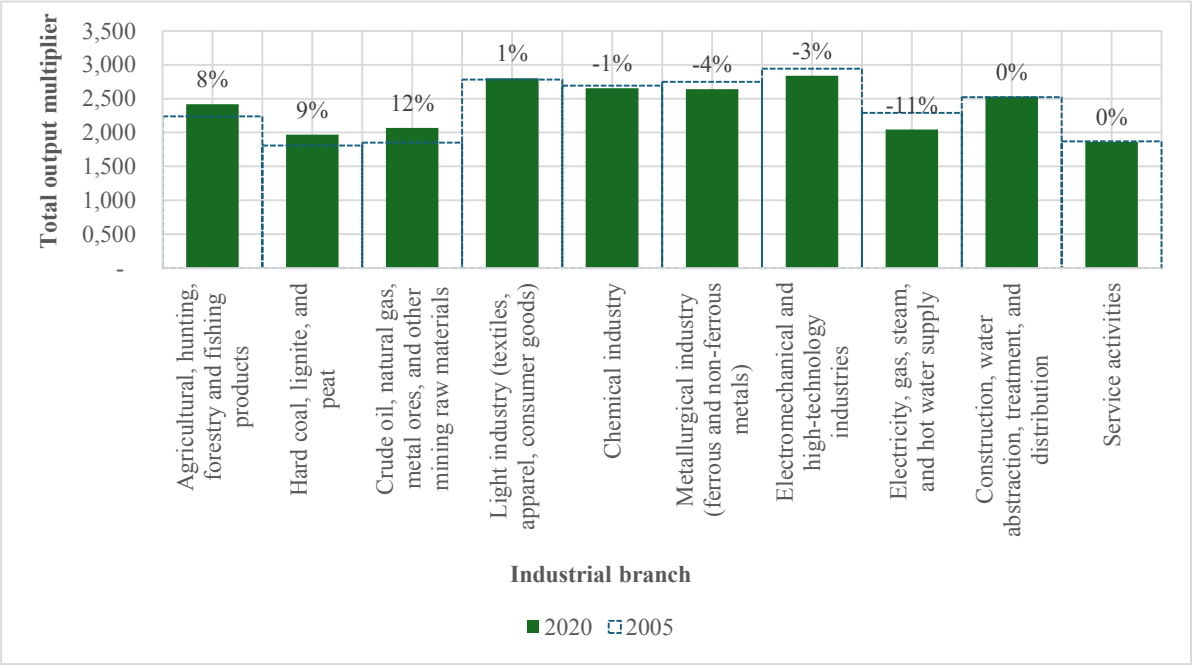


Figure 6. Total output multiplier and its changes in the Polish economy in 2005 and 2020.
Source: author's own work

Based on the calculated production multipliers, the following tendencies can be observed in the analyzed sectors of the economy:

- Agriculture, forestry, and fisheries – the multiplier increased from 2.240 in 2005 to 2.460 in 2015, then slightly declined to 2.417 in 2020. This indicates growing but stabilizing inter industry linkages.
- Hard coal, lignite, and peat – values rose systematically (from 1.810 to 1.967), pointing to a gradual strengthening of multiplier effects in this sector.

- Crude oil, natural gas, and metal ores – a clear increase until 2010 (2.120), maintained in subsequent years, reflecting the strong influence of the resource sector on other branches of the economy.
- Light industry – values remained stable (around 2.77-2.80), suggesting durable and relatively high linkages with other sectors.
- Chemical industry – minor fluctuations with a downward tendency in 2020 (2.656), which may indicate partial efficiency improvements or structural changes in inputs.
- Metallurgical industry – the highest values in 2010 (2.900), followed by a decline to 2.638 in 2020, suggesting a weakening of multiplier effects in this sector.
- Electromechanical and high technology industry – the highest multipliers in the entire economy (3.070 in 2010), consistently remaining at a high level, confirming the strategic importance of this sector for economic development.
- Energy sector (power plants, gas, steam, hot water) – values declined from 2.290 in 2005 to 2.043 in 2020, reflecting technological modernization and the gradual reduction of this sector's linkages with others, resulting from improved energy efficiency and increasing diversification of energy sources.
- Construction and water management – stable values (around 2.45-2.53), indicating the lasting importance of the infrastructure sector in multiplier effects.
- Services – multipliers remained at a low level (around 1.87-1.90), confirming weaker linkages with other branches of the economy.

The electromechanical and high technology industry achieves the highest total output multipliers, showing its particularly significant role in driving overall economic development – its growth strongly stimulates other sectors. High multipliers are also observed in the chemical, metallurgical, and light industries, though a gradual decline has been noted in recent years. In contrast, the energy sector and services exhibit relatively low multipliers, meaning their influence on other branches of the economy is limited. In the context of this article, this implies that changes in energy resource prices do not remain confined to the energy sector but spread throughout the economy, affecting production, prices, and employment in other industries.

3.4. Labor inputs in the Polish economy

Labor inputs constitute one of the fundamental elements of economic analysis in the input-output framework. They refer to the total amount of human labor engaged in production processes within a given sector or across the entire economy. This indicator makes it possible to determine how intensively individual branches utilize labor resources and what their interconnections with other sectors are.

The analysis of labor inputs enables the assessment of employment structure, productivity, and the impact of changes in final demand on the labor market.

Table 4.
Changes in labor input coefficients in the Polish economy, 2005-2020

Industrial branch	Labor input coefficient value			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	0.090	0.070	0.100	0.076
Hard coal, lignite, and peat	0.450	0.450	0.440	0.534
Crude oil, natural gas, metal ores, and other mining raw materials	0.240	0.230	0.270	0.243
Light industry (textiles, apparel, consumer goods)	0.130	0.120	0.120	0.129
Chemical industry	0.100	0.090	0.100	0.124
Metallurgical industry (ferrous and non-ferrous metals)	0.140	0.140	0.140	0.167
Electromechanical and high-technology industries	0.130	0.130	0.130	0.150
Electricity, gas, steam, and hot water supply	0.130	0.140	0.110	0.123
Construction, water abstraction, treatment, and distribution	0.140	0.140	0.140	0.134
Service activities	0.230	0.240	0.250	0.272

Source: author's own work.

Table 4 presents the values of the labor input coefficient for individual sectors of the economy, while their graphical representation is shown in Figure 7. In most sectors, we observe moderate stability of labor input coefficients, with only slight fluctuations over time. Clear increases occurred in coal mining, services, and in the chemical and metallurgical industries, whereas sectors such as agriculture or light industry show fluctuations without a lasting upward trend.

Since this indicator shows what share of production in a given sector relies on human labor, the following tendencies were observed in the analyzed area:

- Agriculture, forestry, and fisheries – values are variable: a decline from 0.090 in 2005 to 0.070 in 2010, then an increase to 0.100 in 2015, followed by another decline to 0.076 in 2020. This reflects fluctuations in labor intensity, likely linked to mechanization and modernization processes that reduced labor demand, but also temporarily increased it due to EU subsidies and transitional structural changes.
- Hard coal, lignite, and peat – the coefficient remained at a high level (around 0.45), rising to 0.534 in 2020. This reflects difficulties in the sector—declining productivity, the need to maintain employment, and social and political pressure to preserve jobs.
- Crude oil, natural gas, and metal ores – values oscillated around 0.23–0.27, with a slight increase in 2015 and a decline in 2020. The sector remains moderately labor‑intensive, with fluctuations linked to global raw material price volatility and Poland's limited role as a producer of these resources.
- Light industry – stable values (around 0.12-0.13), suggesting a consistent level of employment relative to production.
- Chemical industry – a slight decline to 0.090 in 2010, followed by an increase to 0.124 in 2020, which may indicate greater importance of labor in production processes in recent years.

- Metallurgical industry – stable values until 2015 (0.140), then rising to 0.167 in 2020, suggesting growing labor intensity in the sector, resulting from the increasing importance of these branches in the economy, the development of chemical and pharmaceutical production, and modernization of metallurgy requiring additional technological support.
- Electromechanical and high-technology industry – stable values (0.130), with a clear increase to 0.150 in 2020, possibly reflecting greater importance of specialized labor.
- Energy sector (power plants, gas, steam, hot water) – minor fluctuations, with a decline to 0.110 in 2015 and a rise to 0.123 in 2020, possibly reflecting modernization processes and the development of new energy sources.
- Construction and water management – stable values (0.134-0.140), indicating a lasting employment structure in this sector.
- Services – systematic growth from 0.230 in 2005 to 0.272 in 2020, confirming the growing importance of the service sector in job creation and the natural effect of a market economy, in which services gradually assume a dominant role.

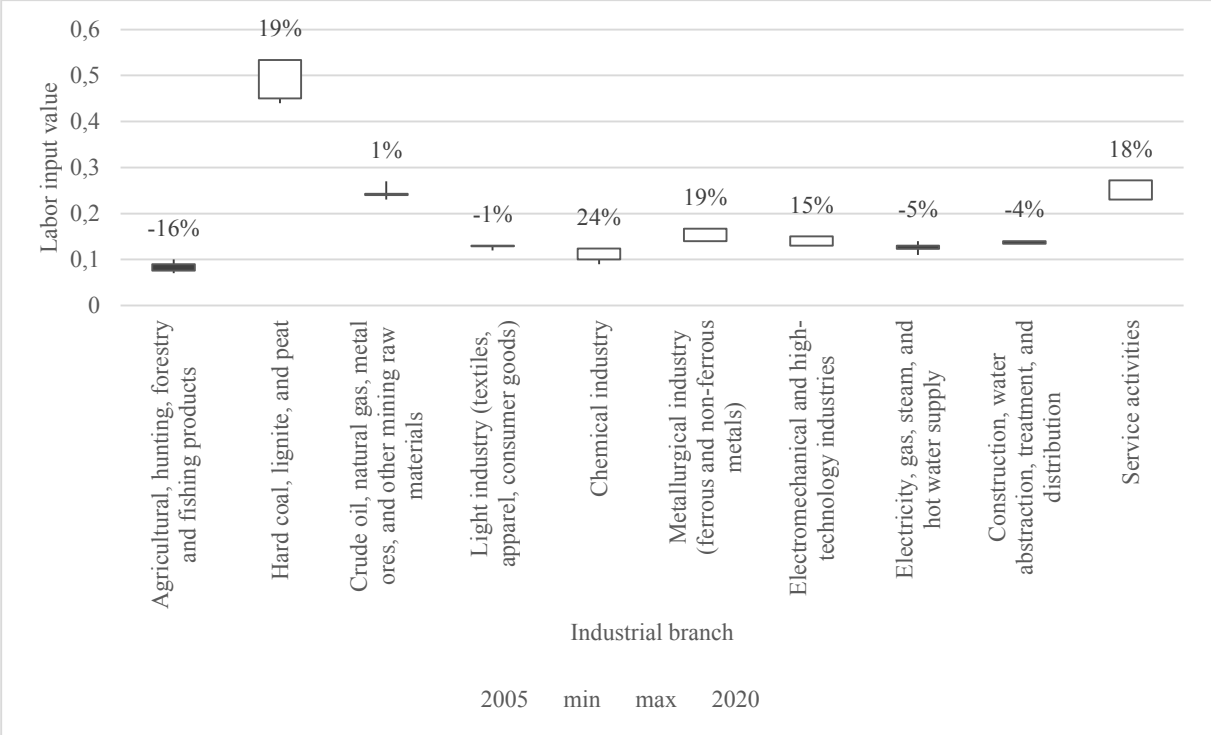


Figure 7. Labor input coefficients and its changes in the Polish economy, 2005-2020.

Source: author's own work.

The analysis of labor input coefficients indicates significant differentiation between individual sectors of the economy as well as clear changes over time. The average level for the entire economy remained relatively stable during the analyzed period, at around 0.18-0.20, which corresponds to labor costs of approximately 180-200 thousand PLN per 1 million PLN of production.

The highest values were consistently recorded in mining (hard coal, lignite, and peat), where the labor input coefficient was around 0.45 in 2005-2015 and rose to 0.534 in 2020. This means that labor costs accounted for more than half of the production value in this sector, making mining the most labor‑intensive branch of the economy. Such a high share of employment costs results both from occupational risk and from organizational specifics as well as historical wage conditions.

In summary, between 2005 and 2020 the structure of labor inputs in the Polish economy showed relative stability, but with clear sectoral differences. Mining remains the most labor-intensive sector, while services and high-technology industries gradually increase their share of labor costs. Agriculture and energy, on the other hand, benefit from modernization effects, which reduce the intensity of labor inputs.

3.5. Price model in the Polish economy

Price analysis within the input-output methodology is based on Leontief's concept, which assumes that the economy is a system of mutually interconnected production sectors. Each sector produces goods and services while simultaneously using the products of other sectors as inputs. In this framework, prices are not treated solely as the outcome of supply and demand, but rather as the result of the technological structure of the economy and the cost relations between individual branches.

The input-output price model makes it possible to trace how changes in the costs of production factors – such as labor, capital, or raw materials – spread throughout the entire economic system and affect final prices. In particular, it enables:

- determining the share of individual inputs in shaping production prices,
- analyzing indirect effects, i.e., the impact of costs in one sector on prices in others,
- studying the consequences of technological and structural changes for price levels,
- assessing the impact of economic policy (e.g., taxes, subsidies, energy regulations) on costs and prices across different industries.

Introducing the price model into input-output analysis is crucial for understanding inflationary mechanisms and for assessing the competitiveness of the economy. This tool captures not only the direct effects of cost increases in a given sector but also their diffusion throughout the entire economic system (Miller, Blair, 2009).

The analysis of import shares in the input-output model allows us to capture the degree of dependence of individual sectors of the economy on foreign supplies. Data from 2005-2020 (Table 5) show clear differences between industries – from sectors almost entirely reliant on imports to those based mainly on domestic resources. Among the sectors with a growing importance of imports, we can distinguish:

- Agriculture and agricultural products, where the share of imports rose from 8.7% in 2005 to 17.4% in 2020. This indicates the increasing presence of foreign agricultural products on the Polish market, resulting from EU integration, trade liberalization, and rising demand for goods unavailable in domestic production.
- Light industry (clothing, textiles, consumer goods), where a systematic increase in import share to 27.5% in 2020 reflects the relocation of production to countries with lower labor costs and the dominance of imported consumer goods.
- Chemical and metallurgical industries, both showing a stable but high import share (around 33-39%), due to the need to import raw materials and semi‑finished products not sufficiently available domestically.
- Electromechanical and high‑technology industry, where the import share rose to over 46% in 2020, showing strong dependence on foreign components and technologies, particularly in electronics and IT.

Among the sectors highly dependent on imported raw materials are:

- Crude oil, gas, and metal ores, where the import share remained very high (around 78%), dropping only in 2020 to 69%. Poland is largely dependent on foreign supplies here, and the decline in the last year may reflect diversification of sources,
- Hard coal and lignite, with an initially low import share (3.4% in 2005), but a sharp increase to over 18% in 2010 and 2020. This points to the growing importance of imported coal despite large domestic reserves, linked to extraction costs and the price competitiveness of foreign coal.

In the remaining sectors – Energy (electricity, gas, heat), Construction and water management, and Services – the share of imports remains very low.

Table 5.
Changes in import share in the Polish economy, 2005-2020

Industrial branch	Import share value			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	8.70%	12.20%	16.45%	17.38%
Hard coal, lignite, and peat	3.40%	18.50%	12.24%	18.38%
Crude oil, natural gas, metal ores, and other mining raw materials	78.80%	79.10%	78.01%	69.03%
Light industry (textiles, apparel, consumer goods)	18.30%	22.80%	25.51%	27.48%
Chemical industry	35.60%	34.30%	36.51%	39.13%
Metallurgical industry (ferrous and non-ferrous metals)	30.90%	32.20%	31.93%	33.28%
Electromechanical and high-technology industries	43.60%	43.10%	43.93%	46.25%
Electricity, gas, steam, and hot water supply	0.50%	1.10%	2.07%	2.96%
Construction, water abstraction, treatment, and distribution	1.20%	1.40%	2.27%	1.57%
Service activities	2.60%	3.80%	4.53%	4.88%

Source: author's own work.

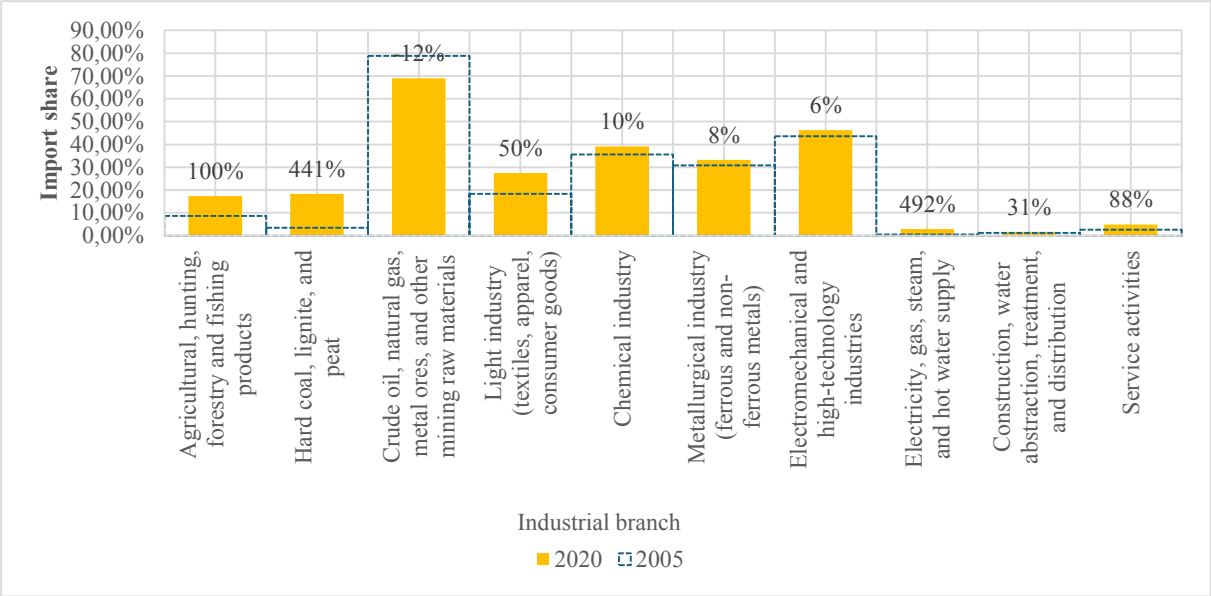


Figure 8. Import share and its changes in the Polish economy in 2005 and 2020.

Source: author's own work.

Figure 8 illustrates that between 2005 and 2020 the Polish economy strengthened its integration with global markets. Industrial and consumer sectors became increasingly import-dependent, while resource-based and high-technology industries show the highest vulnerability to external supply shocks. In contrast, construction, energy, and services continue to rely predominantly on domestic inputs, underscoring their relative resilience.

Table 6.

The impact of rising oil and natural gas prices on domestic product prices, 2005-2020

Reaction – sectoral price changes	Impulse - an increase in oil and natural gas prices by one unit (100%)			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	1.70%	1.96%	1.58%	1.01%
Hard coal, lignite, and peat	1.40%	1.63%	1.71%	1.31%
Crude oil, natural gas, metal ores, and other mining raw materials	1.90%	5.62%	8.44%	2.60%
Light industry (textiles, apparel, consumer goods)	1.70%	1.61%	1.09%	0.90%
Chemical industry	18.00%	21.42%	16.79%	12.96%
Metallurgical industry (ferrous and non-ferrous metals)	4.30%	4.37%	3.51%	3.12%
Electromechanical and high-technology industries	1.30%	1.95%	1.33%	0.97%
Electricity, gas, steam, and hot water supply	10.00%	10.56%	7.83%	8.92%
Construction, water abstraction, treatment, and distribution	3.30%	3.69%	2.51%	1.95%
Service activities	1.10%	1.26%	0.80%	0.58%

Source: author's own work.

Since crude oil, natural gas, and related raw materials account for the largest share of imports, it was assumed that the Polish economy is most sensitive to price changes in this group of resources. Therefore, simulations were conducted to examine how changes in the prices of these products would affect the Polish economy if their price increased by one unit. Detailed results are presented in Table 6. In addition, a graphical illustration of the sensitivity of domestic production sector prices to changes in the prices of imported crude oil and natural gas for the year 2020 is shown in Figure 8.

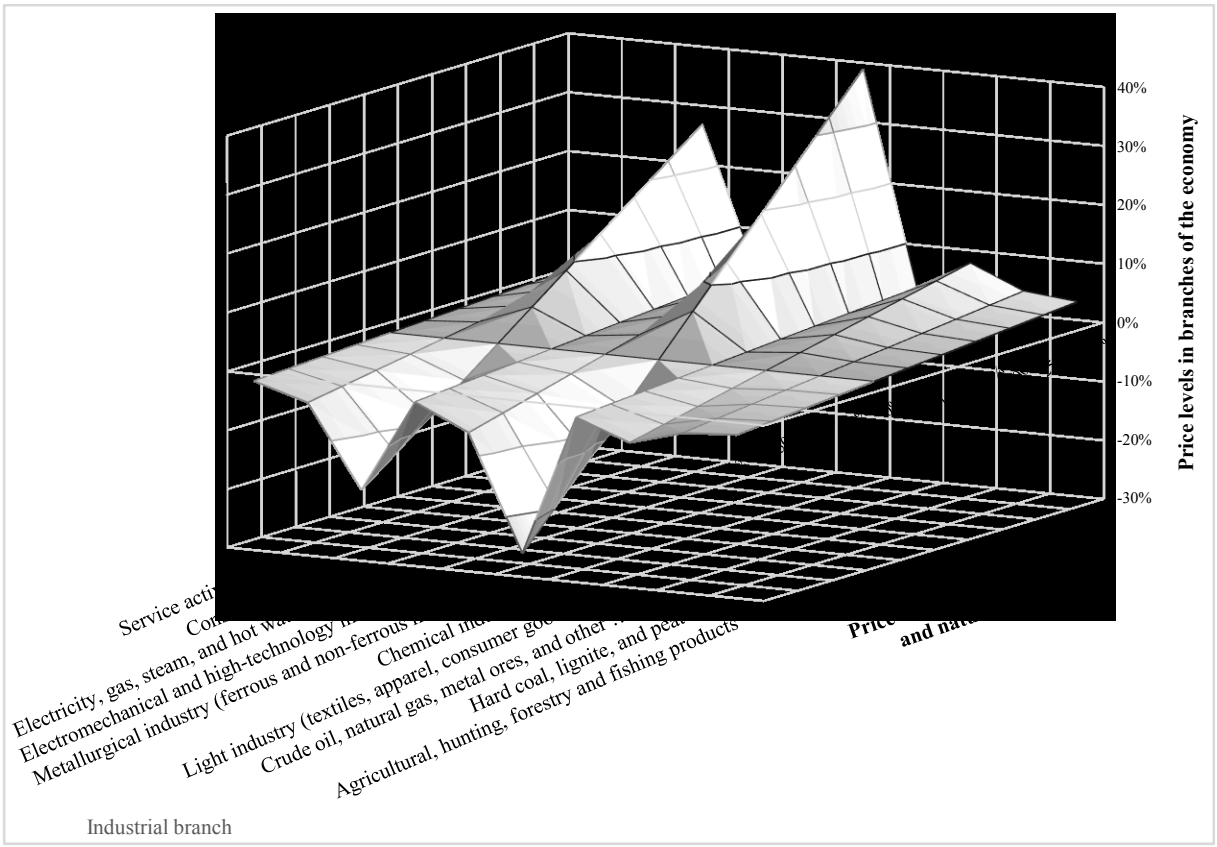


Figure 9. Price sensitivity of domestic production sectors to changes in imported crude oil and natural gas prices.

Source: author's own work.

Figure 9 presents a three‑dimensional simulation of the impact of price changes in two key energy resources – crude oil and natural gas (Z-axis) – on price levels in different branches of the economy (Y-axis), broken down by sectors (X-axis). The analysis makes it possible to assess which sectors are most vulnerable to fluctuations in the prices of these resources and how the intensity of this impact changes depending on the scale of the price impulse.

The greatest price sensitivity is observed in industrial sectors with high energy intensity and strong linkages to raw material markets: the chemical, metallurgical, and electromechanical industries. In these sectors, even a moderate increase in oil and gas prices (e.g., by 50-100%) translates into a significant rise in production costs – reaching several percentage points. In the case of sharp price changes, the effect in these branches may be even more pronounced, confirming their systemic vulnerability to such shocks. By contrast, service sectors and construction show lower direct price sensitivity, although with large changes in resource prices the effect becomes noticeable. This results from the indirect impact of energy costs on service prices, especially in transport, logistics, and operating costs.

Resource sectors such as coal mining, oil and gas extraction, and agriculture exhibit varied reactions. Coal mining and agriculture are relatively less sensitive to oil and gas price changes, which may stem from their local character and limited dependence on imported energy carriers.

The oil and gas extraction sector, however, reacts strongly, reflecting its direct linkage to market prices of these resources.

It is worth noting the non-linearity of price reactions – in many sectors the impact of changes in energy resource prices does not grow proportionally, but shows a threshold effect once certain levels are exceeded (e.g., a 100% price increase). This may result from transfer pricing mechanisms, long-term contracts, and technological constraints in adapting to new cost conditions.

For a complete picture of the phenomenon under study, it is also important to consider changes in price multipliers during the analyzed period (Table 7).

Table 7.
Changes in price multipliers in the Polish economy, 2005-2020

Industrial branch	Price multipliers			
	2005	2010	2015	2020
Agricultural, hunting, forestry and fishing products	0.466	0.534	0.604	0.624
Hard coal, lignite, and peat	0.074	0.232	0.097	0.118
Crude oil, natural gas, metal ores, and other mining raw materials	3.009	3.686	2.651	1.996
Light industry (textiles, apparel, consumer goods)	2.448	2.265	2.414	2.325
Chemical industry	5.180	5.330	5.519	5.318
Metallurgical industry (ferrous and non-ferrous metals)	2.913	2.894	2.965	3.036
Electromechanical and high-technology industries	4.102	4.762	4.742	4.812
Electricity, gas, steam, and hot water supply	0.027	0.001	0.075	0.085
Construction, water abstraction, treatment, and distribution	0.112	0.147	0.267	0.256
Service activities	1.666	2.619	2.786	3.372

Source: author's own work.

Table 7 and figure 10 shows the changes in price multipliers across different sectors of the Polish economy between 2005 and 2020. This indicator reflects how strongly price changes in a given sector affect prices throughout the economy via inter-industry linkages. The analysis of price multipliers reveals clear differences between sectors. The highest values are consistently observed in the chemical industry, the electromechanical and high-technology industries, and the metallurgical industry, highlighting their strategic importance in shaping prices across the entire economy. Agriculture and services show systematic growth, indicating their increasing influence on price formation. The largest decline in 2020 compared to the base year 2005 is observed in the sector crude oil, natural gas, metal ores, and other mining raw materials, while the most pronounced drop is in electricity, gas, steam, and hot water supply.

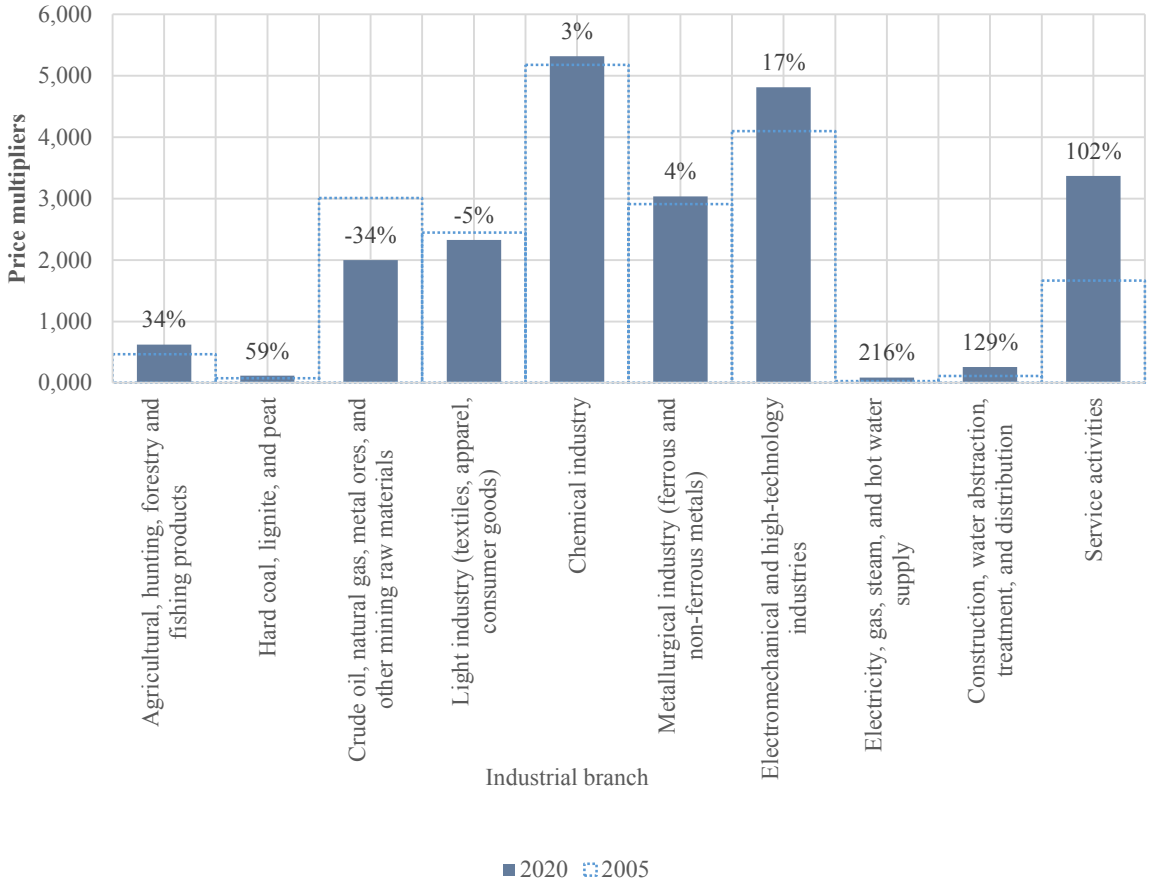


Figure 10. Price multipliers and its changes in the Polish economy in 2005 and 2020.
Source: author's own work.

Overall, the analysis indicates that the role of traditional raw materials in shaping price dynamics has diminished, while sectors such as chemicals, high technology, and services have become the primary drivers of cost transmission across the economy. This structural shift underscores the growing importance of knowledge-intensive and service-oriented industries in determining Poland's economic resilience to price shocks.

4. Discussion

The conducted analysis made it possible to capture the complex mechanisms of the Polish economy's sensitivity to changes in energy resource prices in the years 2005-2020. The results indicate that individual sectors differ in the intensity of multiplier effects, reflecting their position in the economic structure and the degree of inter-industry linkages. High multiplier values in the chemical, metallurgical, and electromechanical industries confirm that these sectors are particularly vulnerable to energy price fluctuations, and their strong connections with other branches cause price shocks to spread widely throughout the economy. In contrast,

stable, low values in services point to limited material intensity and lower direct exposure to raw material prices, although the growing role of services in the economy means that energy costs are gradually permeating this sector as well.

An important trend is the decline in multiplier values in the energy sector, which can be interpreted as the result of technological modernization, improved efficiency, and diversification of energy sources – also visible in statistical data on primary production and gross inland consumption. The reduction of energy sector linkages with other industries does not imply a loss of importance, but rather a change in the nature of its impact – from a traditional, material-intensive structure toward more efficient and sustainable solutions. These findings are consistent with broader observations pointing to the growing importance of energy transition and climate policy as factors shaping the economic structure.

The analysis of import intensity reveals an additional dimension of economic vulnerability. Sectors such as the chemical, electromechanical, and metallurgical industries remain heavily dependent on foreign raw materials and components, increasing the risk of transmitting price shocks from international markets. Agriculture and services, despite traditionally low import dependence, show a gradual increase in indicators, reflecting growing integration with global supply chains.

The results have important implications for economic policy. First, they highlight the need to strengthen the resilience of sectors most sensitive to energy price changes through diversification of sources, investment in energy efficiency, and the development of low-emission technologies. Second, they emphasize the importance of monitoring import intensity, especially in strategic sectors, to limit the risk of excessive dependence on foreign supplies. Third, the growing role of services in the economy requires incorporating energy costs into policies supporting the competitiveness of this sector.

At the same time, the limitations of the analysis must be underlined. The input-output model is static and based on aggregated data, which may conceal significant differences within individual sectors, as noted in other studies (Bunsen, Finkbeiner, 2023). Moreover, ending the analysis in 2020 does not account for subsequent shocks such as the COVID-19 pandemic or the energy crisis linked to the war in Ukraine, which significantly affected cost structures and economic linkages. An additional limitation is the delay in the publication of input-output tables by Statistics Poland (GUS), which reduces the timeliness of the results.

Future research should be expanded to include dynamic models and comparative analyses with other countries to better understand the specificity of the Polish economy in an international context. Incorporating microeconomic data would make it possible to capture distributional effects and assess how energy price changes affect different groups of enterprises and households.

5. Summary

The aim of the research presented in this publication was to analyze and assess the changes occurring in the Polish economy between 2005 and 2020, as well as to evaluate its sensitivity to energy resource price fluctuations using input-output tables. Based on these tables, changes and trends in material intensity, labor costs, and import dependence were identified. In view of the persistently high level of crude oil and natural gas imports, the study also examined how price fluctuations in these resources could affect the Polish economy.

The results show that sectors reacted differently to energy price fluctuations. Coal and electricity-related sectors had relatively low and unstable price multipliers, indicating a limited direct impact on the overall price level. However, it should be noted that the analyzed period does not cover the most recent years, marked by significant price volatility due to the COVID-19 pandemic and the war in Ukraine.

The study covering 2005-2020 reveals a clear structural shift in the Polish economy. The strongest production linkages and the highest price multipliers are found in the chemical, metallurgical, and electromechanical industries, which play a key role in transmitting price impulses throughout the economy. The high import intensity of these branches makes them particularly vulnerable to fluctuations in energy resource and component prices. Coal mining remains the most labor‑intensive sector, with labor costs accounting for more than half of production value. Services, on the other hand, show growing sensitivity to energy costs, indicating that price effects are gradually permeating wider areas of the economy.

Simulations demonstrate that increases in oil and gas prices hit hardest in the chemical industry, energy, and metallurgy. Sectors such as agriculture, light industry, and services respond more weakly, but their rising price multipliers indicate growing vulnerability to such shocks.

In summary, the Polish economy during the analyzed period remained strongly dependent on energy resource prices, with the greatest risk to price stability concentrated in energy-intensive and import‑dependent industries. At the same time, the growing role of services shows that the impact of energy on the economy is becoming increasingly widespread, extending beyond industry to the service sector.

Overall, the findings highlight a structural shift: the sensitivity of the Polish economy has moved away from traditional energy resources toward complex, energy‑intensive industrial sectors, while the rising importance of services demonstrates that energy price changes now affect a much broader spectrum of economic activity than in the past.

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ENERGY SECURITY AND EFFECTIVITY OF ENERGY COMPANIES

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Purpose: The purpose of the article is to empirically identify the effectivity of energy companies in crisis conditions. The aim was formulated based on a critical analysis of the literature and the identified gap.
Design/methodology/approach: The article focuses on the characteristics of energy security in terms of the need for effectivity of energy companies. The concept of energy security was defined, and the obligations of the energy company in the field of ensuring energy security in terms of effectivity were indicated. A literature review was then carried out and a research gap was identified. The research problem focused on answering the question: Does the crisis equally affect the effectivity achieved by energy companies, which determines their ability to ensure energy security? Empirical studies tested the following hypotheses: the crisis equally affects the efficiency achieved by energy enterprises, which determines their ability to ensure energy security and not all efficiency distributions in crisis conditions are identical. The research methods are as follows: desk research and Friedman test.
Findings: There is evidence that the crisis situation has an unequal impact on the effectivity achieved by energy companies. There are companies that are capable and companies that are not able to ensure energy security
Originality/value: Implementation of the postulate of effectivity in a practical approach using statistics. The article presents the authors' own research.
Keywords: Energy security, Management, Microeconomics, Research, Effectivity, Energy enterprise.
Category of the paper: Research paper.

1. Introduction

Energy security means having enough energy to meet demand and having a power system and infrastructure that are protected against physical and cyber threats (Department of Energy, 2004). Other definition of energy security includes a wider range of factors, often referred to as the “four As” of energy security – availability, affordability, accessibility and acceptability.

Availability ensures that energy supplies are available in sufficient amounts. Affordability aims to have these resources available at sufficiently-low prices. Accessibility focuses on ensuring all citizens have access to energy, which is to some extent about ensuring that reliable infrastructure is in place to ensure a robust supply for the end user, but this is generally interpreted in practice as ensuring that energy prices are kept low and fuel poverty is minimised. Acceptability is concerned with the negative impacts of energy, such as pollution and environmental damage, and ensuring that these impacts are minimised in order to make the energy acceptable to the customer (Jones, Dodds, 2017).Energy security is an important guarantor of national development (Ma, Feng, Chang, 2024). Meanwhile, reports on the results of monitoring the security of electricity supplies published by the Ministry of Climate and Environment show that already in 2030, the demand for power (net) at the annual peak in Poland will exceed 30.5 GW. At the same time, the power available in existing conventional units will decrease due to the decommissioning of obsolete units. The decrease in power will probably be so great that even the projected increase in power from renewable sources and possible nuclear units will not meet the country's growing needs (Rekord zapotrzebowania na energię pobity. Czy grozi nam blackout?). Achieving this security requires efforts to reduce risks to energy systems (Dreyer, Stang, 2013). In terms of the country's energy security, energy companies are subject to regulations in two areas: ensuring the security of the power system operation and ensuring fuel stocks in an amount ensuring the continuity of electricity supply to consumers (Dołęga, 2009).On the other hand, there is currently an energy crisis caused by the coronavirus pandemic, the war in Ukraine and Russian energy (Pawlowski, 2023). In November 2028, The Parliament declared a climate emergency asking the European Commission to adapt all its proposals in line with a 1,5ºC target for limiting global warming and ensure that greenhouse gas emissions are significantly reduced (Green Deal, 2022). Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Removing carbon oxide from the atmosphere and then storing it is known as carbon sequestration. In order to achieve net zero emissions, all worldwide greenhouse gas emissions will have to be counterbalanced by carbon sequestration. The European union commited to an ambitious climate policy. Under the Green Deal it aims to become the first continent to remove as many CO_2 emissions as it produces by 2050. this goal became legally binding when the European Parliament and council adopted the Climate Law in 2021. The EU'a interim emission reduction target for 2030 was also updated from 40% to at least 55%. The EU is currently revising old legislation and setting new laws that will help deliver the 2030 goal of 55% cut in emissions. the package of legislation is known as "Fit for 55" and includes among others rules on emissions trading, national emissions reduction targets, carbon removal in the land use sector and transport emissions (What is carbon neutrality and how can it be achieved by 2050, 2019). Therefore, the efficiency of energy companies is important. The aim of the article is to empirically identify the effectivity of energy companies in crisis conditions. In the article, effectivity is understood as: the result of a specific project undertaken as part of

the business entity's activities, which is a factor in the relationship between the effects and the expenditure incurred: Bielski, 1992; Puszko, 2018.

A review of literature indicates that the energy industry in times of crisis is of interest to researchers in Poland. Literature review in 2019-2023 is presented in Table 1. The macronomic approach dominates (Kiciński, Czaja, 2021a, 2021b; Skotarek, 2023; Bojar-Fijałkowski, 2021; Kaznowski, Sztafrowski, 2023; Dyląget al., 2019; Manowska, 2019; Makuch, 2020; Sobieraj, 2023). Is being investigated whether the current state of the Polish energy system may lead to its crisis and in turn threaten the country's energy security (Cop, 2023), the energy crisis is a justification for postponing the EU climate targets (Sobieraj, 2023) or what should Poland do to meet the goals set out in the EU regulations (Bojar-Fijałkowski, 2021; Kaznowski, Sztafrowski, 2023): limiting the use of fossil fuels in the energy sector (Manowska, 2019), the development of large-scale photovoltaics, energy based on the combustion of primary forest biomass, the development of hydrogen energy (Naworyta, 2024), the final use, the end of coal use in electricity generation, the development of decarbonization (Czyżak, Hetmański, 2020). The premises and manifestations of innovation are emphasized (Stec, 2020; Kinelski, 2020; Pilipczuk, 2023). Few studies focus on energy companies and their effectivity (Pilipczuk, 2023; Kinelski, 2020). The research is qualitative in nature. There is a lack of research using statistical tests. This article fills this research gap. The article is a continuation of the authors' research in the field of effectivity. So far, the following publications have been published: Puszko, 2018; 2021a, 2021b, 2023a, 2023b, 2023c.

Table 1.
Literature review in 2019-2023

Item	**Literature review**
Reseacher's name	**Note**
Bojar-Fijałkowski T.	The article analysis the correlation between The European Green Deal and wind farm development projects in the polish part of the Baltic Sea.
Cop K.	The article aims to answer whether the current state of the Polish energy system may lead to its crisis and in turn threaten the country's energy security.
Czyżak P., Hetmański M.	The goal of the paper is to compare existing climate modelling results from major instiurions (IPCC, IEA, Climate Analytics) in order to provide evidence for decarbonizing power generation sector in Europe and Poland in particular.
Dyląg A. et al.	The goal of the paper is to provide information about the current state of citinzens energy, its legal and socio-political environment in Poland.
Firlit A. et al.	The article attemps to present contemporary trends and chalenges in the area of power quality in the context of the development of intelligent power systems (smart grids) and distributed generation.
Jarosz S. et al.	The aim of the paper is to present the methods of financing inthe renewable energy sectors and the hard coal sector based on a comparative anlysis of the methods and sources of obtaining financing for capital groups in the enrgy sectos.
Jasic B.	The goal of the article is to outline and to analyse the key chalenges to be faced by the Polish energy market, as it is only at the begining of the energy transition process.
Kiciński J., Czaja P.	Energy sufficiency: various instytitions, organizations, scientists and publicts develop long-term scenarios, visions and recommendations in order to resolve one of the main problems of our civilisation e.g., energy suffiency for future generations.

Cont. table 1.

Kiciński J., Czaja P.	Situation of Poland from the point of view of energy is specyfic. Poland has a national treasury in a form of coal, which is used and it provides Poland with energy security. Poland has also a green coal in a form of biomass and other RES that are used in a lesserthampossible extend.
Kinelski G.	Industry 4.0 has the potential to transform economies, jobs, and societies. A characteristic technology widely associated with this transformation is Artificial Intelligence, which is increasingly being adopted by energy companies. Therefore, it is worth analysing the available possibilities, relationships, solutions, and efficiency measures used in this sector. Such analysis can help assess management effectiveness and, despite political and regulatory challenges, enable us to take advantage of the opportunities brought by the Fourth Industrial Revolution.
Kazanowski R., Sztafrowski D.	The article presents issues related to the problems that need to be overcome in order to achieve the goal of achieving a high share of renewable energy from wind and solar energy in the country's power system.
Kostecka-Jurczyk D., Marak K.	The aim of the article is to analyse the legal conditions for the functioning of energy cooperatives and energy clusters in Poland, as well as to point out the short commings of the current solutions and the desired changes that could accelerate the development of community energy.
Kozieł P.	The article discusses the role of customer value on the electricity market in Poland
Knop L., Staszewska J.	The aim of the article is to characterise the business models of energy compenies in the context of building and maintainingtheirresilienceapplyingclimateneutralobjectiveswithin the framework of a suistanable development strategy.
Makuch K.	The purpose of the article is to present contentious points in the field of waste management hierarchy and waste to energy.
Manowska A.	The article analysis whether Poland will meet renewable energy obligations by 2020 under the current conditions, presents current energy consumption in the word and in the country, local conditions taken into account when creating the country's energy mix and forecast of renewable energy demand.
Mol B. et al.	The paper presents an analysis of possibility of use technical, organizational solutions that improve local energy security and riability of customer supply, including those related to the creation of mini energy centers.
Naworyta W.	The paper critically evaluates selected technical solutions in the field of broadly understood energy sector.
Pilipczuk O.	The aim of the article is to determine the current main directions of research on the concept of the cognitive enterprise and its adaption in energy enterprises. Nowadays, information technologies have become a tool for solving many problems arising in the energy industry, such as creating and managing removable technologies, saving energy and searching for new sources. Many new concepts are emerging, such as industry 5.0, society 5.0, smart city, smart enterprise and others. In turn, a few years ago, IBM introduced the concept of the "cognitive enterprise" instead of the "intelligent enterprise", which assumes, among others, using cognitive technologies to increase enterprise intelligence.
Prokopowicz D.	The paper identifies the key determinants and sources of the various economic, financial, othercrisesthathaveoccuredsince the begining of the 21st century.
Skotarek K.	The presented text highlights the benefits of making parts of electricity market public comparing to the risks associated with the politicization, the most important problems arising from policization (e.g investment delays, problems related to the characteristics of the production and connection of energy from renewable sources and insufficient use of the international integration potential of the power grid), the motival function of market competition and globalisation processes.
Sobieraj K.	The aim of the article is to address the question (to dispel doubts) of whether the energy crisis is a justification for postponing the EU climate targets. The answer to this question must be sought in the nature of climate change and the nature of climate protection policy and law. The thesis of the paper is that, in the growing energy crisis, the importance of EU climate protection law immobilising Member States to take appropriately ambitious climate protection measures is growing.

Cont. table 1.

Stec S.	The article contains a synthetic description of activities related of innovation in the energy industry in the countries of Central Europe namely in the Czech Republic, Poland, Slovakia, Hungary.

Source: Own study based on (Bojar-Fijałkowski, 2021; Cop, 2023; Czyżak, Hetmański, 2020; Dyląg et al., 2019; Firlit et al., 2023; Jarosz et al., 2022; Jasic, 2021; Kiciński, Czaja, 2021a, 2021b; 2020; Knop, Staszewska, 2024; Kostecka-Jurczyk, Marak, 2024; Kozieł, 2020; Makuch, 2020; Manowska, 2019; Mól et al., 2022; Naworyta, 2024; Pilipczuk, 2023; Propokowicz, 2023; Sobieraj, 2023; Skotarek, 2023; Stec, 2020).

2. Characteristics of empirical research

Taking into account the fact that energy security can be considered from the subjective point of view, i.e. from the point of view of energy companies, the research problem focused on answering the question: Does the crisis equally affect the effectivity achieved by energy companies, which determines their ability to ensure energy security? The answer to this question requires testing the following hypotheses: H0: the crisis equally affects the efficiency achieved by energy enterprises, which determines their ability to ensure energy security and H1: not all efficiency distributions in crisis conditions are identical. Empirical research was carried out in the period January 2020 - June 2024.The item of empirical research consisted of: collecting information on the effects and expenditures of enterprises using the desk research method, calculation of enterprise efficiency according to the formula: $W_e = E / N$ (where E - the result of the enterprise's operations, N - expenditure incurred on the enterprise's operations (Adamczyk, Nehring, 1995) and implementation of the Fiedman test (Achel, 2000), (Szwed, 2008, p. 323).The subjective scope of the research is:14 energy companies understood in accordance with the Energy Law (Act, 1997, Art. 3.12), present on the Stock Exchange. The characteristics of energy companies are presented in table 2.

Table 2.
The characteristics of organizations

Item Effects and expenditures (PLN thousand) in years	THE CHARACTERISTICS OF ORGANIZATIONS				
	year2019 (pln thousand)	year2020 (pln thousand)	year2021 (pln thousand)	year2022 (pln thousand)	year2023 (pln thousand)
I.ELEKTROCIEPŁOWNIA BĘDZIN S.A.					
1. Sales revenue	222.655	161.529	244.295	322.081	244.114
2. Cost of manufacture of products sold	272.319	230.828	332.447	477.405	340.761
3. Sales costs	0	0	0	0	0
4. Management cost general	0	0	0	0	0
5. Other operating income	4.139	6.860	3.360	9.030	153.741
6. Other operating expenses	63.853	2.324	106.290	54.043	255.472
7. Financial income	1.636	754	234	137	7.531
8.Financial costs	37.040	53.190	8.937.801	55.850	61.460
II. ČEZ. S.A.					
1. Sales revenue	33.818.496	3.629.207	41.592.070	54.580.493	59.169.946
2. Cost of manufacture of products sold	29.915.092	35.167.810	37.903.540	35.072.520	42.115.385
3. Sales costs	0	0	0	0	0

4. Management cost general	0	0	0	0	0
5. Other operating income	2.014.720	1.812.076	549.635	1.443.294	738.956
6. Other operating expenses	1.488.623	1.167.323	1.260.035	1.157.044	2.927.856
7. Financial income	67.543	66.088	79.735	738.737	1.104.476
8. Financial costs	1.234.542	1.266.367	1.150.700	1.529.131	2.390.129
9. Other income (costs)	-176.818	380.050	576.645	342.957	318.907
III. COLUMBUS ENERGY S.A					
1. Sales revenue	204.249	657.110	704.347	593.375	459.324
2. Cost of manufacture of products sold	187.989	571.229	697.666	652.993	494.807
3. Sales costs	0	0	0	0	0
4. Management cost general	0	0	0	0	0
5. Other operating income	5.658	12.698	2.057	4.763	20.467
6. Other operating expenses	1.658	5.280	9.808	20.687	14.103
7. Financial income	0	0	3.023	3.226	10.177
8. Financial costs	5.382	11.479	12.845	48.589	41.237
9. Other income (costs)	12	4.689	-4.230	-3.379	-5.695
IV. ENEA S.A					
1. Sales revenue	16.401.298	18.176.505	21.210.647	30.117.52	48.183.419
2. Cost of manufacture of products sold	14.716.400	16.530.760	19.245.575	29.531.508	47.111.418
3. Sales costs	0	0	0	0	0
4. Management cost general	0	0	0	0	0
5. Other operating income	320.076	-3.178.180	229.612	215.329	266.337
6. Other operating expenses	148.454	173.824	127.317	223.433	382.659
7. Financial income	441.858	346.336	214.803	276.630	486.445
8. Financial costs	-607.512	-605.300	176.963	-247.153	-1.199.831

Source: Own study based on Biznesradar.pl

The information in Table 2, such as: sales revenue, cost of manufacture of products sold, management cost general, other operating income, other operating expenses, financial income, financial costs, other income (costs) were used to carry out the item scope of the research, i.e. the calculation of the efficiency of energy companies. Due to editorial requirements related to the number of pages of the article, table 2 presents the characteristics of selected organizations. Detailed information can be found on the website: Biznesradar.pl. The spatial scope of the research includes entities located in the following voivodeships: Masovia, Lesser Poland, Silesia, Greater Poland, West Pomerania, Lower Silesia, Podkarpackie, Kujawsko-Pomorskie, Lublin.The territorial scope of the research is presented in table 3.

Table 3.
Territorial scope of research

Item	**Territorial scope research**
Company name	**Voivodeship**
ELEKTROCIEPŁOWNIA BĘDZIN S.A.	Silesian voivodeship
ČEZ. S.A	Masovian Voivodeship, Lesser Poland Voivodeship, Silesian Voivodeship, Greater Poland Voivodeship, West Pomeranian Voivodeship
COLUMBUS ENERGY S.A.	Lesser Poland Voivodeship
ENEA S.A.	Greater Poland Voivodeship
ZESPÓŁ ELEKTROCIEPŁOWNI WROCŁAWSKICH KOGENERACJA S.A.	Lower Silesian Voivodeship
Ml SYSTEM S.A.	Podkarpackie Voivodeship
NOVAVIS GROUP S.A.	Masovian Voivodeship
ONDE S.A.	Kuyavian-Pomeranian Voivodeship
PHOTON ENERGY N.V.	Greater Poland Voivodeship, Masovian Voivodeship
POLENERGIA S.A.	Masovian Voivodeship
PGE S.A.	Lublin Voivodeship, MasovianVoivodeship

Cont. table 3.

RAEN S.A.	Masovian Voivodeship
TAURON POLSKA ENERGIA S.A.	Silesian Voivodeship
ZESPÓŁ ELEKTROCIEPŁOWNI PĄTNÓW-ADAMÓW-KONIN S.A.	Greater Poland Voivodeship

Source: Own study based on Serwis informacyjno-usługowy dla przedsiębiorcy.

Therefore, the empirical research was carried out in energy companies from the largest Polish provinces. The time scope of the research is: energy crisis period - 2019-2023.

3. The Results of Empirical Research

The efficiency of energy companies in individual sub-periods of the period covered by the research was calculated. Effectivity of energy enterprises in 2019-2023 is shown in Table 4.

Table 4.
Effectivity of energy enterprises in 2019-2023

Item	**EFFECTIVITY OF ENERGY ENTERPRISES IN 2019-2023**				
Effectivity in years / **Company name**	**Year 2019**	**Year 2020**	**Year 2021**	**Year 2022**	**Year 2023**
ELEKTROCIEPŁOWNIA BĘDZIN S.A.	0,67	0,70	0,55	0,61	0,67
ČEZ. S.A	1,09	1,03	1,06	1,51	1,29
COLUMBUS ENERGY S.A.	1,07	1,14	0,97	0,82	0,88
ENEA S.A.	1,05	0,85	1,10	1,00	0,98
ZESPÓŁ ELEKTROCIEPŁOWNI WROCŁAWSKICH KOGENERACJA S.A.	1,10	1,13	1,05	1,11	1,11
Ml SYSTEM S.A.	1,03	1,08	1,01	1,00	0,98
NOVAVIS GROUP S.A.	0,26	1,04	0,91	1,44	2,36
ONDE S.A.	1,04	1,07	1,05	1,01	1,03
PHOTON ENERGY N.V.	1,02	0,81	0,87	1,06	0,83
POLENERGIA S.A.	1,05	1,07	1,11	1,02	1,06
PGE S.A.	0,89	1,00	1,09	1,05	0,95
RAEN S.A.	0,38	2,78	0,39	0,26	1,27
TAURON POLSKA ENERGIA S.A.	0,99	0,89	1,02	1,00	1,04
ZESPÓŁ ELEKTROCIEPŁOWNI PĄTNÓW-ADAMÓW-KONIN S.A.	0,86	0,88	0,82	1,07	1,27

Source: Own study based on Biznesradar.pl, Adamczyk, Nehring, 1995.

The information in Table 4 shows that the effectivity of energy companies does not change much from year to year. The calculated effectivity allowed the implementation of the Friedman test methodology. Data for the Friedman test were presented in tabular form (Achel, 2000). The rows correspond to energy companies (there are 14 rows). The columns correspond to the effectivity achieved by energy companies in 2019-2023. Then the observations (efficiency of energy companies) were transformed into ranks. Auxiliary calculations are presented in table 5. In each cell of table 18 there is a rank, which is a function of the ordering within each row. The smallest observation in a row receives rank 1, the next one receives rank 2, 3, 4.

The largest observation receives a rank of 5. In the case of the same values (0,67; 1,11), the rank awarded was the arithmetic mean of two adjacent ranks, i.e. (3+4)/2 = 3,5.

Table 5.
Auxiliary calculations

Item Effectivity ranking in years Company name	AUXILIARY CALCULATIONS									
	year 2019		year 2020		year 2021		year 2022		year 2023	
	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank
ELEKTROCIEPŁOWNIA BĘDZIN S.A.	0,67	3,5	0,70	5	0,55	1	0,61	2	0,67	3,5
ČEZ. S.A	1,09	3	1,03	1	1,06	2	1,51	5	1,29	4
COLUMBUS ENERGY S.A.	1,07	4	1,14	5	0,97	3	0,82	1	0,88	2
ENEA S.A.	1,05	4	0,85	1	1,10	5	1,00	3	0,98	2
ZESPÓŁ ELEKTROCIEPŁOWNI WROCŁAWSKICH KOGENERACJA S.A.	1,10	2	1,13	5	1,05	1	1,11	3,5	1,11	3,5
Ml SYSTEM S.A.	1,03	4	1,08	5	1,01	3	1,00	2	0,98	1
NOVAVIS GROUP S.A.	0,26	1	1,04	3	0,91	2	1,44	4	2,36	5
ONDE S.A.	1,04	3	1,07	5	1,05	4	1,01	1	1,03	2
PHOTON ENERGY N.V.	1,02	4	0,81	1	0,87	3	1,06	5	0,83	2
POLENERGIA S.A.	1,05	2	1,07	4	1,11	5	1,02	1	1,06	3
PGE S.A.	0,89	1	1,00	3	1,09	5	1,05	4	0,95	2
RAEN S.A.	0,38	2	2,78	5	0,39	3	0,26	1	1,27	4
TAURON POLSKA ENERGIA S.A.	0,99	2	0,89	1	1,02	4	1,00	3	1,04	5
ZESPÓŁ ELEKTROCIEPŁOWNI PĄTNÓW-ADAMÓW-KONIN S.A.	0,86	2	0,88	3	0,82	1	1,07	4	1,27	5

Source: Own study based on Biznesradar.pl, Achel, 2000.

The efficiency ranking was used to calculate the Friedman statistic (Szwed, 2008).

$$\chi_r^2 = \frac{12}{Nk(k+1)} \Sigma\left(R_j^2\right) - 3 \cdot N(k+1) \tag{1}$$

$$\chi_r^2 = 14{,}265$$

4. Discussion

The use of the Friedman test allows for testing hypotheses regarding the variability of the intensity of the studied variable depending on the conditions (Szwed, 2008, p. 284). On the basis of the presented empirical results, it is discussed that with df = 5-1 = 4 and $\alpha = 0.05$, the critical value of the statistic χ^2 is 9,488. Since the empirical value of the statistic $\chi 2$ is greater than the critical value $\chi 2$ read from the tables, the null hypothesis was rejected and the alternative hypothesis was accepted. The methodology for testing hypotheses was based on statistical literature (Szwed, 2008). The worsening energy crisis requires more than ad hoc measures to support. Action must be stepped up that can have long-term effects, including increasing the resilience of the EU and Member States to the negative economic and social impacts that future energy crises may cause. At the same time, the energy crisis should provide

a rationale for an appriopriate choise of measures to implement climate protection actions, increase solidarity among Members States also in terms of bearing the burden of implementing actions to protect the common good (climate protection) (Sobieraj, 2023). Reffering to the broader context, i.e. energy transformation, carbon neutrality, the European Union's decarbonisation policy, it is worth considering the efficiency in the teritorial dimension, i.e. in the voivodeships in crisis conditions. Efficiency in voivodeships in the years 2019-2023 is presented in table 6. Based on the information presented in Table 6, it can be seen that the highest average efficiency was achieved in Masovian Voivodeship (4,46), and the lowest in West Pomeranian Voivodeship (0,23). The average efficiency in the viovodeships in 2019-2023 is presented in Figure 1.

Table 6.
Efficiency in voivodeships in the years 2019-2023

Item Efficiency in years Name of the Voivodeship	EFFICIENCY IN VOIVODESHIP					
	year 2019	year 2020	year 2021	year 2022	year 2023	Arithmetic mean
Greater Poland Voivodeship	3,29	3,03	3,10	3,51	3,58	3,30
Kuyavian-Pomeranian Voivodeship	1,04	1,07	1,05	1,01	1,03	1,04
Lesser Poland Voivodeship	1,27	1,34	1,17	1,12	1,13	1,20
Lower SilesianVoivodeship	1,10	1,13	1,05	1,11	1,11	1,10
Lublin Voivodeship	0,44	0,50	0,54	0,52	0,47	0,49
Masovian Voivodeship	2,84	5,99	3,58	4,07	5,82	4,46
Podkarpackie Voivodeship	1,03	1,08	1,01	1,00	0,98	1,02
Silesian Voivodeship	1,19	1,09	1,22	1,30	1,29	1,22
West Pomeranian Voivodeship	0,2	0,2	0,2	0,30	0,25	0,23

Source: Own study based on Biznesradar.pl, Achel, 2000.

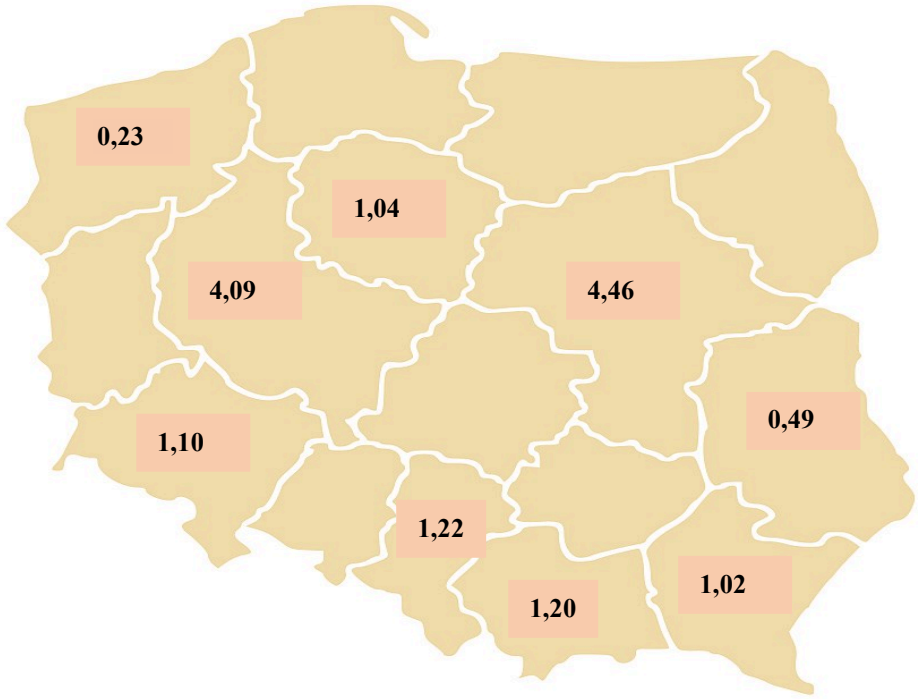


Figure 1. Average efficiency in Polish voivodeships.

Source: Own study based on Biznesradar.pl, Achel, 2000.

Figure 1 shows the differentiation of the efficiency and regional structure of the Polish energy sector. It is therefore worth examining whether the crisis has an equal impact on the efficiency achieved in the voivodeships, which is crucial for ensuring energy security? Auxiliary calculations are presented in table 7.

Table 7.
Auxiliary calculations

Item Effectivity ranking in years Voivodeship	AUXILIARY CALCULATIONS									
	year 2019		year 2020		year 2021		year 2022		year 2023	
	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank	Effectivity	Rank
Greater Poland Voivodeship	3,29	3	3,03	1	3,10	2	3,51	4	3,58	5
Kuyavian-Pomeranian Voivodeship	1,04	3	1,07	5	1,05	4	1,01	1	1,03	2
Lesser Poland Voivodeship	1,27	4	1,34	5	1,17	3	1,12	1	1,13	2
Lower SilesianVoivodeship	1,10	2	1,13	5	1,05	1	1,11	3,5	1,11	3,5
Lublin Voivodeship	0,44	1	0,50	3	0,54	5	0,52	4	0,47	2
Masovian Voivodeship	2,84	1	5,99	5	3,58	2	4,07	3	5,82	4
Podkarpackie Voivodeship	1,03	4	1,08	5	1,01	3	1,00	2	0,98	1
Silesian Voivodeship	1,19	2	1,09	1	1,22	3	1,30	5	1,29	4
West Pomeranian Voivodeship	0,2	2	0,2	2	0,2	2	0,30	5	0,25	4

Source: Own study based on Biznesradar.pl, Achel, 2000.

$$X_r^2 = 0{,}86.$$

Since the empirical value of the statistic $\chi 2$ is smaller than the critical value $\chi 2$ read from the tables, it should be stated that the crisis equally affects the efficiency achieved in the voivodeships, which determines their ability to ensure energy security.

5. Summary

The aim of the article is to empirically identify the effectivity of energy companies in crisis conditions. The article focuses on the characteristics of energy security in terms of the need for effectivity of energy companies. The concept of energy security was defined, and the obligations of the energy company in the field of ensuring energy security in terms of effectivity were indicated. A literature review was then carried out and a research gap was identified. The research problem focused on answering the question: Does the crisis equally affect the effectivity achieved by energy companies, which determines their ability to ensure energy security? Empirical studies tested the following hypotheses: H0: the crisis equally affects the efficiency achieved by energy enterprises, which determines their ability to ensure energy security and H1: not all efficiency distributions in crisis conditions are identical. The efficiency in the years 2019-2023 was calculated and the Friedman test was performed.

Because the empirical value of the Friedman statistic is greater than the critical value read from the tables, the null hypothesis was rejected and the alternative hypothesis was accepted. There is evidence that the crisis situation has an unequal impact on the effectivity achieved by energy companies. There are companies that are capable and companies that are not able to ensure energy security. A crisis usually forces companies to review all activities. As a result, in the conditions of crisis, companies carry out many non-standard activities that ensure their functioning and development and, after a certain period of time, improve effectivity. Future research could focus on: the use of parametric statistical tests or developing an energy company effectivity model focusing on ensuring energy security.

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THE SOCIAL DIMENSION OF TOURIST DEMAND IN SOCIAL MEDIA: THE CASE OF OKUNINKA AT LAKE BIAŁE

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Purpose: The purpose of this paper is to investigate how demographic factors (gender, age, place of residence) and seasonality shape the content and effectiveness of accommodation inquiries formulated by tourists in social media. The study aims to identify behavioral patterns of online communication between tourists and service providers, using the case of Okuninka at Lake Białe as an example of a seasonal tourist destination.
Design/methodology/approach: The research applies a mixed-methods approach, combining quantitative and qualitative analyses of user-generated content. The empirical material includes approximately 1500 posts and 8000 responses collected from the Facebook group "Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)" between 2022 and 2025. Quantitative methods include descriptive statistics, chi-square tests, Cramér's V, and logistic regression, while qualitative analysis focuses on categorizing inquiry content (number of persons, date, price, location, standard). This approach allows the identification of demographic, geographical, and seasonal determinants of online tourist behavior.
Findings: The analysis confirms that gender and age significantly influence the type and precision of inquiries. Women more often emphasize family- and child-friendly facilities, while men prioritize proximity to recreational infrastructure. Younger tourists (18-34) are more price-sensitive and active in high season, whereas older age groups display a stronger preference for higher-standard accommodation and off-season stays. Residents of large cities tend to formulate more detailed queries, whereas those from smaller towns often ask general availability questions. Seasonality strongly impacts activity peaks, with the majority of inquiries posted in July–August. Detailed inquiries containing price and standard information significantly increase the likelihood of receiving a response from accommodation providers.
Research limitations/implications: The study is limited to a single Facebook group representing one tourist destination, which may constrain the generalizability of results to other regions or platforms. Demographic data were estimated from user profiles, which may involve minor inaccuracies. Future research should broaden the scope by including multiple destinations, cross-platform comparisons, sentiment analysis of host responses, and the role of visual content in shaping effectiveness.
Practical implications: The results provide valuable guidance for accommodation providers and local tourism organizations. Tailoring communication strategies and offers to demographic segments and maintaining year-round social media presence can increase booking effectiveness and support sustainable destination management. Clear, detailed, and transparent offers are

more likely to generate responses and conversions, which has direct commercial benefits for businesses.
Social implications: By highlighting how demographic and seasonal factors influence online tourist communication, the study contributes to a deeper understanding of consumer behavior in digital tourism markets. The findings may inform public policy on regional tourism development, support local communities in managing seasonality and overtourism, and promote sustainable tourism practices through better communication strategies.
Originality/value: This paper provides one of the first empirical studies analyzing the social dimension of tourist demand in social media at the micro-destination level. Its originality lies in combining demographic, geographical, and seasonal perspectives in the context of direct tourist–provider communication. The study is valuable to academics researching tourism behavior, as well as practitioners managing accommodation facilities and local tourism marketing.
Keywords: tourist behavior; social media; accommodation inquiries; demographics; seasonality.
Category of the paper: Research paper; Case study.

1. Introduction

The dynamic development of social media in recent years has significantly transformed the way communication takes place between consumers and providers of tourism services. Platforms such as Facebook, Instagram, and TikTok have become not only tools for maintaining social connections but also one of the main channels for searching information about destinations, accommodation, and tourist attractions. Users engage with these platforms both to seek inspiration and to obtain recommendations from other travelers, which directly influences the tourism decision-making process.

Recent studies emphasize that digital tourism behavior is shaped not only by access to information but also by interactive, community-based communication patterns on social media platforms. Concepts such as electronic word-of-mouth (eWOM), social presence, and user-generated content (UGC) are considered essential for understanding online tourist decision-making. These frameworks explain how tourists construct meanings, trust, and expectations in virtual environments, which is particularly relevant for micro-destinations like Okuninka, where social media groups replace traditional booking platforms. In the context of digital tourism, social media communities serve as both information sources and decision-support systems, allowing users to evaluate accommodation offers through peer interactions. Therefore, analyzing communication dynamics in Facebook groups provides valuable insight into tourists' decision-making processes at the local level (An, Ozturk, 2022; Leung et al., 2013; Li et al., 2023; Litvin et al., 2008; Munar, Jacobsen, 2014; Srivastava et al., 2025; Vermeulen, Seegers, 2009; Xiang, Gretzel, 2010; Ying et al., 2022; Zabudská, Pompurová, 2024).

In the academic literature, increasing emphasis is placed on analyzing tourists' online behavior from the perspective of demographic and social factors. Research shows that gender, age, place of residence, and seasonality affect how inquiries are formulated and what expectations are directed toward accommodation offers. Women tend to pay more attention to issues related to safety, comfort, and family amenities, whereas men display greater interest in offers linked to recreational activities. Younger generations, particularly Generation Z, rely more heavily on social media as a primary tool for travel planning, while older age groups prefer stable, reliable offers that guarantee a higher standard of service.

Another important dimension of tourist behavior is the geographical and seasonal context. Residents of large cities usually formulate more precise inquiries, which stems from their habit of comparing online offers and their higher expectations regarding service quality. In contrast, tourists from smaller towns more often ask general questions, focusing mainly on accommodation availability. Social media activity also shows strong seasonal variation - peaking during holiday periods, festive seasons, and long weekends, reflecting the traditional cycle of tourism demand.

Against this backdrop, the analysis of communication among tourists seeking accommodation in social media groups appears particularly relevant. These groups serve as virtual forums for the exchange of information between travelers and accommodation providers. The case study of Okuninka, a popular tourist destination located by Lake Białe, makes it possible to identify demographic and seasonal patterns in the content of inquiries directed to lodging service providers. The research findings offer valuable insights both for the field of tourism studies and for marketing practice among stakeholders in the accommodation industry.

2. Demographic, Geographical and Seasonal Determinants of Tourist Behavior in Social Media – Literature Review

The dynamic development of social media in recent years has significantly transformed the way individuals participate in consumption processes. These platforms have become one of the most visible and influential forms of user activity, playing a key role in shaping consumer preferences and decision-making (Boley et al., 2018). In the tourism sector, social media increasingly functions both as a source of information and as a channel for sharing experiences. Tourists use them not only to search for accommodation offers but also to share opinions and recommendations, which can substantially influence the choices of other travelers (Huang et al., 2010).

2.1. Demographic determinants of tourists' inquiries in social media

Research on tourist behavior in social media reveals clear differences depending on gender and age. Women demonstrate greater activity in sharing travel experiences, which may stem from their tendency to create visual content, such as photos and videos, and to provide recommendations to other users. Men, in contrast, are more likely to engage with travel-related content, which can affect their destination choices (Karatsoli, Nathanail, 2020). Similar results were found in a study conducted in Turkey, which showed that women more often use social media for travel planning, whereas men are more engaged in interactions with tourism-related content (Armutcu et al., 2023).

Age is also a significant factor shaping tourist behavior on social media. Younger age groups, particularly Generation Z, make intensive use of platforms such as Instagram, TikTok, and YouTube in their travel decision-making, often relying on influencers' opinions and online reviews (Faculty of the College of Business and Hospitality Management, Madridejos Community College, Cebu, Philippines et al., 2024). Studies indicate that younger groups are more likely to interact with travel-related content, which directly influences their destination choices (Canadian Journal of Discovery, 2025).

Scientific research shows that both gender and age significantly determine how tourists use social media, influencing not only the intensity of interactions but also preferences regarding destinations and types of trips.

2.2. The impact of place of residence on tourist choices

Studies on tourist behavior in social media highlight significant differences related to place of residence, which influence preferences and behaviors. Individuals from highly urbanized cities are more likely to use social media in search of tourism information, whereas those from smaller towns may rely more heavily on traditional sources. Moreover, tourists from different countries may exhibit varying preferences in terms of communication style and expectations toward accommodation services (Lee, Gretzel, 2010; Palazzo et al., 2021)

Urban residents, especially those from large metropolitan areas, demonstrate higher activity levels in business travel and international tourism, which may result from greater availability of transport, better infrastructure, and higher incomes (Mattioli et al., 2021). By contrast, rural residents may prefer domestic travel or short weekend getaways, often motivated by economic and logistical considerations. These differences are also reflected in social media activity. City dwellers are more likely to use platforms such as Instagram or TikTok to share travel experiences, whereas people from smaller towns may use social media to a lesser extent or for different purposes, such as maintaining contact with family and friends (Galiano-Coronil, Blanco-Moreno, 2025).

In the context of travel planning, residents of urban areas more frequently use social media as a tool for finding tourism information. Research indicates that individuals from more urbanized regions tend to rely on social media to search for travel information, while those from smaller towns may depend more on traditional sources (Lee, Gretzel, 2010; Shang et al., 2021).

In sum, tourists' place of residence significantly shapes their preferences and tourism behaviors, including the ways in which they use social media during the travel planning process. These differences arise from factors such as technological access, level of urbanization, and the economic and social conditions of a given location.

2.3. Seasonality of tourists' activity in social media

Seasonality plays a crucial role in tourists' activity on social media. Research shows that the number of accommodation inquiries increases during holiday periods as well as during festive seasons and long weekends (Villamediana et al., 2019). Moreover, younger age groups are more active in seeking accommodation during the summer, whereas older groups may plan their trips off-season (Martins et al., 2025).

Tourist destinations with seasonal operations, particularly those of rural or coastal character, often face challenges in organizing business activity. Many accommodation facilities remain closed in the off-season, which makes it difficult to maintain stable income. Furthermore, a lack of social media activity outside the high season may lead to a decline in potential tourists' interest. Therefore, effective marketing strategies should include year-round activities, such as promoting local events, attractions, or culinary offers, in order to maintain engagement and attract tourists also beyond the main season (*Seasonal Travel Marketing*, 2025).

At the same time, these destinations frequently face the problem of "overtourism", i.e., an excessive influx of tourists within a short time, leading to infrastructure overload, environmental degradation, and a negative impact on residents' quality of life (Montenegro's Adriatic Gem Struggles with Tourist Influx, 2024; *We live in „Little Venice" UK - tourists wee on street & spit at us...it's hell*, 2025; Smith, 2024).

To conclude, tourism seasonality in seasonal destinations entails organizational and marketing challenges. Proper management of seasonality, including maintaining social media activity year-round, is crucial for the sustainable development of tourism in these regions.

2.4. The role of social media in shaping tourist preferences

Social media platforms such as Facebook, Instagram, and TikTok play an increasingly important role in shaping tourist preferences. Travelers often use them to find inspiration, compare accommodation offers, and read other users' reviews. Influencers and online reviews significantly influence decisions regarding the choice of accommodation and tourist attractions (Javed et al., 2025).

Research indicates that social media plays a key role in shaping the image of tourist destinations. User-generated content (UGC)—such as photos, videos, and live streams—affects how potential tourists perceive destinations. High-quality visual content and authentic travel stories can enhance the attractiveness of a destination and encourage visits (Hussain et al., 2024).

Influencers also play an important role in the travel decision-making process. Their recommendations and travel accounts often serve as a trusted source of information for audiences. However, despite their influence, they are not always perceived as fully reliable sources, which may result from the commercial nature of their activities (Zawadka, Liwińska, 2022).

Furthermore, the quality of information available on social media significantly influences users' travel intentions. High-quality content that is consistent, credible, and visually appealing can positively impact the perceived authenticity of a destination and increase trust in the tourism offers presented (Wang, Yan, 2022).

In the context of tourism seasonality, social media also plays a role in maintaining interest in destinations outside the peak season. Regular posting about local events, promotions, or unique attractions can attract tourists during periods of low demand, helping to balance the burden on tourism infrastructure (Pop et al., 2022).

In conclusion, social media is of crucial importance in shaping the travel preferences of contemporary tourists. Incorporating these platforms into tourism destination marketing strategies can significantly enhance both their attractiveness and the effectiveness of promotional efforts.

3. Research Methodology

The study was based on an analysis of user activity in the Facebook group "Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)", which serves as the main space for information exchange between tourists seeking accommodation and property owners in this destination. The dataset covered the years 2022-2025, which made it possible to capture variations in tourist preferences and activity over a multi-year period. The analysis included approximately 1500 posts published by individuals searching for accommodation and about 8000 responses to these posts.

The scope of the analysis comprised four main areas:

- the content of tourist inquiries posted in the group regarding accommodation searches,
- demographic data of users (age, gender),
- geographical data indicating tourists' place of origin (city, country),
- seasonality of activity, determined on the basis of post publication dates.

A mixed-methods approach was applied, combining quantitative and qualitative analysis. The following procedures were employed:

- descriptive statistics, allowing for the identification of user groups by gender, age, and country of origin,
- χ^2 tests and Cramér's V coefficient to assess the relationship between demographic variables (gender, age) and the type of inquiries,
- qualitative content analysis of posts, with categorization according to key elements of the requested accommodation: number of persons, length of stay, accommodation standard, price, and preferred location,
- ongoing observation of the group from the perspective of the administrator approving posts and comments.

This methodological framework made it possible to capture both the quantitative patterns of tourist behavior and the qualitative determinants underlying their choices and accommodation preferences.

The following research hypotheses were formulated:

H1: Tourist gender influences the type of accommodation inquiries.

H2: Tourist age determines the nature of accommodation inquiries, including preferences regarding standard and cost of stay.

H3: Place of residence affects the frequency and form of social media use in searching for accommodation.

H4: Seasonality determines the intensity of accommodation inquiries in the Facebook group, with the number of inquiries increasing during holiday and festive periods.

H5: The content of the inquiry (number of persons, length of stay, standard, price, location) is associated with the likelihood of receiving a response from property owners.

H6: The type of inquiry varies depending on the interaction between seasonality and the tourist's place of residence.

To summarize, the formulated hypotheses collectively address the multidimensional relationships between demographic characteristics, place of residence, and seasonality in shaping tourists' communication behavior on social media. The adopted mixed-methods approach allows for a comprehensive verification of these assumptions through both quantitative and qualitative analyses. The next section presents the empirical results obtained from the study and discusses them in the context of the proposed hypotheses.

4. Research Findings

The analysis of data from the Facebook group "Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)" covered a total sample of 1500 posts concerning accommodation inquiries and 8000 responses from property owners between 2022 and 2025. The results are presented across four dimensions: demographic characteristics of users, geographical origin, typology of inquiries, and seasonality of activity. Statistical analyses were conducted to verify the relationships between variables.

4.1. Demographic characteristics of users

The demographic analysis of group users revealed clear variation in terms of age and gender. The largest age category was 25-34 years, accounting for 35% of all inquiries. This group dominates domestic tourism—young adults, often with small children, who make intensive use of social media when planning holidays. The second largest group was 35-44 years (29%), followed by 18-24 years (21%). These data indicate that more than four-fifths of activity is generated by young and middle-aged individuals (18-44 years), who are the most touristically mobile.

Older age groups had a markedly lower share—those aged 45-54 accounted for 11% of inquiries, while individuals aged 55+ represented only 4%. This may reflect lower levels of social media activity in these groups or reliance on alternative channels for seeking accommodation (e.g., travel agencies, word-of-mouth recommendations).

In terms of gender, women accounted for the majority of inquiries (58%), compared to men (42%). This pattern may confirm the tendency for women to more often assume the role of family trip organizers and to be primarily responsible for searching for accommodation offers.

Table 1.
Demographic distribution of Facebook group users (2022-2025)

Age (years)	Female	Male	Total	Share (%)
18–24	185	130	315	21
25–34	305	220	525	35
35–44	250	185	435	29
45–54	65	100	165	11
55+	25	35	60	4
Total	870	670	1500	100

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

The statistical analysis revealed a significant relationship between age and preferences regarding the standard of accommodation ($\chi^2 = 36.12$; $p < 0.001$). Although the strength of this association was weak (Cramér's $V = 0.16$), certain patterns could be identified:

- younger users (18-24 years) were more often interested in lower-standard facilities, which may be linked to budget constraints,

- individuals aged 25-34 displayed the most diverse expectations, including both mid-range and premium accommodation,
- users aged 35-44 more frequently preferred mid- or higher-standard facilities, reflecting their family situation and greater financial capacity,
- the oldest participants (55+), although representing a small share of inquiries, more often indicated interest in higher-standard facilities and peaceful locations.

The demographic structure of the group demonstrates the dominance of young and middle-aged users, with a majority of women, which is also reflected in the accommodation preferences they express.

4.2. Geographical origin of tourists

The geolocation analysis showed that 95% of inquiries originated from Poland, while only 5% came from abroad. Among domestic users, the majority were residents of large cities: Warsaw (20%), Lublin (15%), Radom (9%), and Chełm (6%). The share of foreign tourists amounted to 5% of the sample, with the largest groups coming from the United Kingdom (2%), Germany (2%), and the Netherlands (1%).

Ongoing observation also indicated a significant presence of tourists from the Podlasie, Podkarpacie, Małopolska, Mazowsze, and Lower Silesia regions, alongside the dominant group of tourists from the Lublin Voivodeship.

Table 2
Type of inquiry by place of residence (2022-2025)

Place of residence	Detailed questions (standard, price, location)	General questions about availability	Premium objects / lakeside	Total
Large cities (Warsaw, Lublin, Radom)	380 (55%)	170 (25%)	140 (20%)	690 (100%)
Small towns / villages	130 (33%)	200 (50%)	70 (17%)	400 (100%)
Abroad	28 (55%)	10 (20%)	13 (25%)	51 (100%)
Total	538 (47%)	380 (33%)	223 (20%)	1,141 (100%)

Note. Table includes 1141 inquiries for which the place of residence was identified.

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

Differences in the structure of inquiries were evident depending on the place of residence. Residents of large cities more frequently submitted detailed questions (55%), while individuals from smaller towns limited themselves in half of the cases to general inquiries about accommodation availability. Among foreign tourists, precise inquiries dominated (55%), along with an expressed interest in premium facilities or lakeside locations (25%).

The chi-square test confirmed a statistically significant relationship between place of residence and type of inquiry ($\chi^2 = 23.88$; $p < 0.001$). Although the strength of the association was weak (Cramér's $V = 0.20$), the structure of inquiries indicates that:

- residents of large cities and foreign users more often expected detailed information,
- residents of small towns adopted a more general approach to accommodation searches,
- foreign users stood out due to their higher expectations regarding the standard and location of facilities.

These findings highlight the role of socioeconomic and cultural context in shaping online accommodation inquiries. Urban residents, accustomed to comparing diverse offers online, tend to formulate more precise and information-rich requests. In contrast, users from smaller towns display a less differentiated demand structure, focusing primarily on availability. The behavior of foreign tourists underscores the internationalization of the destination, as their greater emphasis on quality and location reflects both higher purchasing power and expectations aligned with global tourism standards.

4.3. Typology of Accommodation Inquiries

The analysis of 1500 posts made it possible to distinguish five main categories of information that users included in their inquiries: number of persons, length of stay, standard of the facility, price, and location.

Table 3
Typology of tourist accommodation inquiries (N = 1500)

Category of inquiry	Details	Number of inquiries	Share (%)
Number of persons	2-4 persons	645	43
	5-6 persons	420	28
	>6 persons	225	15
Period of stay	July-August	885	59
	May-June	300	20
	September-October	180	12
Standard of facility	Medium	735	49
	High	465	31
	Low	300	20
Price	With price inquiry*	945	63
	Without price info	555	37
Location	Near the lake	825	55
	Town center	450	30
	Remote locations	225	15

Note. * Inquiries regarding price were not always included directly in the initial posts; in most cases, they appeared as follow-up comments to accommodation offers.

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

The most frequently indicated criterion was the number of persons – in over 80% of inquiries, users specified how many tourists were planning to stay. The majority concerned groups of 2-4 persons (43%), less often family or group stays (5-6 persons – 28%, more than 6 persons – 15%). This may indicate the predominance of couples and nuclear families as the main target group for accommodation offers.

The second key element was the length of stay. The summer season clearly dominated – 59% of inquiries referred to July-August, and another 20% to May-June. Only 12% of inquiries appeared in the autumn months, confirming the strong seasonality of demand.

With regard to the standard of facilities, inquiries most often concerned mid-range accommodation (49%), while 31% of users sought higher-standard places and 20% expressed interest in cheaper, simpler options. These data suggest that the studied group of tourists had rather moderate expectations concerning quality, with a relatively large share willing to pay more for higher comfort. In many inquiries, specific expectations regarding jacuzzis or hot tubs were noted.

Price was another important element of inquiries – 63% of users asked about the cost of stay. Importantly, the qualitative analysis revealed that such questions often appeared not in the main posts but in the comments under offers added by accommodation providers.

As for location, the greatest interest was directed towards lakeside accommodation (55%), while 30% of inquiries referred to facilities in the town center, and only 15% concerned more secluded places. This points to tourists' preference for staying in close proximity to the lake while also being near the center of entertainment.

The logistic regression analysis showed that the inclusion of price information in the inquiry significantly increased the likelihood of receiving a response from an accommodation provider ($\beta = 0.41$; $p = 0.001$). Similarly, the inclusion of information about the facility's standard also significantly increased this probability ($\beta = 0.32$; $p = 0.007$).

4.4. Seasonality of Tourist Activity

User activity in the group exhibited a clearly seasonal pattern. More than half of all inquiries (59%) were posted in the months of July and August. Activity declined significantly during the off-season period (November-March), when an average of 6-7% of inquiries per month was recorded. Although this is not directly visible in the summary statistics, observational analysis indicated a certain increase in group activity related to the search for accommodation offers at the end of December and at the turn of January and February.

Table 4

Demographic distribution of Facebook group users (2022-2025)

Months	18-24	25-34	35-44	45-54	55+	Total
May-June	70	125	75	20	10	300
July-August	185	310	250	100	40	885
Sept.-Oct.	45	75	45	10	5	180
Nov.-March	15	15	25	15	5	75
Total	315	525	435	165	60	1500

Note. Age categories were estimated, as it is not always possible to determine users' exact age from Facebook profiles.

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

The activity of users in the group displayed a clear seasonal pattern, confirmed both by the overall number of inquiries and by the demographic distribution of respondents. The highest intensity of activity occurred during the summer months (July-August), when 885 inquiries were posted, accounting for 59% of the entire sample. During this period, the dominant age groups were 25-34 years (310 inquiries, 35%) and 35-44 years (250 inquiries, 28%), indicating high activity among individuals in life stages typically associated with families with children or young adults planning summer holidays.

The second most active period was May-June (300 inquiries, 20%), where the 25-34 age group also prevailed; however, the share of younger users (18-24 years) was clearly higher (23% compared to 21% in July-August). This may suggest that younger individuals tend to plan trips before the peak season, for instance, during exam sessions or academic breaks.

In September–October, the number of inquiries decreased to 180 (12%). The age structure resembled that of June, although activity among the 35-44 age group declined, while the participation of younger and older users remained relatively balanced.

The lowest level of activity was observed between November and March (a total of 75 inquiries, 5%). In this phase, the age distribution flattened: no age group clearly dominated, and the differences in numbers were minor. Interestingly, qualitative observations revealed a slight increase in activity around the turn of the year, possibly linked to planning winter trips or school holidays.

Statistical analysis confirmed a significant relationship between season and users' age ($\chi^2 = 31.05$; $p < 0.001$). Although the strength of this relationship was relatively weak (Cramér's $V = 0.18$), several regularities can be identified:

- users aged 25-34 and 35-44 are the most active during the high (holiday) season,
- the 18-24 age group is relatively more engaged in planning trips before and after the peak season,
- users aged 55+ show consistently low levels of activity throughout the year, suggesting limited reliance on the group as a source of accommodation information.

The seasonality of group activity is strongly linked to the holiday cycle, with different age groups displaying distinct engagement patterns.

5. Discussion of Results

The aim of this study was to analyze the communication behaviors of tourists searching for accommodation in social media, using the Facebook group "Okuninka Jezioro Białe – noclegi …" as a case study. The findings allow for a discussion in the context of the proposed research hypotheses and the existing body of literature.

H1: Tourist gender influences the type of accommodation inquiries.

This hypothesis was confirmed. The chi-square test revealed a statistically significant relationship between gender and the type of inquiry formulated ($\chi^2 = 30.05$; $p < 0.001$). Content analysis of posts showed that women (58% of the sample) were significantly more likely than men to ask about family- and child-friendly facilities and to specify requirements related to family-oriented leisure. Conversely, men more frequently focused on locations close to sports and recreational infrastructure. This finding is consistent with Karatsoli and Nathanail (2020), who highlighted women's greater propensity to share experiences and seek recommendations in the context of family travel. It also supports the broader thesis on gender-conditioned differences in tourist priorities (Kumar, Misra, 2023; Millán et al., 2024; Zhang et al., 2024).

H2: Tourist age determines the nature of accommodation inquiries, including preferences regarding facility standard and cost of stay.

This hypothesis was confirmed. Statistical analysis indicated a significant relationship between age and preferred accommodation standard ($\chi^2 = 36.12$; $p < 0.001$), allowing for the identification of clear age-related profiles. Results showed that younger tourists (18-34 years, 56% of the sample) were more likely to seek budget options, which can be linked to lower disposable income and a preference for flexibility and reduced costs. This aligns with previous research suggesting that younger generations, particularly Generation Z and Millennials, tend to prioritize price over higher standards (Kumar, Misra, 2023; Minazzi, Grechi, 2025). Older tourists (45+, especially 55+) demonstrated different behavioral patterns, with a stronger preference for higher-standard facilities. Existing studies confirm that seniors are significantly more inclined to choose premium hotels over platforms like Airbnb, prioritizing safety, comfort, and service quality (Nicolau et al., 2024). Moreover, differences in hotel attribute preferences across demographic groups, including age, have been widely documented (Kim et al., 2020). The readiness of older, financially stable tourists to pay more for additional amenities and higher standards is further supported by findings on Generation X and Baby Boomers, who value comfort, quality, and safety to a greater extent than younger cohorts (Fuentes-Moraleda et al., 2019).

H3: Place of residence influences the frequency and form of using social media to search for accommodation.

This hypothesis was partially confirmed. Although the chi-square test revealed a statistically significant relationship between place of residence and type of inquiry ($\chi^2 = 23.88$; $p < 0.001$), the strength of the relationship was weak ($V = 0.20$). The data nevertheless indicated differences in the formulation of inquiries: residents of large cities (Warsaw, Lublin, Radom – 46% of inquiries with specified location) significantly more often posed detailed questions (55%), including expectations regarding standard, price, and precise location. This may reflect greater familiarity with online comparison tools and higher service expectations. Residents of smaller towns and foreign tourists, by contrast, tended to ask general availability questions.

These observations resonate with earlier findings by Lee and Gretzel (2010) and Palazzo et al. (2021) on geographic and cultural differences in communication patterns.

H4: Seasonality determines the intensity of accommodation inquiries in the Facebook group, with the number of inquiries increasing during holiday and festive periods.

This hypothesis was confirmed. Seasonal analysis showed an unequivocal, sharp rise in activity during the summer months (July-August: 59% of inquiries), fully consistent with the cycle of leisure tourism in temperate climates. The concentration of inquiries in this period reflects the classical model of tourist demand, in which climatic conditions and the school calendar are the main determinants. This finding corroborates previous research emphasizing the crucial role of seasonality in shaping tourists' online activity (Villamediana et al., 2019; Martins et al., 2025).

H5: The content of an inquiry (number of persons, period of stay, standard, price, location) is linked to the probability of receiving a response from accommodation providers.

This hypothesis was confirmed. Logistic regression analysis provided strong support for this assumption. Inquiries containing price information (63% of all inquiries; $\beta = 0.41$; $p = 0.001$) and facility standard ($\beta = 0.32$; $p = 0.007$) significantly increased the likelihood of receiving a reply. This indicates that providers preferentially respond to precise messages that signal serious interest and enable rapid pricing. Such behavior is consistent with observations that detailed customer signals enhance response efficiency on the supply side (Kim et al., 2022). Similarly, studies on family-run accommodation businesses indicate that clarity and completeness of inquiries foster interaction and increase hosts' willingness to respond (Krishnan et al., 2024).

H6: The type of inquiry differs depending on the combination of seasonality and place of residence.

This hypothesis was confirmed. A statistically significant interaction between these variables was observed ($\chi^2 = 31.05$; $p < 0.001$). Residents of large cities were considerably more active and tended to formulate more detailed inquiries during the summer peak season, reflecting greater mobility and a tendency to plan holidays around widely available vacation periods. In contrast, residents of smaller towns and older tourists were relatively more active in off-peak months (May-June, September), which may be linked to greater time flexibility or a desire to avoid crowds and higher prices. This supports the notion of differentiated tourism strategies depending on origin and life stage. The findings also align with earlier evidence that managerial and communicative features of listings significantly affect host activity on short-term rental platforms (Contu et al., 2023). Big-data analyses further confirm that the topic and level of detail in host–guest communication influence host responsiveness, which explains the significant impact of including price and standard information in inquiries (Jiang et al., 2024).

Overall, the results confirm that demographic factors, place of residence, and seasonality significantly influence the communication behaviors of tourists in social media when searching for accommodation. Gender and age shape the content and priorities of inquiries, with women

and younger users showing distinct patterns compared to men and older groups. Place of residence differentiates the level of detail in questions, while seasonality remains the strongest determinant of activity intensity. Importantly, the precision of inquiry content, particularly the inclusion of price and standard information—substantially increases the likelihood of receiving a response from providers. These findings highlight the interplay between demographic, temporal, and geographic factors in shaping online tourist behavior and underscore the need for accommodation providers to tailor their communication strategies accordingly.

6. Conclusions

Based on the study conducted in the Facebook group "Okuninka Jezioro Białe – noclegi (domki, pokoje, kwatery, pola namiotowe)", it can be concluded that gender, age, and place of residence significantly influence how tourists use social media to search for accommodation, as well as the effectiveness of obtaining responses from property owners. Women more frequently formulate detailed inquiries about family- and child-friendly facilities, while men show greater interest in accommodation located near sports or recreational attractions. Younger age groups (18-34 years) are markedly more active during the summer season, whereas older users tend to plan trips outside the peak period. Users from large cities are more likely to use social media as a tool for seeking tourist information and submit more detailed inquiries, including the number of persons, facility standard, price, and location, thereby increasing the likelihood of receiving a response. By contrast, individuals from smaller towns more often limit themselves to general questions, which may reduce communication effectiveness. Seasonality of tourist activity is evident, with the peak occurring in July and August, while during the off-season (November-March) the number of posts decreases significantly. Qualitative analysis of post content showed that inquiries containing detailed information are more effective, and tourists are interested not only in basic parameters but also in additional amenities such as pet-friendly options, children's attractions, or parking availability.

This study has certain limitations. The analysis focused on a single, albeit significant, Facebook group, which may limit the generalizability of the findings to other destinations or platforms. Furthermore, demographic data were estimated based on user profiles, which may introduce a margin of error. From a scientific perspective, the study confirms that demographics, place of residence, and seasonality play a crucial role in shaping tourists' online behavior and accommodation choices. Despite these limitations, the research makes a substantial contribution to understanding the mechanisms governing direct interactions between tourists and accommodation providers in the era of social media. Expanding the analysis to a larger sample strengthens the validity of the results and supports the appropriateness of the adopted methodology.

The findings provide a foundation for further studies on the effectiveness of user-generated content in social media and the factors determining tourist decisions in empirical contexts. Future research may include analyses of other social media platforms, comparisons of tourist behavior across regions, the conversion of online inquiries into actual bookings, and examinations of language and form in posts, including photos, videos, and emojis. Another promising direction would be sentiment analysis of host responses or the impact of visual content on the effectiveness of listings. Pursuing these research avenues would enrich academic knowledge and equip tourism practitioners with precise tools for managing communication.

The study results also have important practical implications for accommodation providers and tourism organizations. Adapting communication and accommodation offers to age, gender, and place of residence can increase the effectiveness of tourist interactions and the likelihood of booking. Maintaining social media activity throughout the year, including the off-season, through the promotion of local events and attractions, can attract tourists during periods of low demand and support sustainable tourism development. Moreover, in the context of marketing, providers should ensure that their listings contain complete and accurate information, which enhances communication effectiveness and customer satisfaction.

In conclusion, the study highlights significant relationships between demographic characteristics, place of residence, seasonality of activity, and the effectiveness of tourist communication in social media. Incorporating these factors into the marketing strategies of destinations and accommodation providers can improve promotional effectiveness and contribute to the sustainable development of tourism in the Okuninka region.

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THE IMPACT OF CORPORATE SOCIAL RESPONSIBILITY ON EMPLOYER BRANDING

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Purpose: The purpose of this paper is to examine the relationship between Corporate Social Responsibility (CSR) and Employer Branding (EB). The study aims to identify how CSR contributes to building an attractive employer image, which CSR dimensions are most influential, and whether differences exist across industries, regions, and employee profiles.
Design/methodology/approach: The paper is based on a systematic literature review of peer-reviewed articles and empirical studies published in recent years. The analysis was structured around four research questions, focusing on the conceptual links between CSR and EB, the impact of CSR on employer attractiveness, the role of specific CSR dimensions (social, ethical, environmental), and contextual differences across sectors and cultures.
Findings: The review shows that CSR is a significant antecedent of Employer Branding, strengthening reputation, attractiveness, and employee loyalty. Social and ethical dimensions (e.g., employee well-being, diversity, fairness) have the strongest impact, while environmental practices gain importance in contexts under ecological pressure. CSR enhances trust and identification among candidates and employees, but its effectiveness depends on authenticity and consistency of communication. Differences in perception are observed across industries, regions, and employee profiles, indicating that CSR is not a universal tool.
Research limitations/implications: The study is limited by the scope of available literature and the diversity of methodological approaches in the reviewed articles. Future research should include comparative empirical studies across cultures, industries, and generations to better understand when CSR strengthens EB and when its impact is limited.
Practical implications: The findings suggest that organizations should tailor CSR communication to their sector and cultural context. Authentic and consistent CSR practices can enhance recruitment outcomes, reduce turnover, and strengthen employee loyalty.
Social implications: CSR practices that emphasize inclusivity, employee well-being, and environmental responsibility contribute to shaping positive public attitudes toward organizations and support broader societal goals such as diversity, sustainability, and ethical business conduct.
Originality/value: This paper contributes to the literature by synthesizing existing research on CSR as a driver of Employer Branding. It highlights the multidimensional nature of CSR and its varying impact depending on cultural, sectoral, and employee contexts, providing value for both scholars and practitioners.
Keywords: Corporate Social Responsibility; CSR; Employer Branding; Employee Attractiveness; Organizational Reputation; Sustainability.
Category of the paper: Literature review.

1. Introduction

Contemporary enterprises increasingly face the challenge of competing not only for customers but also for employees. In the context of dynamic social and economic changes, the importance of socially responsible activities is steadily growing, and these have become an integral element of management strategies. Corporate Social Responsibility (CSR) is no longer perceived merely as an additional image-building activity; instead, it is increasingly regarded as a foundation for building organizational trust and reputation.

Alongside the concept of CSR, the notion of Employer Branding has been evolving, understood as the deliberate shaping of a company's image as an attractive workplace. Both job candidates and employees increasingly pay attention not only to employment conditions or opportunities for professional development, but also to the values represented by the organization. These values are particularly important for generations currently entering the labor market. As a result, CSR initiatives addressing environmental, social, and ethical issues play a growing role in employer brand building, influencing decisions related to taking up or continuing employment.

The number of publications concerning CSR and Employer Branding has grown steadily in recent years; however, the relationship between these concepts has not yet been fully clarified. Existing studies indicate that perceptions of this relationship may vary depending on industry and geographical context. The literature also emphasizes the need for more in-depth analyses to identify which CSR dimensions—environmental, social, or ethical—are most relevant for shaping the employer brand.

The originality of this study lies in systematically linking Corporate Social Responsibility (CSR) and Employer Branding (EB) through a comprehensive review of fifty studies published between 2010 and 2025. The article provides a novel synthesis, highlighting the conceptual mechanisms and contextual factors that connect CSR with employer attractiveness. By identifying and systematizing gaps in the existing literature—such as the heterogeneity of CSR dimensions and the limited consideration of cultural, industry, and generational differences—this study clarifies current knowledge and highlights directions for future research, offering both theoretical contributions and practical guidance for organizations seeking to strengthen their employer image.

The purpose of this paper is to conduct a systematic literature review on the relationship between Corporate Social Responsibility (CSR) and Employer Branding. The analysis is guided by the following research questions:

1. How does the academic literature describe the links between CSR and Employer Branding?
2. How does CSR influence the perception of an organization as an attractive employer among candidates and employees?

3. Which CSR dimensions (social, ethical, environmental) are considered crucial for employer brand building?
4. Are there differences in the perceived impact of CSR on Employer Branding depending on industry, geographical region, or employee profile?

The systematic literature review provides answers to these questions, highlighting the main connections between the two concepts and identifying areas that require further research.

2. Literature Review

2.1. Corporate Social Responsibility (CSR)

Bowen (1953) was one of the first authors to attempt to define CSR, emphasizing that "it refers to the obligations of businessmen to pursue those policies, to make those decisions, or to follow those lines of action which are desirable in terms of the objectives and values of our society" (Bowen, 1953, p. 6).

Davis (1960) stressed that social responsibility refers to "businessmen's decisions and actions taken for reasons at least partially beyond the firm's direct economic or technical interest" (Davis, 1960, p. 70). He also introduced the concept known as the *Iron Law of Responsibility*, according to which the social responsibility of enterprises (organizations) should be proportional to their social power. In a later work, he argued that "the substance of social responsibility arises from concern for the ethical consequences of one's acts as they might affect the interests of others" (Davis, 1967, p. 46).

McGuire (1963) expanded earlier approaches to CSR, pointing out that "the idea of social responsibilities supposes that the corporation has not only economic and legal obligations but also certain responsibilities to society which extend beyond these obligations" (McGuire, 1963, p. 144).

Carroll (1979) recognized that earlier definitions of CSR required supplementation and systematization; therefore, he proposed a four-dimensional model in which corporate social responsibility "encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time" (Carroll, 1979, p. 500).

The European Commission in 2011 proposed one of the simpler definitions of CSR, describing it as "the responsibility of enterprises for their impact on society" (European Commission, 2011). Later, however, the Commission decided to broaden this definition, suggesting that "corporate social responsibility refers to businesses taking responsibility for their behaviour and its impact on society. This can include employment conditions and labour standards, freedom of association, well-being at work, non-discrimination and gender balance, stakeholder engagement, human rights, preventing environmental harm, including reducing

emissions and pollution, and eliminating bribery and corruption" (European Commission, 2024).

In summary, CSR has evolved from a moral obligation of entrepreneurs to a comprehensive strategy encompassing economic, legal, ethical, and environmental aspects. Today, it constitutes a key element in building reputation and social trust, particularly in the face of the growing role of social media and the expectations of younger generations. Therefore, organizations that care about their reputation and social trust should consistently fulfill their commitments and minimize their negative impact on the environment.

2.2. Employer Branding (EB)

Employer Branding emerged when marketing principles were first applied to employee recruitment. Ambler and Barrow (1996) defined it as "the package of functional, economic and psychological benefits provided by employment, and identified with the employing company" (Lievens et al., 2007, pp. 46-48). Backhaus and Tikoo later expanded the concept, describing it as "the process of building an identifiable and unique employer identity" (Backhaus, Tikoo, 2004, p. 502). From the outset, Employer Branding was perceived as a tool that enabled companies to stand out from their competitors.

Employer Branding shapes the image of an organization as an ideal workplace in the eyes of both current and prospective employees. A strong employer brand is consistent, attractive, and distinctive. Consistency refers to the extent to which the employer brand is implemented reliably over time and across different stakeholder groups, while attractiveness reflects the degree of interest the brand generates among employees and candidates (Moroko, Uncles, 2008).

Increasingly, job seekers compare their needs, personalities, and values with the employer's image. Employer Branding allows organizations to differentiate themselves by attracting candidates whose values align with those of the company (Foster, 2010).

Contemporary perspectives treat Employer Branding as a strategic process. Theurer et al. defined it as "the process of strategically promoting the employer brand externally and internally, using brand marketing activities with the aim of establishing the desired employer image in the organization's target groups" (Theurer et al., 2018, p. 159). Similarly, Divya and Venkatalakshmi describe Employer Branding as a strategic effort to create a unique workplace that attracts candidates with the skills needed to achieve organizational goals. They emphasize that effective Employer Branding facilitates recruitment and retention, making the organization distinctive by securing talent and reducing turnover. In recent years, research on Employer Branding has gained momentum due to the intense competition for talent and the pursuit of becoming an employer of choice (Divya, Venkatalakshmi, 2023).

In summary, Employer Branding has evolved from a simple package of employee benefits into a strategic process of building a unique employer identity. Today, it is a key instrument in the competition for talent and in strengthening organizational advantage, with CSR initiatives serving to further enhance its effectiveness.

2.3. Operational Definitions in This Paper

For the purposes of this study, Corporate Social Responsibility (CSR) is defined as a strategic approach that integrates economic objectives with environmental, social, and ethical considerations. CSR is understood here not merely as a set of voluntary initiatives, but as a systematic commitment to minimizing negative externalities and enhancing organizational accountability toward stakeholders.

Employer Branding (EB) is operationalized as the process of shaping and communicating the image of an organization as an attractive workplace. In this paper, EB is treated as a strategic instrument that influences both current and prospective employees' perceptions of the organization, emphasizing consistency, distinctiveness, and alignment with employee values.

This study assumes that socially responsible activities constitute a significant asset in building a strong employer brand. The operational definitions provided above establish the conceptual framework for subsequent analysis and enable a coherent linkage between CSR and EB throughout the paper.

3. Methods

3.1. Search strategy

A systematic literature review was conducted using two leading databases, Scopus and Web of Science. The choice of these databases was based on their broad coverage and the high quality of the scientific journals they index.

3.2. Scopus

In the Scopus database, the search was restricted to the fields *Article title, Abstract,* and *Keywords*, applying the following keywords: "CSR", "employer branding", and "corporate social responsibility". The time frame covered the years 2010-2025, reflecting the fact that in 2010 the ISO 26000 standard related to the concept of Corporate Social Responsibility (CSR) was published, which became an important reference point for subsequent research. Additional restrictions included: *Document type: Article* and *Language: English*. Applying these criteria resulted in the identification of 48 articles.

3.3. Web of Science

In the Web of Science database, the search was conducted in the *Topic* field, which includes title, abstract, and keywords. The keywords applied were: "CSR", "employer branding", and "corporate social responsibility". The time frame also covered the years 2010-2025, and the document type was limited to *Article*. This search yielded 28 articles.

3.4. Selection process

In total, 76 publications were identified (48 in Scopus and 28 in Web of Science). After removing duplicates, 66 articles remained. The selection process was then carried out based on titles and abstracts, followed by full-text screening. The analysis of full texts was conducted in relation to the research questions formulated in the *Introduction*, which allowed for a systematic linkage of the literature to the study's objectives and the identification of research gaps. The selection process is illustrated in the figure below.

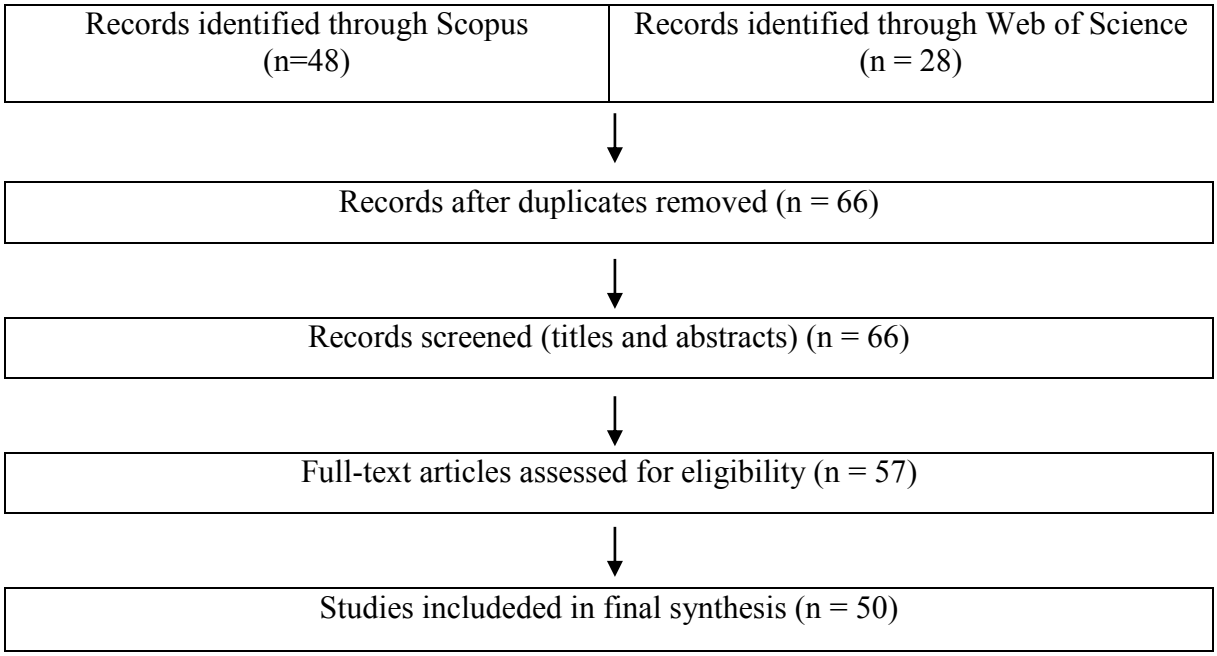


Figure 1. Stages of identification, selection, evaluation, and synthesis of studies.

4. Results

The findings of the systematic literature review were structured around the four research questions formulated in the study. Each subsection presents the results corresponding to a specific question, drawing on the analysis of articles identified and selected during the screening process. This approach ensures that the outcomes are directly linked to the research objectives and provides a coherent framework for discussing the relationship between Corporate Social Responsibility (CSR) and Employer Branding.

Results for RQ1: How does the academic literature describe the links between CSR and Employer Branding?

Biswas and Suar (2016) examined 209 companies in India and demonstrated that Corporate Social Responsibility (CSR) constitutes a significant antecedent of Employer Branding (EB). CSR, alongside the leadership of top management and perceived organizational prestige, emerged as one of the strongest predictors of EB. Their analysis revealed that organizational engagement in CSR positively influences all three dimensions of EB: Employer Brand Equity, Attraction and Retention of Talents, and Employer Brand Loyalty and Employee Engagement.

Corporate culture, grounded in ethical values and stakeholder relations, provides the foundation for building employer reputation (Kotras, 2010). CSR is treated as a tool of both internal and external communication, strengthening the image of the company as a responsible and attractive employer. The way CSR is communicated further shapes the perceived personality of the brand (Kotras, 2010; Ganucci Cancellieri et al., 2017).

Qualitative research has shown that digital communication and employer branding are increasingly linked to CSR practices. Organizations use internal communication and social media to promote socially responsible behaviors (e.g., combating discrimination, sustainable development), making CSR an integral element of EB that enhances reputation and employee loyalty (Fernandes et al., 2023).

CSR strengthens employer attractiveness by improving engagement and retention (Talaulikar, Mali, 2016; Florez, Kanzler, 2025). Socially responsible companies are perceived as more attractive and trustworthy (Hinson et al., 2018; Bielicka et al., 2021; Mishra, Chakraborty, 2021; Yasin et al., 2023; Kuo et al., 2024). However, Kozak (2018) emphasizes that while CSR increases employer attractiveness, its significance may vary across generations, as younger employees expect greater involvement.

Buzzao and Rizzi (2024) presented CSR as a symbolic attribute of the employer brand, highlighting that candidates perceive CSR as evidence of ethicality and responsibility. A SEM study conducted by Kumar et al. (2021) revealed a strong, positive, and significant relationship between CSR and Employer Branding, with a large effect size, meaning that higher levels of CSR are associated with stronger EB. Similar results were reported by Khan et al. (2024).

Millennials in Indonesia positively perceive corporate CSR engagement, indicating that it can significantly increase applications to socially responsible firms (Hakam, 2024). Candidates—particularly "talents"—actively seek CSR content during recruitment and treat it as a cultural signal of value alignment and employer reputation. CSR is increasingly seen as a standard rather than a "unique benefit", and its absence reduces employer attractiveness. HR professionals confirm the growing importance of CSR in recruitment but note that communication is often not tailored to the specific expectations of talents (Boehncke, 2025).

CSR is regarded as a symbolic element of the employer brand that complements instrumental factors (salary, benefits) and influences perceived person–organization fit (P–O fit), which is crucial for employer attractiveness. EB gains strength when CSR aligns with candidate values (Klimkiewicz, Oltra, 2017; Nanjundeswaraswamy et al., 2022; Szegedi et al., 2023). Nyborg and Zhang (2013) found that firms with strong CSR reputations attract employees despite offering lower wages, suggesting that CSR enhances employer branding by enabling organizations to compete not only on pay but also on reputation. Similar findings were reported by Barbara et al. (2019) and Le & Morschett (2024), who showed that CSR can be as important as compensation, with candidates willing to accept lower salaries in exchange for working at a company with a strong CSR reputation.

Bonaiuto et al. (2013) emphasized that attributes related to ethics and social responsibility are integral to the employer brand and particularly important for attracting talent. Afrahi et al. (2025) reached similar conclusions, noting that CSR strengthens employee attachment to the organization, builds pride, and increases willingness to recommend the employer to others—an essential element of EB. Interviews with SME owners conducted by Szegedi et al. (2023) also revealed that CSR and EB are closely intertwined, with CSR perceived as the foundation of organizational reputation and culture, both critical for attracting and retaining employees.

Various studies highlight that CSR plays an important role in employer brand building, though its significance is interpreted differently. Chopra et al. (2022) identified socially responsible practices as one of five key factors that make a company attractive as a workplace. Nanjundeswaraswamy et al. (2022) similarly emphasized CSR as an integral element of employer image. Francis et al. (2025), analyzing the IT sector, observed that while CSR was not the strongest predictor of organizational attractiveness, it functioned as a symbolic attribute that reinforced company reputation and values, thereby enhancing credibility in the eyes of employees.

Carlini et al. (2019) demonstrated that CSR is treated as a key signal in the employer branding process. Referring to signaling theory, they argued that EB effectiveness depends on the consistency between external signaling (CSR employer brand identity) and internal experience (internal CSR). Azimi et al. (2023) found that CSR has a strong and positive impact on Employer Brand Personality Appeal (EBPA), meaning that CSR not only improves organizational reputation but also enhances employer attractiveness through the perceived "personality" of the brand. CSR also directly influences employee satisfaction and reduces turnover intentions. Content analyses of global firms revealed that CSR is one of the key dimensions of EB and that companies frequently publish CSR initiatives to strengthen employer brand perception. CSR in the digital space has become a tool for building employer reputation and attractiveness among both potential and current employees (Temel, Esen, 2024).

Nevertheless, some studies suggest limitations. Research in the Indian IT sector indicated that CSR does not significantly influence candidate application decisions and does not enhance EB effectiveness (Punn, 2020). Bustamante et al. (2021) similarly argued that while CSR

contributes to employer attractiveness, its impact on EB is selective. Klimkiewicz (2014) also noted that although positive attitudes toward CSR are linked to choosing responsible employers and rejecting those violating CSR principles, salary and working conditions remain the most decisive factors for potential employees.

Results for RQ2: How does CSR influence the perception of an organization as an attractive employer among candidates and employees?

CSR and sustainability practices are integral elements of Employer Branding, supporting both recruitment and employee loyalty (Andruszkiewicz et al., 2024). Research findings indicate that CSR strengthens organizational reputation, increases attractiveness and prestige (Biswas, Suar, 2016; Ganucci Cancellieri et al., 2017; Ibrahim, 2017; Buzzao, Rizzi, 2024), as it enables both candidates and employees to experience greater alignment between their personal values and those of the company (Miethlich, 2022). Andruszkiewicz et al. (2024) emphasize that CSR communication confirms organizational values by demonstrating care for the local community, the environment, and employees. Puncheva-Michelotti et al. (2018) add that CSR communication in recruitment advertisements serves as a signal to potential candidates about organizational values.

However, studies reveal that CSR in recruitment advertisements is often used in a limited and inconsistent manner, which prevents its full potential in Employer Branding from being realized (Wołodźko, Woźniak, 2017; Puncheva-Michelotti et al., 2018). The absence of CSR in internal and external communication may be perceived as a signal that the organization does not care about public opinion, negatively affecting its image as a potential employer (Bielicka et al., 2021).

CSR communicated through digital channels (social media, internal communication) enhances perceived employer attractiveness by building the image of a company that is responsible and cares for employee well-being. Yet interview results show that the mere presence of CSR in communication does not always translate into stronger emotional attachment among employees; while Employer Branding is positively evaluated, emotional bonds remain limited (Fernandes et al., 2023).

Stronger Employer Branding, reinforced by CSR, positively impacts non-financial outcomes such as higher employee satisfaction, more applications, and lower turnover, as well as financial outcomes such as higher return on assets (Biswas, Suar, 2016). Importantly, studies by Nyborg and Zhang (2013) and Le and Morschett (2024) demonstrated that employees are willing to accept lower wages to work for companies with a strong CSR reputation.

CSR is considered one of the key dimensions of organizational attractiveness and directly supports Employer Branding by building a positive employer image (Bendaravičienė, Vitkauskas, 2024; Gandasari et al., 2024; Salim, Widhianto, 2024). Research shows that organizations with strong CSR are perceived as more fair and responsible, which strengthens their reputation and attractiveness in the eyes of employees (Kumar et al., 2021; Bendaravičienė, Vitkauskas, 2024; Khan et al., 2024).

A study conducted on a sample of over 300 Millennials in Poland revealed that individuals with positive attitudes toward CSR perceive socially responsible organizations as more attractive. Conversely, candidates with strong prosocial engagement are more likely to reject offers from companies that fail to meet basic CSR standards. Candidate emotions toward CSR (e.g., pride, lack of trust) significantly influence recruitment decisions (Klimkiewicz, Oltra, 2017).

CSR provides employees with information about organizational values and principles, influencing their application decisions and engagement. In the IT sector, professionals prefer employers with strong CSR involvement, perceiving them as more ethical and stable. Results show that CSR correlates with organizational attractiveness, although prestige and workplace happiness were found to be more influential (Francis et al., 2025).

CSR, understood as ethical actions toward employees and the broader community, enhances organizational credibility and trust. Employees who participate in developing ethical codes or CSR programs identify more strongly with the company and demonstrate greater loyalty. External stakeholders (e.g., job candidates) perceive firms as more attractive when CSR is authentic and embedded in organizational culture (Kotras, 2010). CSR directly influences employer attractiveness, as employees feel pride and purpose in working for a responsible organization. Perceptions of the company as socially responsible and ethical increase employee satisfaction and loyalty (Bharadwaj, Yameen, 2020; Nanjundeswaraswamy et al., 2022).

For candidates, CSR signals increase application intentions (Ibrahim, 2017; Soleha, Satrya, 2024) by fostering pride, value alignment, and organizational reputation. Uncontrolled sources (e.g., media, rankings) may further reinforce or undermine the perceived authenticity of CSR. For current employees, CSR influences satisfaction, organizational identification, and loyalty—provided that internal experiences confirm CSR promises. Inconsistency, however, leads to negative outcomes such as reduced trust or increased turnover intentions (Carlini et al., 2019).

Similar findings were reported by Boehncke (2025), who noted that candidates identified as talents perceive CSR initiatives as enhancing employer attractiveness when communicated credibly and supported by evidence (e.g., reports or concrete initiatives). He also emphasized that overly promotional communication generates skepticism and reduces organizational attractiveness, suggesting the need for discreet, evidence-based CSR communication. Boehncke further observed that CSR plays a particularly important role in the early stages of the recruitment funnel—at the awareness level—and in the onboarding process of new employees (Boehncke, 2025). Nevertheless, some studies indicate that although CSR has a strong and significant impact on Employer Branding, it does not directly influence application intentions (Gandasari et al., 2024; Salim, Widhianto, 2024).

Results for RQ3: Which CSR dimensions (social, ethical, environmental) are considered crucial for employer brand building?

Biswas and Suar (2016) measured CSR using a scale that encompassed stakeholder-related activities; however, they analyzed CSR as a single construct without examining the separate impact of individual dimensions on Employer Branding. Puncheva-Michelotti et al. (2018) emphasized that diversity, inclusiveness, and employee development were the most frequently highlighted aspects in recruitment advertisements, while environmental issues and community relations were marginalized—with environmental aspects almost entirely absent.

The most important CSR dimensions identified in a study conducted by Bonaiuto et al. in Italy included ethical responsibility, employee well-being, diversity and inclusion, and good governance. Candidates, particularly highly talented ones, considered these elements crucial for employer attractiveness (Bonaiuto et al., 2013). A study involving employees and firms in Norway revealed that gender equality, as well as ethical and social standards, were key dimensions shaping perceptions of employer attractiveness (Nyborg, Zhang, 2013). Khan et al. (2024), examining the banking sector in Pakistan, found that ethical and environmental dimensions were particularly significant for reputation and Employer Branding.

Research conducted among young labor market participants in Poland showed that legal and ethical aspects of CSR were especially important to them, and violations of these led to a loss of trust and even rejection of job offers (Klimkiewicz, 2014). Another study in Poland indicated that the dimensions most strongly enhancing employer attractiveness included: employee support (promoting good relations, transparent bonus rules, equal treatment); relations with local communities (supporting schools/clubs and improving local living conditions); ethics and law (compliance with regulations); and environmental actions (e.g., clean-up initiatives, waste management). Concrete examples of CSR activities were found to increase attractiveness more than general declarations or external sponsorship alone (Kotras, 2010; Wołodźko, Woźniak, 2017).

Cid-Bouzo et al. (2025) demonstrated that the environmental dimension of CSR is directly linked to employer attractiveness, with companies holding ISO 14001 certification receiving higher CSR scores in job attractiveness rankings, thereby strengthening reputation and Employer Branding. Other studies also highlight the importance of the environmental dimension (e.g., sustainable development, minimizing negative environmental impact), while additionally emphasizing ethical (e.g., fair business practices, absence of corruption scandals) and social dimensions (e.g., fair treatment of employees and suppliers, human rights, equality) (Kotras, 2010; Carlini et al., 2019; Garai-Fodor et al., 2021; Chopra et al., 2022; Azimi et al., 2023; Szegedi et al., 2023; Fernandes et al., 2023; Yasin et al., 2023; Temel, Esen, 2024; Le, Morschett, 2024; Buzzao, Rizzi, 2024; Hakam et al., 2024; Andruszkiewicz et al., 2024; Bendaravičienė, Vitkauskas, 2024; Francis et al., 2025; Boehncke, 2025). The strongest impact on Employer Branding was observed in CSR activities directed specifically toward employees (Jain, 2013; Kotras, 2010; Stuss, 2018; Bharadwaj, Yameen, 2020; Bustamante et al., 2021;

Szegedi et al., 2023; Yasin et al., 2023; Temel, Esen, 2024; Afrahi et al., 2025). Bustamante et al. (2021) found that CSR enhances employer attractiveness only when it relates to employee well-being. Conversely, Salanță et al. (2019) revealed that employees were more interested in CSR campaigns targeting society at large.

Studies consistently show that CSR practices in the social and ethical domains are crucial for building Employer Branding. The most frequently cited valuable CSR activities include training and reskilling, occupational health and safety, transparency, anti-corruption measures, and stakeholder information provision. These actions enhance employer attractiveness because they are perceived as genuine care for employees, while also strengthening trust and reputation, which indirectly increases attractiveness (Caha et al., 2024). Other studies confirmed that social and ethical values—such as honesty, equality, human rights, employment of people with disabilities, and prosocial initiatives—are essential for employer attractiveness (Miethlich, 2022; Nanjundeswaraswamy et al., 2022; Azimi et al., 2023).

A study by Seara et al. (2023), conducted in Portugal primarily among young people, highlighted the significant role of employee volunteering, emphasizing that it is crucial for Employer Branding. Employees become more loyal and perceive the organization as more attractive when they have opportunities to engage in volunteering (Garai-Fodor et al., 2021; Seara et al., 2023). Miethlich (2022) further noted that companies supporting people with disabilities are perceived as more ethical and attractive. He argued that integrating vocational rehabilitation (CSR) with Employer Branding can create added value, with outcomes such as loyalty and inclusiveness aligning with Employer Branding goals and enabling organizations to build an authentic image of a "caring employer".

Results for RQ4: Are there differences in the perceived impact of CSR on Employer Branding depending on industry, geographic region, or employee profile?

The study conducted by Biswas and Suar did not reveal significant differences in the strength of the relationship between Corporate Social Responsibility (CSR) and Employer Branding across different industries (manufacturing and services), nor between public and private enterprises. This suggests that, in the Indian context, CSR functions as a universal factor enhancing Employer Branding regardless of the sector of activity (Biswas, Suar, 2016). Similar results were obtained by Bendaravičienė and Vitkauskas (2024), who found no significant differences in CSR assessments between employees in the public and private sectors.

Findings from Puncheva-Michelotti et al. (2018) in the United States indicate sectoral differences: the financial sector communicated CSR to the least extent, while companies in healthcare and education naturally emphasized their positive social impact. Importantly, CSR was more prominently presented on corporate websites than in recruitment advertisements, highlighting inconsistencies in communication directed at candidates.

Nyborg and Zhang's study of Norwegian firms, situated in the Scandinavian context, emphasized that CSR is strongly linked to gender equality policies and high social standards. However, the authors suggested that the effect of CSR on wages and attractiveness may vary across industries (Nyborg, Zhang, 2013).

In Central and Western Europe, research conducted on small and medium-sized enterprises in the fashion industry—where sustainability pressures are particularly high—showed that CSR is a key element of Employer Branding. Owners of firms in Central Europe more often associated CSR with voluntarism, whereas in Western countries the emphasis was placed on stakeholder impact and ethical business practices (Szegedi et al., 2023).

A comparative study of business and management students in the USA and Vietnam revealed cultural differences: U.S. students placed greater importance on the social and environmental aspects of CSR, while Vietnamese students valued financial stability, fair business practices, and the absence of corruption scandals more highly (Le, Morschett, 2024).

Research conducted in Germany by Boehncke (2025) indicated that industry differences may be significant. Candidates from humanities and social sciences more frequently regarded CSR as a key element of employer attractiveness, interpreting it as a signal of ethicality and value alignment. By contrast, candidates from technical fields (e.g., engineering, IT) paid less attention to CSR and placed greater emphasis on innovation, originality, and technological advancement.

Afrahi et al. (2025), in a study across various sectors in Germany, found that CSR was particularly important in healthcare and manufacturing, where employees strongly responded to working conditions and safety. In technology and communications industries, development and innovation played a greater role, although CSR still reinforced employee attachment to the firm.

Andruszkiewicz et al. (2024) observed that manual workers rated financial and social support programs more highly, whereas office employees more often emphasized the importance of ecological and educational initiatives. Miethlich (2022) further demonstrated that CSR has greater significance for Employer Branding in sectors characterized by a high share of physical labor and health-related risks.

5. Discussion

The literature indicates that CSR is one of the key antecedents of employer branding, alongside leadership and organizational prestige (Biswas, Suar, 2016; Kumar et al., 2021). It strengthens employer reputation and attractiveness, supports employee loyalty, and serves as a tool of both internal and external communication (Kotras, 2010; Fernandes et al., 2023). Candidates increasingly perceive CSR as a standard, the absence of which reduces employer

attractiveness, while CSR reputation can compensate for lower wages (Nyborg, Zhang, 2013). At the same time, the effectiveness of CSR depends on the authenticity of actions and the consistency of communication. In some industries its impact is selective, while salary and working conditions remain decisive factors (Punn, 2020; Klimkiewicz, 2014). CSR is strongly linked to employer branding, enhancing reputation, attractiveness, and employee loyalty, but its effectiveness is conditioned by authenticity, communication consistency, and cultural or generational expectations. In certain industries CSR plays a symbolic role, while in others its influence on candidate decisions is limited.

The literature further demonstrates that CSR plays a crucial role in shaping employer image, supporting recruitment and employee loyalty (Biswas, Suar, 2016; Miethlich, 2022). CSR enhances organizational reputation and attractiveness, and CSR communication signals organizational values to candidates, although inconsistency weakens its potential in employer branding (Puncheva-Michelotti et al., 2018; Wołodźko, Woźniak, 2017). Stronger employer branding supported by CSR leads to higher satisfaction, more applications, and lower turnover (Biswas, Suar, 2016), while in some contexts CSR reputation compensates for lower pay (Nyborg, Zhang, 2013). CSR also influences candidate emotions, building trust and organizational identification (Klimkiewicz, Oltra, 2017). However, its effectiveness depends on authenticity and communication consistency—an overly promotional tone generates skepticism, and inconsistency undermines employer branding (Boehncke, 2025). CSR strengthens employer attractiveness through reputation, value alignment, candidate emotions, and employee loyalty, but inconsistency may erode trust and weaken employer branding.

Research shows that different CSR dimensions have varying significance for employer branding, depending on cultural, industry, and employee contexts. Social and employee-related activities—well-being, workplace safety, training, and diversity—exert the strongest influence, as they are perceived as direct care for employees (Bonaiuto et al., 2013; Caha et al., 2024). Ethics remains a fundamental pillar of employer branding: honesty, compliance with law, and anti-corruption, with violations leading to loss of candidate trust (Klimkiewicz, 2014; Miethlich, 2022). The environmental dimension plays a more differentiated role—marginalized in some studies, but considered crucial in contexts subject to ecological pressures (Cid-Bouzo et al., 2025). Additionally, volunteering and inclusiveness strengthen employee loyalty and build an authentic image of a "caring employer" (Seara et al., 2023). Overall, CSR activities directed at employees have the strongest impact, though the importance of ethical and environmental dimensions grows depending on context. Authenticity, concreteness, and alignment with candidate values are essential.

Studies also highlight that the impact of CSR on employer branding differs across cultural and industry contexts. In India and Lithuania, CSR acted as a universal factor enhancing employer attractiveness regardless of sector (Biswas, Suar, 2016). In the USA and Germany, clear differences emerged—financial and technology industries emphasized CSR less,

while healthcare, education, and manufacturing highlighted it more strongly (Puncheva-Michelotti et al., 2018). In Scandinavia, CSR is closely tied to gender equality and high social standards, while in Central and Western Europe differences concern interpretation—CSR as voluntarism versus obligation toward stakeholders (Szegedi et al., 2023). Expectations are also culturally conditioned—Americans emphasize social and environmental aspects, while Vietnamese students value financial stability and business integrity (Le, Morschett, 2024). The nature of work further shapes CSR perception—manual workers appreciate financial and social support, while office employees emphasize ecological and educational initiatives (Miethlich, 2022). CSR is not a uniform tool of employer branding—its significance and reception depend on industry, region, and employee profile. In some contexts it acts universally, while in others it differentiates employer attractiveness according to cultural and occupational expectations.

The literature review highlights areas requiring further exploration. First, there is a lack of conclusive evidence regarding the role of authenticity and communication consistency in shaping candidate decisions and employee loyalty. Second, the significance of individual CSR dimensions (social, ethical, environmental) in shaping employer attractiveness across cultural and industry contexts remains insufficiently studied. Third, generational and profile differences—for example, between manual and office workers or candidates from humanities versus technical fields—are rarely considered. These gaps point to the need for further empirical research to better understand under what conditions CSR strengthens employer branding and when its impact is limited.

Limitations

A limitation of this review is the heterogeneity of measurement approaches across studies. While some research treats CSR as a single construct, others differentiate between social, ethical, and environmental dimensions, leading to inconsistent findings. Moreover, differences in communication channels (e.g., recruitment advertisements vs. corporate websites) further complicate comparability. This diversity reduces methodological transparency and makes synthesis challenging. Future research should adopt standardized frameworks or meta-analytic techniques to enhance comparability and reliability.

Future Research Agenda

Future research should explore under what conditions CSR strengthens employer branding and when its impact is limited. In particular, studies should examine the role of authenticity and communication consistency in shaping candidate decisions and employee loyalty. Further work is needed to assess the relative importance of social, ethical, and environmental CSR dimensions across industries and cultural contexts. Generational and occupational differences—such as between manual and office workers or humanities versus technical

candidates—also require systematic investigation. Addressing these gaps would provide a more nuanced understanding of CSR's role in employer branding.

6. Summary

Corporate Social Responsibility (CSR) is an integral component of employer branding, although its significance varies depending on cultural, industry, and generational contexts. Research indicates that CSR enhances employer attractiveness, strengthens organizational reputation, and fosters employee loyalty; however, its effectiveness depends on the authenticity of actions, the consistency of communication, and alignment with the values of candidates and employees.

Social and ethical initiatives—such as employee well-being, workplace safety, diversity, and integrity—exert the strongest influence, as they are perceived as direct care for employees and as the foundation of trust. The environmental dimension is gaining increasing importance in contexts subject to ecological pressures, while volunteering and inclusiveness further reinforce loyalty and contribute to building an authentic image of a "caring employer".

CSR, however, is not a universal tool. In some cultures it operates cross-sectorally, while in others it differentiates employer attractiveness depending on industry, region, and employee profile. The nature of work (manual versus office-based) also shapes CSR perception. In practice, this means that organizations should tailor CSR communication to sector-specific characteristics and cultural expectations in order to effectively build an attractive employer image.

Theoretical Implications

This review advances the understanding of CSR as a multidimensional antecedent of employer branding. It demonstrates that social, ethical, and environmental CSR dimensions exert differentiated effects depending on cultural, industry, and employee contexts. The findings contribute to signaling theory by showing that CSR functions as a symbolic attribute of employer branding, shaping candidate perceptions through authenticity, communication consistency, and value alignment. Moreover, the review highlights the need for standardized measurement frameworks to address heterogeneity in CSR operationalizations, thereby strengthening methodological transparency in future research.

Practical Implications

For practitioners, the findings provide guidance on how to integrate CSR into employer branding strategies. Organizations should prioritize employee-related CSR activities as these exert the strongest influence on employer attractiveness. CSR communication must be

authentic, consistent, and evidence-based; overly promotional messages generate skepticism and reduce credibility. Integrating CSR into recruitment strategies, onboarding processes, and internal communication builds trust and loyalty. Importantly, CSR reputation can compensate for lower wages, offering firms a competitive advantage in talent acquisition. Tailoring CSR communication to generational and occupational expectations further enhances effectiveness.

Future Research Directions

The findings also highlight the need for further comparative research to better understand differences in CSR perception across cultures, industries, and generations. Future studies should examine the role of authenticity and communication consistency in shaping candidate decisions and employee loyalty, assess the relative importance of CSR dimensions across contexts, and explore generational and occupational differences more systematically. Addressing these gaps would provide a more nuanced understanding of CSR's role in employer branding.

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MANAGING ACADEMIC DROPOUT: AN INNOVATIVE SERVICE FOR MITIGATING INFORMATION APATHY

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Purpose: The paper presents an innovative academic service designed to prevent student drop-out by operationalising the research findings on information apathy, a newly conceptualised phenomenon in information science. The goal is to demonstrate how information science can contribute to academic retention by developing a professional, ethically responsible service that supports students experiencing informational dysfunctions that impair their motivation, decision-making, and agency.
Design/methodology/approach: The study applies the design-science research logic combined with analytical-descriptive approach and draws on empirical study and conceptual work previously reported in Korycińska (2025). The service is analysed through the lens of eight parameters defining a viable knowledge product, integrating the Knowledge Readiness Level Framework (KRLs) and elements of design thinking, phenomenon-based learning, and co-creation with students. The theoretical framework is grounded in academic drop-out prevention models and information behaviour theories within higher education.
Findings: The analysis demonstrates that the proposed service meets the criteria of a knowledge product and an innovative service in higher education. It addresses informational, motivational, and behavioural vulnerabilities linked to academic disengagement and aligns with current best practices in primary, secondary, and tertiary drop-out prevention. The prototype has reached level 5 on the Knowledge Readiness Level scale, with ongoing development aimed at level 6. Expert validation confirms its conceptual soundness and its potential for implementation in academic settings.
Research limitations/implications: The service remains at the pre-implementation stage and requires further empirical testing in diverse academic environments to confirm its scalability and measurable impact on retention. Future research should focus on longitudinal evaluation of outcomes and cross-institutional adaptability.
Practical implications: The service can be implemented without additional infrastructure costs and may be delivered by students, librarians, or academic staff within existing university structures. It offers a replicable, low-cost model for strengthening students' informational resilience and preventing premature withdrawal from studies.

Social implications: By enhancing students' informational well-being and resilience, the service contributes to reducing academic exclusion and promoting mental and social stability in the academic community. It can be adapted to non-academic contexts, supporting informational health and workforce retention.
Originality/value: This is the first study to propose an academic service explicitly derived from research in information science and framed as a knowledge product. The service, delivered within an ethics-of-care paradigm and under the guidance of Self-Determination Theory (SDT), introduces a novel application of informational resilience in higher education and extends the conceptual reach of information science into the field of academic retention and student support.
Keywords: academic drop-out prevention; information apathy; knowledge product; informational resilience; higher education innovation.
Category of the paper: Research paper / Conceptual paper.

1. Introduction

Academic drop-out is a global phenomenon of multifaceted causality and far-reaching social, economic, and personal consequences. Managing it through preventive strategies and the proactive enhancement of student retention has therefore become a key responsibility of higher education institutions (HEIs). The aim of this article is to present a possible operationalisation of research findings on information apathy by using them as the foundation for a specialised service forming part of academic drop-out prevention programmes at Polish universities.

This study adopts a design-science research logic (Storey, Baskerville, Kaul, 2025), wherein research-borne theory informs the creation of a service prototype, which in turn functions as an empirical testbed for refining theory. Specifically, information apathy is conceptualised as a maladaptive response to informational discontinuity, producing behavioural, motivational, and cognitive effects detrimental to academic persistence.

The proposed service thus represents both: 1) a conceptual contribution, advancing understanding of information apathy as an information-behaviour phenomenon linked to academic risk, and 2) a pragmatic contribution, designing an intervention intended to alleviate this condition and support students' academic resilience.

Although the service has not yet reached full implementation maturity, its conceptual and functional characteristics position it as a promising candidate for staged deployment and evaluation in academic environments. The forthcoming empirical phase will focus on incubation, pilot studies, and iterative refinement. At this stage, while immediate transfer to institutional practice is premature, the initiative already demonstrates qualities that warrant sustained development and, at minimum, justify dissemination of its underlying conceptual approach.

The service in question is conceived as a hybrid intervention that combines institutional preventive support, delivered under the auspices of the university, with personalised, student-centred guidance tailored to individual needs. Its anticipated outcome is the strengthening of students' academic competences and, consequently, a reduction in the risk of attrition.

The very idea of elaborating the service emerged from the application of a heuristic method (Antoszkiewicz, 2016) within a research and development process initially conducted under the Technology Readiness Level (TRL) model, with the aim of identifying the application potential of research findings on information apathy, a novel concept developed within the discipline of information science, itself a subfield of communication and media studies (Korycińska, 2025). The service is characterised using the method of descriptive analysis (Brożek, 2017).

The article is divided into three main parts. Part 1 establishes key definitions, presents statistics illustrating the scale of academic drop-out in higher education, and outlines the theoretical framework of academic prevention in which our proposed service is situated. Part 2 summarises the current state of research on drop-out prevention based on a review of recent literature (2020-2025). Part 3 offers a detailed description of the service, structured around eight parameters that, in our view, substantiate its potential for implementation within academic settings.

2. Definitions, Statistics, and Theoretical Framework

Drop-out, understood as "withdrawal from a chosen course of study before obtaining a degree, regardless of the reasons or circumstances", is an increasingly prevalent phenomenon, both in Poland and across other European Union countries (*Zjawisko drop-outu*…, 2020). It serves as a key quantitative indicator of how effectively the higher education system supports students from admission through to graduation, and as a measure of universities' capacity, under changing societal and technological conditions, to provide learners with the resources necessary to complete their studies within a reasonable timeframe (*Education at the glance*…, 2025).

As synthesised by Ewelina Konieczna from multiple scholarly sources, Polish academic discourse most frequently equates drop-out with academic failure, the cumulative outcome of overt or latent difficulties experienced during the course of study. It represents the inverse of academic success, defined as the failure to achieve "the intended goal of studies (obtaining a qualification appropriate to the level of study) within the time frame prescribed by the curriculum". The difficulties that lead students to abandon their studies, conceptualised as "obstacles to the realisation of intended or ongoing actions", may originate either in the student's environment (e.g. excessive academic demands, ineffective teaching, or limited access to information) or within the student themselves. They are thus both subjective and

objective in nature (Konieczna, 2019, p. 66). While some scholars caution against automatically equating drop-out with academic failure, arguing that, unlike fall-out, it may at times mark the beginning of a positive new trajectory, in this article we focus on those dimensions of drop-out that entail personal distress or suffering. Accordingly, we adopt the definition that aligns drop-out with academic failure (*Education at the glance*…, 2025).

As for the scale of student withdrawal from higher education in Poland, the most recent national dataset remains the report *Zjawisko drop-outu na polskich uczelniach* [*The phenomenon of drop-out in Polish universities*] (2020), prepared by the Laboratory of Statistical Analysis of the National Information Processing Centre (OPI) (*Zjawisko drop-outu*…, 2020) for the Ministry of Science and Higher Education. According to this report, between 2012 and 2020 over 1.3 million students discontinued their programmes and did not re-enrol within a year of removal from the register. The drop-out rates were 46% for first-cycle (bachelor's) studies, 30% for second-cycle (master's) studies, and 41% for long-cycle master's programmes (*Zjawisko drop-outu*…, 2020).

The principal international reference source is the annual OECD *Education at a Glance* report. According to its latest edition (2025), based on data from 2023, the drop-out rate after the first year of tertiary education, by level of education entered, was 19% for first-cycle students (compared with the EU and OECD averages of 13%) and 14% for students enrolled in long-cycle master's programmes (with corresponding averages of 7% for the EU and 6% for the OECD) (Figure 1, Appendix). However, the figures for all levels of study combined present a less favourable picture. The completion rate of full-time students at any tertiary level by the end of the theoretical duration of the programme stood at 53%, compared with 43% for the OECD and 44% for the EU (Figure 2, Appendix).

Consequently, the drop-out rate in Poland reached 47%, a value lower than the OECD and EU averages (57% and 56% respectively), but one that, in absolute numbers, corresponds to a vast cohort of students effectively lost to the higher education system.

In the OPI report, the only individual cause of study withdrawal associated with the cognitive-affective domain was stress, classified under the broader category of "health problems". It was noted that for some respondents, this was the principal reason for discontinuing their studies. Interestingly, all identified sources of stress were external to the individual and included an excessive academic workload, unapproachable or unsympathetic lecturers, financial difficulties, and family pressure to complete the degree. The consequences of chronic stress included physical exhaustion, burnout, sleep disturbances, and learning difficulties; in extreme cases, hospitalisation due to severe health disorders was reported. None of the former students surveyed had sought psychological support.

In Polish literature, Zając and Komendant-Brodowska (2018) proposed a typology of university drop-out encompassing three principal pathways: planned resignation (for instance, enrolment motivated by access to discounts), academic failure (69% of students from the lowest quintile of secondary-school leaving examination scores discontinued their studies during the

first year), and disappointment with the program (over half of students reported unfamiliarity with its structure and requirements). According to these researchers, an inappropriate choice of program, often rooted in insufficient knowledge of the curriculum, frequently resulted in disappointment. They also identified difficulties in social integration: some students noted problems with fitting into new groups in which they felt unwelcome, while others pointed to liberal admission policies and the consequent disparities in academic preparedness between the strongest and weakest entrants. The typology developed by Zając and Komendant-Brodowska (2018) thus demonstrates that university drop-out is not a one-dimensional phenomenon but rather the outcome of multiple, and often interrelated, factors.

Notwithstanding this, numerous recent findings, including systematic reviews, emphasise the importance of individual predictors of drop-out that are rooted in the student's subjectivity and concern the way in which the academic world, including its distinctive informational ecosystem, is experienced. Małgorzata Rosalska refers to these factors as "biographical", as they are directly linked to the characteristics, experiences, and personal resources of at-risk students who effectively self-exclude from the process of study. She argues that taking such factors into account, alongside systemic (institutional) causes, is a *conditio sine qua non* of effective prevention of academic failure. Rosalska posits that universities can reduce drop-out rates through preventive measures aimed at developing students' academic competences (Rosalska, 2019). Many international authors likewise explicitly or implicitly suggest the value of various educational offerings that strengthen students' study-related capabilities and, consequently, improve retention. What distinguishes Rosalska's approach is her consistent use of the concept of academic competences. She stresses that these competences do not merely coincide with learning skills (although they include them), but encompass all activities undertaken by the student as a result of the status they have acquired, performed within the university environment and at its interface with the socio-economic context. This perspective aligns fully with the aims of the present article and therefore serves as the theoretical foundation of our analysis.

Rosalska draws on the fourfold classification of academic competences proposed by Buis, Post, and Visser (2016), who distinguish thirteen specific competences grouped into four areas (Rosalska, 2019, pp. 244-246). In the context of this article, three of these areas are of particular relevance.

The first area encompasses competences that determine the effectiveness of studying. Among these are the ability to organise one's own work across different time frames, the capacity to maintain concentration on tasks, to take examinations effectively, and to sustain an adequate level of motivation (Buis, Post, Visser, 2016, p. 17).

From the second area, which concerns the ability to conduct independent research, one competence of particular interest is the capacity to engage in conversation and discussion with individuals (experts, supervisors, lecturers, tutors) with whom the student collaborates while undertaking educational or research projects, internships, or placements. The intention is that

students should, first, learn to overcome any internal resistance to direct verbal communication with academic interlocutors in study-related situations, and second, come to appreciate the value of information obtained from personal sources. This pertains both to information required for the completion of academic tasks and to the acquisition of knowledge about interpersonal and social relations. The second area also includes another competence whose deficiency may heighten the risk of drop-out – namely, proficiency in searching for scholarly information in appropriate sources and in collecting, analysing, and processing empirical research data (Buis, Post, Visser, 2016, p. 17).

From the perspective of this article, the fourth competence area, referred to by the authors as critical attitude, is also of particular significance. It comprises two specific competences: the ability to participate in discussions, debates, and critical dialogues, and the ability to engage in reflection ((Buis, Post, Visser, 2016, p. 108). Practising academic discussion and debate develops not only the scholarly principles of evidence-based argumentation but also, from an ethical and emotional perspective, the capacity to tolerate confrontation with opposing viewpoints. The ability, and, in time, the need and habit, of reflection concerns self-examination: one's own motivations, aspirations, and limitations, as well as the value of academic forms of work. This domain also encompasses questions about the relevance, in future professional environments, of such practical skills as teamwork, giving feedback, acting as a student representative, or participating in student governance. Rosalska observes that "within academic communities, competences in this area are of great yet underestimated importance" (Rosalska, 2019, p. 246).

Her approach is particularly inspiring because, although her article is intended to be general and introductory, it effectively outlines a comprehensive framework for the prevention of academic drop-out. She achieves this by applying the classical three-level model of prevention, well established in pedagogical theory: primary, secondary, and tertiary.

Primary prevention encompasses all students in the early years of study and focuses on developing the fundamental skills necessary for independent learning and for performing tasks required by individual courses. It is worth noting that all the competences identified by Rosalska within this domain are, without exception, included in the syllabi of first-cycle courses across general university programmes. Yet, since this has not succeeded in halting the progression of drop-out, it seems that the manner of implementation requires modification at the institutional level.

Given the aims of this article, the two remaining levels of prevention are of greater interest. Secondary prevention involves creating individualised forms of support and compensating for vulnerabilities in ways tailored to the needs of specific students. It is directed towards those at elevated risk, individuals willing to seek assistance because, in their subjective assessment, they experience difficulties in studying and sense an emerging dynamic of disengagement. In the English-language literature, such initiatives are generally referred to as academic guidance (see, for instance, Delgado-García et al., 2025). According to Rosalska, this level of

prevention may be undertaken by academic advisors, tutors, or psychological counsellors specialising in study-related issues. Their role is to equip students with the resources necessary to manage emotional and motivational stress, imperfect time management, task prioritisation, interpersonal difficulties, or a loss of sense of purpose. To this catalogue one might also add support for students in the process of resilience following a crisis of agency. In any case, the focus of this work lies in the enhancement of soft competences.

Tertiary prevention, in turn, constitutes an intervention aimed either at halting an already initiated process of withdrawal or at facilitating the return to study of a person who has already left university. For the sake of accuracy, let us add that the revised 2019 edition of this book retains the same division into areas of academic competences (Van der Gaast, Koenders, Post, 2019).

3. The state of research on academic drop-out prevention

Recent literature devoted to the prevention of academic drop-out is less extensive than might be expected, given the significance of the problem, at least on the scale of the EU and OECD. This is evidenced by the results of searches conducted in the Scopus, Web of Science, and Embase databases, presented in Table 1.

Table 1.
Search streams

Database	Query	Results before/after duplicates removal and selection
Scopus	(TITLE(academic dropout OR university dropout) AND TITLE(prevent*)) AND PUBYEAR > 2019 AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"re"))	8/8
WoS	(((TI=(academic dropout OR university dropout)) OR TI=("higher education" AND dropout))) AND (TI=(prevent*))	18/11
Embase	('academic dropout' OR 'university dropout') AND [2020-2025]/py AND ('article'/it OR 'clinical trial'/it OR 'review'/it)	24/6
	Total number of relevant papers	25

Source: authors' own compilation.

A targeted search strategy was employed to identify publications dealing specifically with the prevention of academic drop-out; therefore, keyword occurrences were limited to publication titles. The search included research papers, reviews, and conference papers, while in the Embase database, articles, clinical trials, and reviews were considered. The chronological scope was limited to the years 2020-2025, reflecting the view, articulated in the literature, that remote learning and the social isolation associated with the COVID-19 pandemic marked a turning point in approaches to academic retention and perseverance (Gonzalez et al., 2025).

A subject-matter overview of the collected material (25 articles) is presented in Table 2. For each publication, the following aspects were specified: 1) whether it includes a specific proposal for drop-out prevention measures, i.e., whether it displays a conceptual description of an as yet unimplemented project or a recommendation to design a particular tool or action based on empirical findings, or whether it reports on testing or pre-implementation validation of a tool already in operation or at the final stage of development (column "Measure proposed: Yes/No"); 2) the method applied by the researchers and the purpose of their investigation (column "Method/Goal"); and 3) the tool or intervention that was developed or implemented. Publications were arranged in reverse chronological order.

Table 2.
Results of the bibliographic search for the literature review

References	Measure proposed	Method/Goal	Tool/Action developed
(Romero, Liao, 2025)	Yes	design of a machine-learning models for predicting drop-out	Generalized Additive Model (GAM)
(Ticona et al., 2025)	Yes	design of a machine learning based tool to facilitate early detection of potential drop-outs + usability tests	SDR-Explorer, LLM-assisted visual analytics system
(Salazar et al., 2024)	Yes	prediction of drop-out	AI application for predicting academic performance
(Cruz et al., 2024)	Yes	screening survey to identify students at high risk of drop-out	screening tool + scoring system
(González-González et al., 2023)	Yes	survey, prediction & diagnosis of drop-out	"Survey on Successful Student Retention"
(Kantor et al., 2023)	Yes	systematic review protocol for comparing the effectiveness of customised educational and psychological intervention vs. standard care in HEI in enabling perseverance in students with autism spectrum assessed	systematic review protocol for assessing interventions such as: meta-cognitive and self-regulation training, psychological counselling, social skills training, peer-mentoring/academic coaching
(Urbina-Nájera, Méndez-Ortega, 2022)	Yes	design of a predictive model to anticipate drop-out	model integrating neural networks and decision trees
(Amor, Villamil, Dios, 2021)	Yes	design and validation of a survey tool for assessing guidance and tutoring as a possible protective factor against drop-out prevention in Latin American universities	"Questionnaire for the Assessment of Guidance and Tutoring in Higher Education" (Q-AGT)
(Bustamante, Garcia-Bedoya, 2021)	Yes	prediction of drop-out	machine learning model
(Negreiros, Lanzillotti, de Faria, 2021)	Yes	design of contingency tables and chi-square tests to outline the profile of students prone to drop-out	statistical model
(Amaya-Amaya, Huerta-Castro, Flores-Rodríguez, 2020)	Yes	identification of drop-out causes & influencing factors	Biga Data analytical model
(Olaya et al., 2020)	Yes	design of a tool for assessing the effectiveness of tutorials for students meant to increase retention	uplift modelling framework

Cont. table 2.

(Ferreira et al., 2020)	Yes	design of an interactive visual exploration of data gathered within the FICA project (Tools for Identifying and Combating Dropout) to identify drop-out risk indicators and failure factors	FICAvis, data Visualization tool
(Urbina-Najera et al., 2020)	Yes	design of an attribute selection algorithm to identify major factors influencing drop out decision	multifactorial data mining tool
(González-Ortiz-de-Zárate et al., 2025)	No	statistic inquiry on the effectiveness of a peer mentoring program used in drop-out prevention, encompassing the COVID-19 pandemic	-
(Arian et al., 2025)	No	machine-learning approach based on IPOD model to identify dropout predictors	-
(Heinrichs et al., 2021)	No	qualitative interview study evaluating perception and utility of German HEI counselling services for students	-
(Guerreiro, Jesus, 2025)	No	systematic literature review to assess the utility of peer mentoring in drop-out prevention	-
(Saltos et al., 2025)	No	scoping literature review on the use of AI techniques to predict academic performance, risk of dropout, and the need for academic advising, especially tutoring, with an emphasis on e-learning or technology-mediated environments	-
(Segovia-García, García, 2024)	No	systematic literature review to assess the utility of educational chatbots reducing critical drop-out factors	-
(De la Cruz-Campos et al., 2023)	No	systematic literature review on academic drop-out causes	-
(Ferrándiz et al., 2022)	No	diagnostic survey to identify neurodidactic factors predicting drop-out	-
(de Oliveira et al., 2021)	No	systematic literature review on learning analytics based on data mining procedures to favour retention and prevent drop-out	-
(Marinela, Alexandru, Haralambie, 2020)	No	mixed-method research to identify first-year students at high drop-out risk	-
(Stepanovic-Ilic et al., 2020)	No	exploratory study to analyse drop-out causes, tracking and available prevention forms (based on literature)	-

Source: authors' own compilation.

Out of the 25 analysed publications, concrete examples of actions aimed at preventing academic drop-out were presented in 14. These were mainly large language model (LLM)-based predictive models employing data mining, systems for statistical processing and visualisation of institutional data, survey questionnaires, and one systematic literature review protocol (Embase). The remaining papers did not include any specific proposals.

The sample of publications examined is relatively small, providing no basis for assessing whether the number of concrete initiatives is high or low. What can be stated with confidence, however, is that a large proportion of studies are limited to formulating general recommendations. Only two publications describe interventions supporting the prevention of

academic drop-out in the form of student services, specifically peer mentoring (González-Ortiz-de-Zárate et al., 2025; Guerreiro, Jesus, 2025).

There are, however, no publications presenting an academic service that:

A. fully meets the definition of a knowledge product, that is, one that constitutes a direct manifestation of research conducted within the university that promotes it.
B. satisfies the criterion of radical innovativeness, understood as a solution never previously applied, neither in higher education nor in other spheres of social life.
C. whose prototype emerged through co-creation involving students who themselves potentially belong to the group of service beneficiaries.
D. whose development process was subjected to readiness-level evaluation and conducted in accordance with the methodology of knowledge product incubation in higher education.
E. comprehensively and individually addresses the student's challenges related to adaptation to the university's informational ecosystem and, more broadly, to coping with the demands of the contemporary digital mediasphere.
F. could be swiftly incorporated into primary, secondary, and tertiary levels of academic drop-out prevention and delivered collaboratively by multiple academic actors, at a minimum by students, librarians at various levels, and academic staff.
G. whose implementation within the academic context would be cost-free for both the university and its recipients, requiring no acquisition of additional material resources; and
H. could be exported to other universities or even to non-academic contexts, including business environments, as a means of supporting informational well-being and retention among students, employees, or business partners.

With the aim of addressing this gap, the following section of the paper presents a concise description of a prototype service meeting these criteria. The first six criteria are discussed individually, while the final two (F & G) are considered together.

4. Description of the service mitigating information apathy

The service described below possesses all eight characteristics listed previously (points A-H). This will be substantiated in the subsequent sections of this chapter, where each of these eight features is discussed in turn.

The service consists in providing professional assistance to individuals (in this paper: students) who actively seek ways to overcome information apathy in a professional context. Information apathy is a new scholarly concept outlined, on the basis of long-term research findings, in the article *Designing an information service related to information avoidance*

(Korycińska, 2025). The term originates from information science and denotes "a set of non-adaptive behaviours developed in response to a change (discontinuity) in the way an individual experiences information. It encompasses multiple forms of information avoidance, whose common denominator is the paralysis of core motivational domains, and consequently a functional dysfunction of the individual in everyday life, associated with fatalistic resignation, anhedonia, indecision and inaction, a diminished sensitivity to the informational affordances of the environment, a distinct experience of temporality, a reduced sense of informational security, and prolonged suffering" (Korycińska, 2025, pp. 84-85).

Empirical observations indicate that information apathy manifests itself in two main ways: 1) as the abandonment of information behaviours previously practised by the individual to safeguard their own interests effectively; and 2) as the adoption of new, non-adaptive behaviours, those inappropriate to the intended goal or situation, which undermine the person's sense of agency and self-efficacy. A key distinguishing feature of information apathy is that it develops as a result of an ecosystemic shock that deprives the individual of access to vital informational resources, generating a sense of loss or deprivation. The individual enters an escalating crisis, the resolution of which, i.e. the attainment of informational resilience, requires external assistance. The prototype service is designed to provide such assistance.

It must be emphasised, however, and this is a crucial reservation, that the service is to be delivered exclusively by information professionals and confined strictly to their domain of competence. Accordingly, it explicitly excludes: 1) the diagnosis or mitigation of the psychological or mental causes of information apathy, which fall solely within the remit of qualified specialists (psychologists, psychotherapists, physicians, etc.); and 2) any interventions extending beyond the enhancement of the beneficiary's individual information management practices (Korycińska, 2025, pp. 86-87).

To dispel any potential ambiguities regarding competence, it should be reiterated that the service constitutes a form of academic guidance and is implemented according to the following scheme: 1) substitution – temporarily performing information activities on behalf of the client who has lost the ability to carry them out; objective: to restore a sense of control over reality and to compensate for stressful or objectively threatening arrears; 2) demonstration – modelling new adaptive behaviours for the beneficiary to internalise; objective: adaptation to a new informational ecosystem.

Assuming that a service supporting students in recovering from information apathy can contribute to the prevention of academic drop-out, we propose the following hypotheses:

(H1) Among students, information apathy may arise as a consequence of a rupture (discontinuity) in their established mode of living with information, occurring at the moment of entering higher education.

(H2) The essence of this discontinuity lies in the student's initiation into the academic information culture, to which they fail to adapt without experiencing a marked sense of informational loss and ecosystemic alienation.

(H3) The behaviours characteristic of information apathy fully coincide with the set of causes or risk factors of academic drop-out identified in recent scholarly literature.

(H4) Professional and ethically responsible assistance in coping with information apathy contributes to neutralising the causes and risk factors of academic drop-out and therefore constitutes a preventive measure.

With reference to hypothesis (H2), it should be noted that the cluster of avoidant, withdrawn, and postponing behaviours constituting the pattern of information apathy corresponds to those described as manifestations of the causes or predictors of academic drop-out across all three explanatory models: the sociological, the psychological, and the integrative model combining both.

To recall briefly: in the sociological model, the principal risk factor for dropping out is poor integration into the institutional and social academic system (Tinto, 2010, pp. 51-89), including the university's information culture[1], that is the inability to bridge the gap in one's informational life caused by entry into the university environment. The psychological model, by contrast, focuses on the personal attributes and behaviours that lead students to decide to leave higher education. Gonzalez et al. write: "Students enter university with pre-entry psychological traits like self-efficacy and attributions. These traits influence their interactions with the institutional environment, which trigger psychological processes such as self-efficacy assessment and coping. Successful processes enhance self-efficacy, reduce stress, and foster internal attribution and motivation, aiding academic and social integration, which positively influence students' persistence and determination. For psychological theories, the focus is placed on individual self-regulatory long-term processes, meaning that students' dropout is driven and regulated from within, placing less emphasis on institutional factors" (Gonzalez et al., 2025; Bean, Eaton, 2001; de la Fuente-Arias, 2017).

Hypotheses (H1)-(H4) require empirical verification during the incubation and implementation of the service within the academic environment. Although the service is not yet ready for transfer to practice, it possesses qualities that, in our view, make it a promising candidate for further development and at least justify the dissemination of the underlying concept.

To present the service concept synthetically, its key aspects are discussed below according to the eight criteria outlined in the preceding section (A-H).

A. Knowledge product

The proposed service is an operationalisation of the research presented in the article (Korycińska, 2025). It therefore meets the criteria of a knowledge product (KP), defined as "knowledge resulting from research with potential to improve individual or public health. KPs involve knowledge emerging from scientific research (i.e., systematic, internally valid data collection and analysis aimed at drawing broader, externally valid inferences), [that] might prove effective when applied in specified real-world settings (…). KPs can therefore arise from

research addressing questions around conception, formulation, applications, or context-specific uses and policies. Examples of KPs include such outputs of research as (…) conceptual and analytical tools and methods, (…) information or guidance used to improve health and performance" (Engel et al., 2019).

It is somewhat surprising that the term knowledge product is used in the literature exclusively in relation to the health domain, although in our view it is equally applicable to scientific research outputs produced in the humanities and social sciences. Nevertheless, we assume that the research material underpinning our service may be regarded as a knowledge product because it has the potential to enhance health security within the academic environment.

We define information security, in the spirit of information ecology[2], as the creation of a system that protects individuals and communities from the threats inherent in the contemporary mediasphere, including a system for preventing information disorders (Batorowska, 2021, p. 118). Our service may also be classified as a KP in the original sense (derived from medical and health sciences), as it serves to cultivate sound practices in information hygiene (Rudenko, 2025). It should be clarified that the service would first be implemented at the university where the research forming its basis was conducted.

B. Innovativeness

The service is innovative for two reasons. First, its subject matter concerns a phenomenon (a particular complex of information behaviours) that has not previously been identified or operationalised in research. Second, the literature contains no reports of services identical or comparable being implemented in academic settings.

It corresponds to the most consensual definition of service innovation, which states that it is "a novel combination of new and existing knowledge" (Gustafsson, Snyder, Witell, 2020, p. 111), where the degree of novelty is assessed from the perspective of the organisation. The innovativeness of the service can also be inferred from the fact that it emerged within the university's corporate innovation ecosystem, defined as "the set of actors, activities, resources and institutions and the causal interrelations that are in some sense important for the innovative performance of a corporation or groups of collaborating companies and other actors (e.g. universities, institutes, agencies)" (Granstrand, Holgersson, 2020).

According to the standard model of innovation development in services (Figure 3), the full cycle remains incomplete: the innovation has yet to be adopted by the market and to generate added value for stakeholders. The aim of this article is to encourage progress towards this final stage.

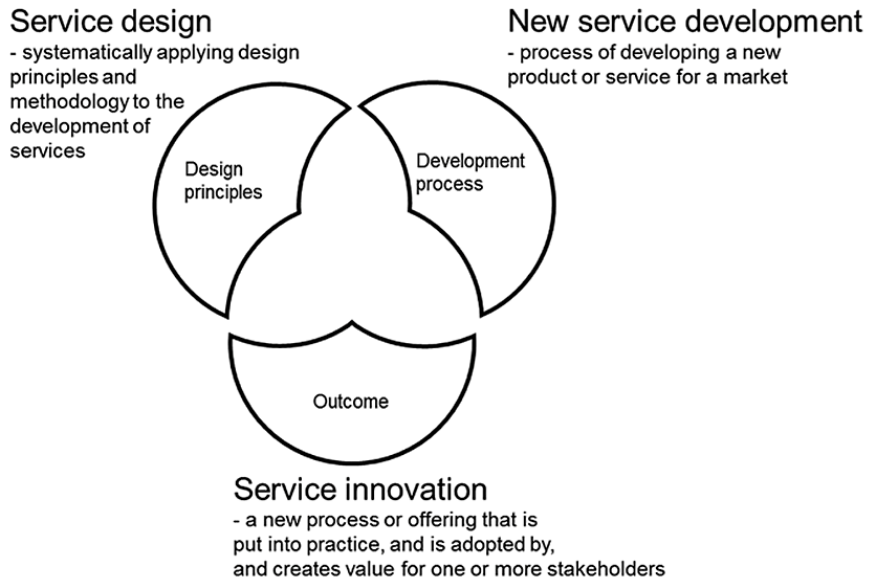


Figure 3. Scheme of service innovation creation.
Source: (Gustafsson, Snyder, Witell, 2020, p. 112).

C. Co-creation

The concept and framework of the service emerged through co-creation processes involving students of the Institute of Information Studies at the Jagiellonian University. Its development employed a combination of teaching and research methods, including simulation, design thinking, project-based methods, personas, and phenomenon-based learning. The latter constitutes part of a broader concept of building the university around a culture of experience, developed by Grzegorz Baran (Baran, 2019). This concept is founded on five pillars: "1) events and interactions as the basis of experience; 2) the human being at the centre of events; 3) logistics instead of tactics; 4) participation; 5) vibrant university" (Baran, 2019, p. 198). The process by which the service was shaped is described in detail in the article (Korycińska, 2025).

D. Maturity assessment

When we began developing the service in 2022, we decided to assess its readiness for market transfer using the 9-level TRL (technology readiness level) scale. In 2024, during routine literature searches conducted for the project, we identified an important study by Luis Salvador-Carulla et al., *Adaptation of the technology readiness levels for impact assessment in implementation sciences: The TRL-IS checklist* (Salvador-Carulla et al., 2024). This systematic literature review examines the application of TRL, including in the development of services, and highlights shortcomings of the method. Consequently, the authors suggest the possibility of using the Knowledge Readiness Level Framework (KRLs) as an alternative (Engel et al., 2019). We concluded that this solution was better suited to the specific nature of our project, and therefore decided to replace TRL with KRLs. Following the pathway outlined by the TRL

model, we reached level 5. Subsequent steps will be carried out according to KRLs. This is feasible because Engel et al. explicitly note a homology between the two systems. Although not fully congruent, they are sufficiently similar to allow a transition during the process. The KRLF ladder is presented in Figures 4 and 5.

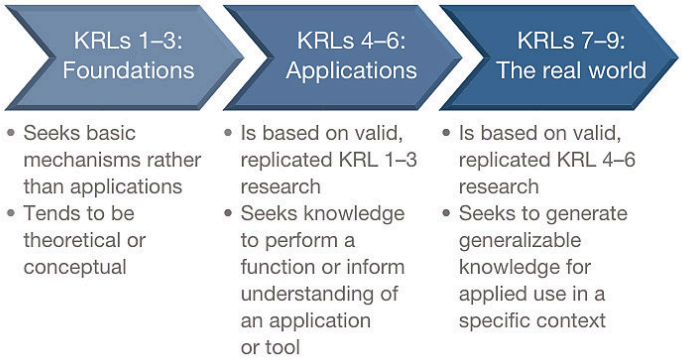


Figure 4. Overall schematic of KRLs.

Source: (Engel et al., 2019).

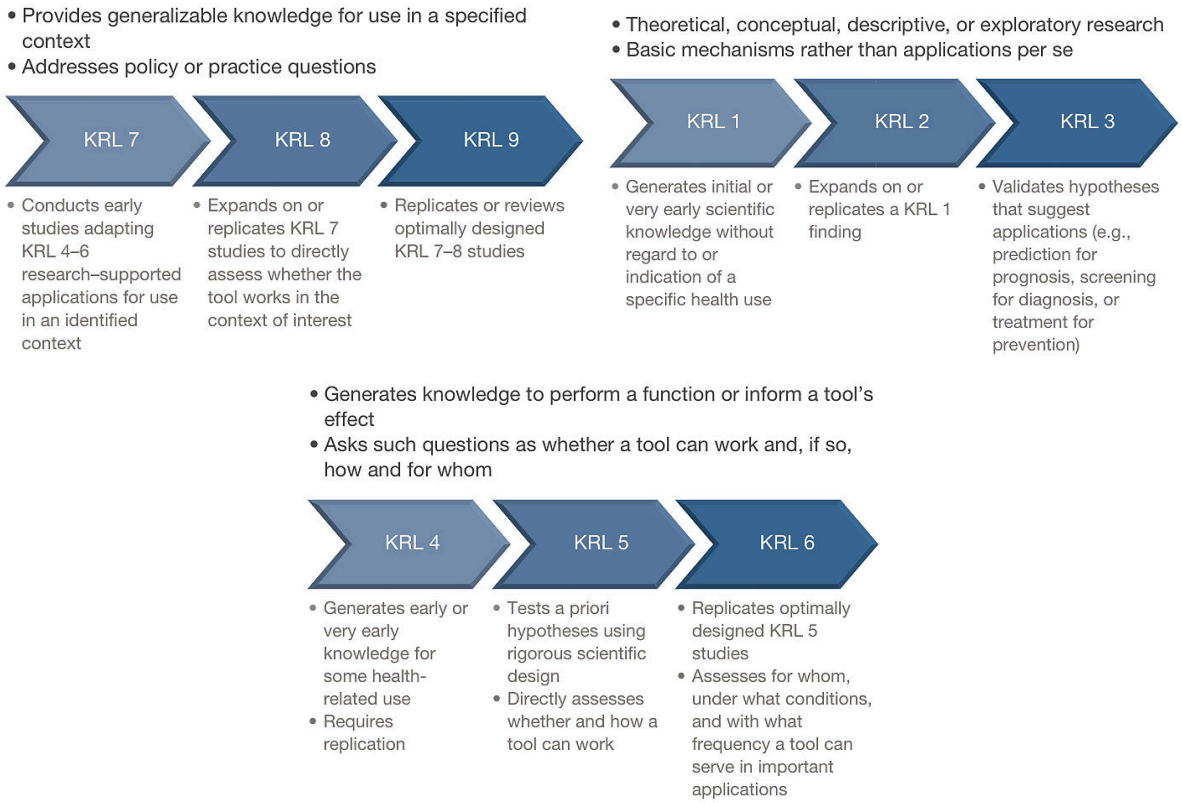


Figure 5. Detailed schematic of KRLs

Source: (Engel et al., 2019)

The article (Korycińska, 2025) describes the process of preparing the service up to TRL level 4 inclusive. In May 2025, a seminar was held at the Institute of Information Studies of the Jagiellonian University, during which the service prototype, together with specific proposals for supporting recipients affected by information apathy, was presented to a panel of seven experts. These included scholars in librarianship and information science, an entrepreneur

managing a knowledge and technology transfer company operating between universities and business, a researcher in psychology, a psychiatrist undertaking postgraduate training in psychodynamic psychotherapy, and a psychotherapist and supervisor with extensive professional experience. During the seminar, we tested hypotheses H1-H4 *a priori*, obtaining confirmation from the experts. It was in the course of the discussion on planning the subsequent stages of project maturation that the experts identified the potential to apply the service in academic drop-out prevention and suggested ways of evaluating its usefulness in this area.

At this stage, the service has therefore reached level 5 of KRLs. Work is currently underway to advance it to level 6.

E. Target beneficiaries

Focusing the service on reversing the effects of information apathy among students means that it would encompass all issues identified in the most recent literature as personal causes (i.e., related to student characteristics) and risk factors of drop-out. These are listed alphabetically in Table 4. We do not divide them into causal factors and predictors, as this distinction is not applied consistently in the literature. Nor do we attempt to group or prioritise them, as we lack the competence to do so. Moreover, such categorisation is not relevant for our purposes, since the reversal of information apathy exerts a global effect on all these problematic aspects. This is because, according to the very definition of information apathy, combating it consists primarily in restoring the student's motivation. Impairment of motivation, in turn, is identified in the literature as the most important correlate of academic drop-out (De Alencar Ribeiro et al., 2025; Quincho Apumayta et al., 2024; Pham et al., 2024; Lorenzo-Quiles et al., 2023). The service should be addressed to students at all levels of education, including doctoral candidates. The rationale is that information apathy may develop in any information user, and its underlying mechanisms are unrelated to the level of study. Apathy is a consequence of any rupture in the way an individual experiences their interactions with a given information ecosystem. Such a rupture may occur at any stage of studying, including among experienced students.

Table 4.
Student-related ("biographical") academic drop-out causes and predictors according to the most recent research output

Feature	Reference
anxiety	(Leow et al., 2025; Sinval et al., 2025; Camarillo-Nava et al., 2024; Lorenzo-Quiles et al., 2023; Buizza et al., 2024a; Vera-Cortázar, Álvarez-Lozano, 2022)
burnout (academic)	(Lorenzo-Quiles et al., 2023; Olson et al., 2023; Estrada et al., 2017) 07/04/2026 09:26:00
competences (academic: low)	(Suárez Perdomo et al., 2025)
depression	(Leow et al., 2025; Sinval et al., 2025; Camarillo-Nava et al., 2024; Lorenzo-Quiles et al., 2023)
efforts and dedication (lack of)	(Suárez Perdomo et al., 2025)
emotional self-regulation (poor)	(Buizza et al., 2024b)

engagement (academic, poor)	(Suárez Perdomo et al., 2025)

Cont. table 4.

engagement (academic: poor)	(González-Morales et al., 2025)
exhaustion (academic: physical and mental)	(González-Morales et al., 2025; Lorenzo-Quiles et al., 2023; Vera-Cortázar, Álvarez-Lozano, 2022; Estrada et al., 2017)
failure and guilt (feelings of)	(Lorenzo-Quiles et al., 2023; Lydner, 2022)
fear	(Lorenzo-Quiles et al., 2023; Vera-Cortázar, Álvarez-Lozano, 2022)
frustration	(Suárez Perdomo et al., 2025; Quincho Apumayta et al., 2024; Lorenzo-Quiles et al., 2023; Vera-Cortázar, Álvarez-Lozano, 2022)
interest in studies (loss of)	(Lorenzo-Quiles et al., 2023)
maladaptation to the university context in terms of competence, autonomy, organization, self-regulation in learning and social skills (lack of integration at university)	(González-Morales et al., 2025; Suárez Perdomo et al., 2025; Buizza et al., 2024a)
motivation (lack of)	(González-Morales et al., 2025; Suárez Perdomo et al., 2025; Buizza et al., 2024a; Quincho Apumayta et al., 2024; Lorenzo-Quiles et al., 2023)
procrastination	(Delgado-García et al., 2025; Gonzales-Morales et al., 2025; Suárez Perdomo et al., 2025)
resilience (poor)	(Suárez Perdomo et al., 2025; López-Aguilar, 2023; Olson et al., 2023)
satisfaction (lack of)	(González-Morales et al., 2025; Buizza et al., 2024b; Lorenzo-Quiles et al., 2023)
self-efficacy (lack of)	(Suárez Perdomo et al., 2025; Buizza et al., 2024b)
self-esteem (lack of)	(Quincho Apumayta et al., 2024; Lorenzo-Quiles et al., 2023)
sense of adequacy (lack of)	(Buizza et al., 2024a)
sense of belonging (poor)	(Álvarez-Pérez et al., 2025; Suárez Perdomo et al., 2025)
sense of insecurity	(Lorenzo-Quiles et al., 2023)
stress	(González-Morales et al., 2025; Leow et al., 2025; Sinval et al., 2025; Lorenzo-Quiles et al., 2023; Vera-Cortázar, Álvarez-Lozano, 2022)

Source: authors' own compilation.

F. Integrating the service into drop-out prevention

A service supporting students in recovering from information apathy may be incorporated into primary, secondary, and tertiary forms of prevention, in accordance with the consensual best-practice recommendation recurrently emphasised in the scientific literature and succinctly summarised by Quincho Apumayta et al.: "To prevent university dropout, it is essential to constantly monitor academic performance and include formal academic reinforcement activities. Educational policies should be designed with the realities and needs of students in mind, using innovative methodologies to increase motivation. Communication between university administration, faculty, and students is crucial in academic retention processes. Strategies to prevent dropout involve constant monitoring of academic performance, designing educational policies aligned with student needs, and implementing interventions that provide support and motivation to at-risk students. Finally, institutional aspects, such as the quality of support services and the availability of academic and social resources, are also critical factors affecting retention" (Quincho Apumayta et al., 2024).

This service may be delivered by students or doctoral candidates in fields related to information science, as well as embedded librarians[3] working in their home academic libraries and, by virtue of their role, familiar with the local information culture (Deja, Wójcik, 2021). Its most natural, though not exclusive, modes of delivery may include mentoring, tutoring, academic coaching, and various workshops in which teaching staff representing information science, particularly specialists in studies of information behaviour, should play a supportive role. These activities could also be implemented under the auspices of university units responsible for ensuring equal access and in cooperation with such units. We propose this form as a priority, as it aligns with current trends in the literature on academic drop-out prevention (Fierro Saltos et al., 2025; González-Ortiz-de-Zárate et al., 2025; Guerreiro, Jesus 2025; Kantor et al., 2023; Skrbinjek, Lesjak, Dermol, 2024, p. 570). Moreover, Yarborough and Fedesco (2020) observe that even simple gestures, such as efforts to get to know students, encouraging them to integrate their personal interests into coursework, or introducing group activities, can strengthen students' sense of connection and relational belonging. A pedagogical approach that addresses these needs is collaborative learning, which involves work in small groups wherein students take an active role in constructing understanding, while the instructor's task is to create conditions conducive to engagement and to provide formative feedback. Such initiatives not only cultivate responsibility and cooperation but also enhance students' sense of belonging and foster the development of durable support networks within the academic environment.

G. Material resources, cost efficiency, and potential for transfer beyond the university

In the proposed format, the service is delivered either on campus or remotely, and therefore does not require the acquisition of additional equipment. In the business model that will be developed at later KRL stages, it will nonetheless be necessary to consider various possible solutions for financing and remunerating the service providers, including cases in which these providers are students. In the longer term, the option of implementing the service commercially on the open market can certainly be envisaged. Such an implementation path has been described by Amelia Gil, Julia Olszewska, Jakub Pietrzak, and Dominika Siciarz, students of the Institute of Information Studies at Jagiellonian University, in the article *Preliminary design of an information service supporting the recovery of information competencies* (preprint), soon to be published in the series *Horyzonty informacji* [*Information Horizons*], which we recommend to interested readers.

5. Limitations

We acknowledge that our transition from a theoretical account of information apathy to the mechanisms underpinning academic dropout is, at this stage, primarily deductive. This is largely due to the paucity of research within informatology that explicitly examines the relationship between students' information competencies and behaviours in the university learning environment, and their potential or actual withdrawal from study. Indeed, we identified only one directly relevant contribution: Hillmert et al. (2019) *Informational Environments and College Student Dropout*, which provides empirical evidence that "informational environments can play an important role for the intention to leave college prematurely beyond academic performance and related factors which have long been studied as predictors of student attrition. The scarcity of such work is further confirmed by the recent and comprehensive *Bibliometric Review of Factors Influencing University Dropout (2018-2022)* by Álvarez-Ferrándiz et al. (2025).

In the absence of established evidence demonstrating the efficacy of optimizing information behaviour as a strategy for reducing dropout, our argument necessarily relies on deduction, albeit deduction grounded in robust premises. The underlying causal chain informing our reasoning unfolds as follows:

a) Empirically anchored research in informatology has demonstrated the objective difficulty of navigating academic information environments, a challenge intensified in contexts of liminality (e.g. entering university, embarking on an academic career) (Ruthven, 2021; Willson, Given, 2020; Willson, 2019).
b) These difficulties render the process of adapting to university information culture emotionally charged, often eliciting negative affective responses.
c) In turn, "emotions and feelings prompt information seeking in multiple ways (starting, expanding, limiting, and terminating), but also lead to information avoidance" (Willson, Given, 2020), because they directly influence the motivation to engage with information. Figure 6 below illustrates the correlations between emotional burden and and information behaviors, including non-using, avoiding and discontinuing, among early career academics (Willson, Given, 2020).
d) Information apathy is a generalized avoidance posture stemming from emotionally induced depletion of motivation. Restoring students' autonomous motivation and sense of agency should, accordingly, mitigate the risk of academic withdrawal.

Although empirical evidence validating this causal pathway is not yet available, our study adopts a design-science research approach precisely to generate such evidence. Through the implementation of the information service described herein, we aim to produce data capable of testing and potentially corroborating these initial deductive propositions.

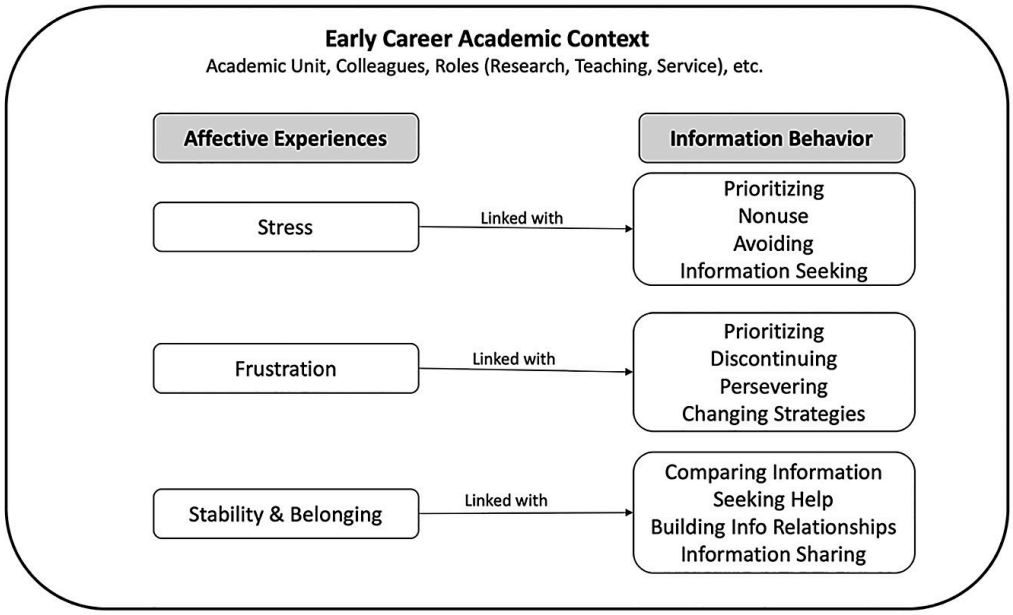


Figure 6. The influence of affective experiences on information behaviour among early career scholars. Source: (Willson, Given, 2020).

Examples of information behaviours associated with information apathy, derived from qualitative inquiry, are presented in (Korycińska, 2025). In their phenomenological concreteness, these behaviours do not diverge from the typical manifestations of information avoidance described in the well-established corpus of informatology research. What distinguishes them, however, is that participants experience them uniformly as debilitating, anxiety-inducing, and obscuring their perception of reality. Hence, the eight features defining the apathetic mode of engaging with information capture these experiential dimensions rather than representing discrete categories of avoidance behaviours.

The innovative component of our service lies in conducting a comprehensive diagnostic assessment of the client's multiple forms of information avoidance prior to implementing tailored interventions aimed at addressing underlying motivational deficits. These interventions will be selected (combined and adapted as necessary) from the broad repertoire of modalities designed to support personal information management (PIM)[4]. The service will be implemented within an ethics-of-care framework (Cushing, 2023) and shaped by Self-Determination Theory (SDT) as developed by Jeno, Danielsen and Raaheim (2018). In this setting, SDT, which "embraces a growth-centred approach", provides a means of directing analytic focus toward the motivational bases of students' academic success. As the authors emphasise, "it differentiates motivation as classes that vary in relative autonomy. Autonomous motivation encompasses behaviours high in autonomy, that is, done out of choice, with a sense of volition and self-endorsement. In contrast, controlled motivation is very low in autonomy and concerns activities done for a separate consequence (e.g. obtaining or avoiding external or internal contingencies). Autonomous motivation, as opposed to controlled motivation, is associated with high-quality

functioning, positive psychological well-being, and behavioural outcomes such as persistence and achievement in school" (Jeno, Danielsen, Raaheim, 2018).

The overarching purpose of our service is thus to assist students in their everyday personal information management, thereby alleviating the stress generated by academic information culture and, in consequence, restoring autonomous motivation. Peer-based support situated within an ethics-of-care environment will help meet apathetic students' "basic needs for autonomy (experience of choice and self-endorsement), competence (feeling efficacious), and relatedness (being cared for)", which are "assumed to facilitate students' autonomous motivation, persistence, and learning". Following implementation, we plan to assess outcomes using, at minimum, an SDT-informed scale and the Academic Motivation Scale (Kotera, Conway, Green, 2023).

6. Conclusion

The study introduces a research-informed, ethically grounded service designed to help students overcome information apathy, a condition that undermines their ability to engage with the academic environment and heightens the risk of drop-out. By translating conceptual insights from information science into a practical, preventive intervention, the project demonstrates how this discipline can meaningfully contribute to institutional strategies for enhancing student retention.

Developed through co-creation and situated within the Knowledge Readiness Level Framework, the service represents an academically rigorous yet operationally feasible form of innovation. Although the prototype has so far reached level 5 of the Knowledge Readiness Scale, expert evaluation has confirmed both its conceptual maturity and its potential for implementation. Progressing toward higher levels of readiness will require further empirical validation to assess its effectiveness across diverse institutional contexts.

Ultimately, the project offers a novel model of academic guidance that builds informational resilience and restores student motivation. Its conceptual coherence and low-cost feasibility make it adaptable to different settings and applicable across all levels of prevention. By reframing student support as a matter of informational well-being, the study links individual resilience with institutional responsibility for sustaining inclusive, responsive learning environments and equitable access to information-related competencies. From a policy and practice perspective, the proposed service promotes information behaviour interventions as relevant tools for addressing academic retention challenges.

By integrating theoretical innovation with applied service design, the project advances a research agenda that situates information apathy as both a conceptual and practical problem, one that the information science community is uniquely positioned to address.

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Footnotes

[1] "Information culture is understood as the norms of information behaviours towards information management in workgroups and organisations that facilitate conditions for effective information use and knowledge creation" (Deja, Wójcik, 2021).

[2] Information ecology: "a discipline concerned with uncovering the laws governing the flow of information within biosystems, including humans and society, their impact on individuals' mental, physical, and social health, and the development of appropriate methodologies aimed at shaping the information environment" (Eryomin, 1998, p. 251, cited in: Babik, 2022, p. 680).

[3] Embedded librarian is defined as "a member of the academic community who is a professional information expert with knowledge of the problems, needs and work environment of a specific group of users. The main role of an embedded librarian as a member of the academic community is to facilitate the process of effective information management. As S. Nagarkar and D. Murari pointed out: Instead of sitting in the library, embedded librarians work outside the library in a group of other domain experts. As a co-worker, they understand the information needs of other group members and try to solve these needs immediately (Nagarkar, Murari, 2010, p. 375; Deja, Wójcik, 2021).

[4] In information science, personal information management (PIM) "refers to people's activities utilized for acquiring, organizing, maintaining and retrieving information" (Alon, Forkosh, Baruch, Nachmias, 2020).

Appendix

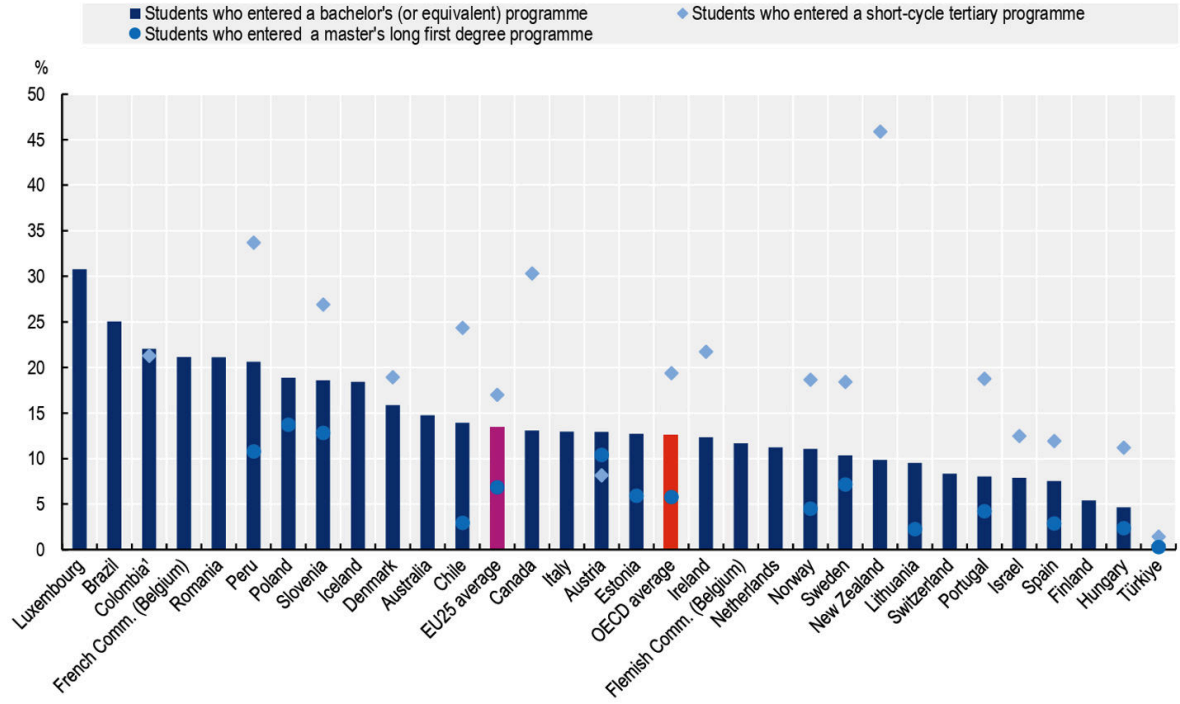


Figure 1. Drop-out rates after the first year of tertiary education, by level of education entered (2023).

Source: Education at a Glance: OECD Indicators 2025.

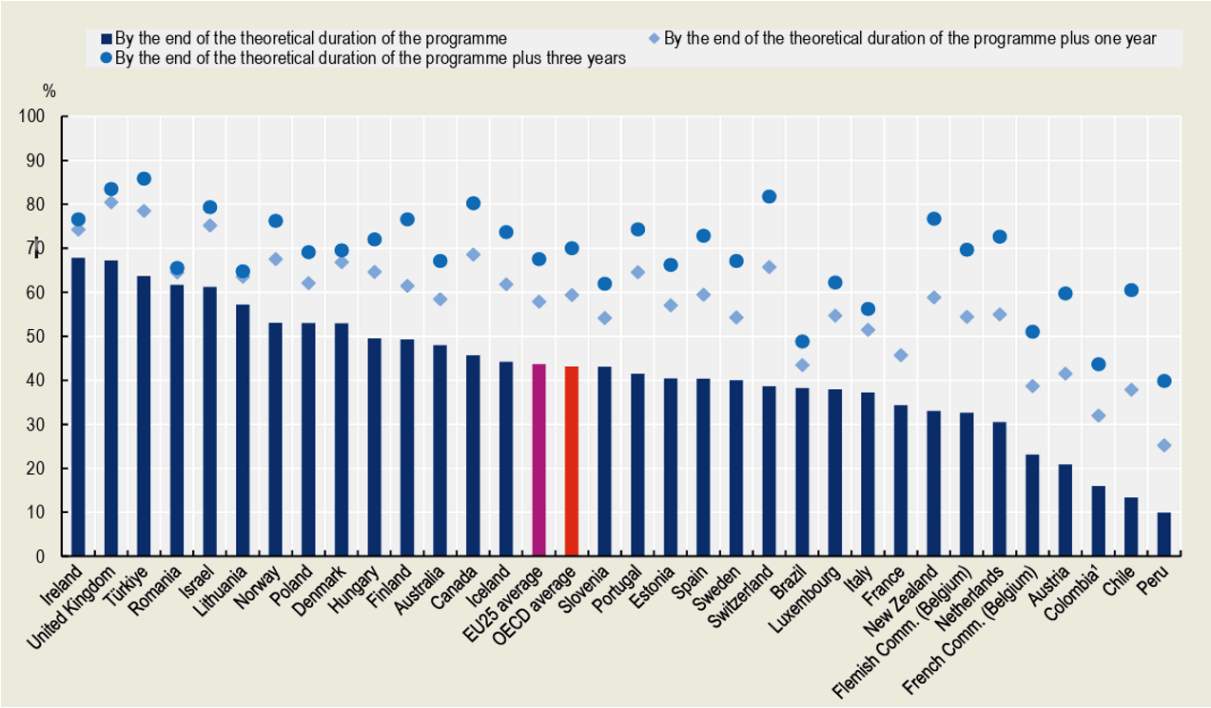


Figure 2. Completion rates of full-time students at any tertiary level (2023).

Source: Education at a Glance: OECD Indicators 2025.

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THE CONCEPT OF A SOCIAL COMPETENCE MODEL FOR MEDICAL PERSONNEL

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Purpose: The purpose of this article is to present the concept of a social competence model for medical personnel and other medical professions.
Design/methodology/approach: In the face of the changing society and new economic and social challenges, such as internationalisation and cooperation between science and business, the new model of relations with patient, the healthcare sector, requires the implementation of new solutions in order to facilitate provision of medical services. The medical industry brings together not only doctors and patients, but also scientific, business, therapeutic and many other sectors. Particular attention should be paid to competences that are often overlooked during education but become very important when starting a career. In this situation, it is necessary to focus on the development of social competences and to attempt to develop model forms of support aimed at soft skills improvement. The analysis includes scientific articles, reports and medical statistics.
Findings: It has been found out that there is no well-developed model for managing social competencies among medical staff. An innovative model for managing soft skills would enable medical and medical-related personnel to more effectively deliver medical, business, and scientific services.
Research limitations/implications: There is no comprehensive social science research that analyses social competences at several levels: professional structures, the level and type of competences, and application requirements. The available analyses are very general and focus only on the communication process, for example, among doctors and nurses.
Practical implications: A practical model, along with a research tool/sheet for assessing and implementing measures to strengthen soft skills, would enable more efficient performance of assigned roles and responsibilities in individual medical and paramedical professions.
Social implications: The health of society is a key indicator of quality of life and social well-being. In a situation of deficits related to social competences, the developed and implemented model would not only allow for a more efficient system of prevention and treatment of patients, but would also contribute to the development of the medical sector in various forms of health service provision.

Originality/value: The article presents an important reflection on the concept of social competences in sociological terms, with reference to a selected professional group. The article may be addressed to healthcare professionals, academics, as well as human resources and professional development managers.
Keywords: model, social competences, medical personnel, social challenges, innovations.
Category of the paper: General review.

1. Introduction

The issue of social competence stems from management disciplines, however, for many years research has also been conducted in the field of sociology and, in this sense, it is associated with considerations such as human capital (Becker, 1994), human capabilities (Sen, 1997) and competence and reflectiveness (Archer, 2018). Presently, the practice of assessing employees in all industries in terms of their competences is becoming quite common. These include hard skills related to the profession, but also soft skills – personal skills (stress resistance, communication skills, composure, etc.). The research on employers' expectations shows that the most valued social competences on the labour market (Jagodziński, 2013) are: self-organisation, punctuality and strong motivation to work (Kocór, Strzebońska, 2011), communication skills, including knowledge of foreign languages (Varga, Szira et al., 2016), creativity and self-improvement (Varga, Szira et al., 2016).

In turn, the research conducted among employers in 11 European countries shows that they value competences related to self-organization (time, pace of work), self-improvement, creativity and analytical thinking, i.e. individual competences related to the characteristics of an individual, rather than social competences such as teamwork and language competences. (Little, Braun, Tang, 2008).

In view of the development of new treatment methods and the need to conduct scientific research and implement research and development (R&D) projects, the question arises as to the model of social competences within medical professions. The complex structure of medical and paramedical professions and areas of healthcare, education in social competencies is inevitable and is even becoming a necessary requirement of the modern labour market.

In humanistic sociology, in the form of symbolic interactionism and phenomenological sociology, attention is drawn to the aspect of competence in everyday thinking and its determinants (Mucha, 1986). E. Mokrzycki, on the other hand, points to the practical aspect of sociology as a socially engaged science, which means that studies and research on the social competences of a selected social group, in this case medical staff, are part of practical analyses and the possibilities of implementing practical solutions (Mokrzycki, 1971). The professional careers and qualifications of medical personnel should take into account not only individual

preferences, but also social expectations and changes in management. K. Frieske (1990), in turn, emphasises the practical model of using sociological knowledge, which is reflected in the theory of sociology in action or practical sociology.

The review of research on healthcare personnel and their social skills clearly shows that most studies focus on relations with patients and communication and the barriers associated with it. The results of the studies indicate that greater attention should be paid to the issues related to a comprehensive approach to various areas of social skills and the need to develop a common concept of a model that serves as a tool for diagnosis and the needs and support of various social skills for different groups of medical staff.

In the context of the rapid development of medical sciences and the involvement of medical personnel in R&D areas (business-related cooperation through the implementation of medical, scientific and design services on a national and international scale), it is necessary to appropriately model social competences, which would allow for more effective actions serving the health of society in a broad sense.

Health is a state of complete physical, mental, as well as social well-being, and individuals and groups must be able to define and pursue their aspirations, meet their needs and change or cope with their environment. Therefore, health is viewed as a life resource, not a life goal. Health is a positive concept, encompassing personal and social resources and physical capabilities, not merely the absence of disease or infirmity (World Health Organization, WHO). This definition is crucial and innovative because it moves beyond the mere negation of health as the absence of disease and strongly emphasizes its positive aspect, namely well-being. This means that in health matters, the focus cannot be solely on diseases and attempts to fight them, but rather on enhancing them. In response to this need, a biopsychosocial model of health emerged as a systemic approach to illness, emphasizing the interrelationship between body and mind and considering disease at all levels. This model deals with the whole person and in this approach to health, competences and qualifications are necessary not only in the scope of individual medical specializations, but also the involvement of all medical personnel in strengthening their own social competences in order to strengthen the health of the society (Łodzińska, 2019).

The developed model of social competences would allow for answering key questions with respect to:

- diagnosis,
- needs,
- support.

The proposed model concept would take into account such detailed scopes as:

- analysis of the didactic process,
- analysis of the job position and workplace,

- analysis of individual resources,
- analysis of institutional resources,
- analysis of support structures.

The concept would also include a jointly developed model (sheet) using research methodology, particularly from the following areas:

- Sociological Sciences.
- Psychology.
- Management Sciences.

There are not many broad, interdisciplinary studies among medical staff on soft skills that analyse the social determinants of the development of these skills and their links to the development of professional skills (e.g. Ye, 2017). This article draws attention to this gap and the need for interdisciplinary research (sociology, psychology, management sciences) not only to monitor the above-mentioned competences on an ongoing basis, but also to develop a specific model at both the education and employment levels and to strengthen various types of social competences. Such a model would allow for the efficient management of soft skills among medical and paramedical staff. It is necessary to conduct sociological research and make comparisons at the level of education, needs and tools strengthening soft skills.

2. Theoretical foundations. Social competences

In order for the treatment and prevention process to bring the expected results, not only financial resources are needed, but also the support of medical staff in those areas of management where deficits have been diagnosed. We define social skills as "a set of behaviours that some people master better than others, which makes them act more effectively in a given situation" (Levy-Leboyer, 1997, p. 32, cited in Jagodziński, 2013). There is a variety of approaches and definitions of social competence, but they can be summarised in one definition proposed by DASCHE (2020): "A single, one-dimensional definition for all is neither possible nor desirable. Despite this diversity of characteristics of social competence conditioned by the tradition of higher education and its legal context, an important feature of all the above approaches can be observed. This is the recognition of social competence as a meta-competence built on knowledge and skills, enriched with axiological reflection allowing for their independent and responsible application leading to social benefits" (Chmielecka, 2020).

This definition implies that there is no single general social competence, but rather many different types. These include, among others:

- skills related to social perception (accurate perception of others, e.g. their intentions, and correct assessment of social situations),
- social sensitivity, empathy, interpersonal decentration,
- knowledge of social rules and the ability to behave appropriately in social situations,
- ability to solve specific interpersonal problems and manage social situations,
- skills necessary for handling conflict situations and situations requiring assertiveness,
- effective self-presentation and the ability to influence others,
- communication skills,
- cooperation skills (Knopp, 2013, p. 2, as cited in: Kruk, 2025, p. 356).

In terms of interaction, the components of social competence are:

- competences determining the effectiveness of behaviour in intimate situations,
- competences determining the effectiveness of behaviour in situations of social exposure,
- competences determining the effectiveness of behaviour in situations requiring assertiveness (Tomorowicz, 2011, p. 92, as cited in: Kruk, p. 356).

The integrated model of social competence proposed by M. Grzesiak (2021) includes five areas covering various clusters of social competence: marketing, relationships, self-fulfilment, management and spirituality (Grzesiak, 2021, p. 129). Social competences are also understood as the ability to establish and maintain relationships with others, the ability to work in a team, the ability to identify social norms, and appropriate moral attitudes related to responsibility (comp. Tinto, 1987).

Empirical research shows that competences positively correlate, among others, with psychological well-being, general life satisfaction, quality of interpersonal relationships, willingness to help others but also with using social support, effective stress-coping strategies, as well as broadly understood adaptation and proper social functioning (Knopp, 2013, p. 2).

The fundamental function of acquiring and developing social competences is to adapt to the social environment, but also to transform it in order to achieve individual and group goals. In this context, the question arises as to what barriers can be observed in the processes of developing the competences of interest to us among medical personnel. Some research shows that the country of origin and education significantly influences the educational experiences of future medical staff, learning styles and the intensity of relationships with the social environment, the professional environment and, thus, the acquisition of social competences. Moreover, significant cultural differences between the country of origin and the country providing medical services cause numerous difficulties in establishing social relationships (Andrade, 2006). This is due to unfamiliarity with the codes of the host culture, a lack of shared biographical experiences, and a lack of language skills (Kamara, 2017).

An example of such a cyclical relationship is social alienation and feelings of estrangement, which are often experienced by patients and medical staff (Sakurai, McCall-Wolf, Kashima, 2010). Research shows that even if the above-mentioned groups create their own groups within the medical community, they will not have as much access to the resources as in the case of contact with residents of the host country, especially in those cities where foreigners constitute a very heterogeneous group (Sawir, Marginson et al., 2008). Social isolation hinders the development of competences, mainly social, cultural and linguistic ones, and a low level of these competences deepens alienation. On the other hand, researchers point out that resource constraints can have a mobilising effect and, by breaking the circular dependency, lead to the development of competences in a multicultural environment, encourage students to reflect on their own cultural identity and evaluate it positively, and strengthen their self-esteem (Starr-Glass, 2014, 2016).

The literature on the issue shows many factors that block or slow down the development of soft skills. It is worth emphasising that the study of this negative impact is not a simple, one-sided relationship, but a circular one. This means that a low level of specific competences (independent variable) affects an individual's functioning in a social environment, limiting access to material, social and institutional resources (dependent variable), and this limitation slows down or blocks the development of competences.

The development of competences depends largely on the material and organizational resources of the healthcare industry, public support, and the entire commercial economy. The starting point for the analysis will be an examination of these resources and an analysis of the support system offered to healthcare workers.

3. Medical Staff and the "Modern Patient"

Healthcare Sector – Description

The healthcare sector in Poland is defined according to the Polish Classification of Activities (PKD), which is the official system used in order to clearly define and organise economic activities carried out by entities on the domestic market. The basic classification section covering the sector's activities is section Q.86 *health care*, which comprehensively describes the activities related to the provision of health services, both those provided by the public health service and by private medical service providers.

The healthcare sector is a complex area of activities that requires the involvement of qualified staff in a wide range of positions and professional specialisations. Key professions and positions in this sector result directly from the specific nature of healthcare processes and the development of modern medical and organisational technologies (Report INDORO, p. 4).

The most important professions and positions include, above all:

- medical specialists,
- nurses and midwives,
- paramedics,
- physiotherapists and medical rehabilitation specialists,
- laboratory diagnosticians,
- medical technicians, operators of specialized diagnostic and therapeutic equipment,
- telemedicine and medical informatics specialists,
- management staff,
- medical caregivers and long-term care specialists,
- health education and promotion specialists,
- radiation protection specialists, medical physicists (Raport INDORO, p. 7).

The expansion of the structure of key professions and positions in the healthcare sector reflects the complexity of healthcare services, the diversity of patient needs, and the dynamic development of new technologies. It is important to emphasize that each of these positions plays a crucial role in the overall functioning of the sector, ensuring the quality, accessibility and efficiency of healthcare services. (Report INDORO, p.7).

An important aspect of the classification of the healthcare sector is the fact that, apart from the strictly therapeutic and diagnostic activities, it also covers advanced technological areas, such as the production and implementation of innovative medical technologies, digitization and activities related to telemedicine (Report INDORO, p. 4). The existence of unlimited contacts via the global Internet also makes it possible to find doctors performing very specific surgical procedures "on the other side of the world". The phenomenon of health tourism is emerging (the global medical services market is regulated by the provisions contained in the so-called GATS General Agreement on Trade in Services) – in order to obtain services unavailable at the place of residence or to purchase services at a more affordable price (Zabielska, 2017, p. 15).

The healthcare sector in Poland is extremely diverse in terms of the number of entities, ownership structure, and territorial distribution. According to official data from the Central Statistical Office (as of the end of 2023), there were 258,774 entities registered in Poland and conducting healthcare activities within the scope of the Polish Classification of Activities (PKD). The vast majority of these entities, 257,202, are private, with only 1572 being public (INDORO Report, p. 8).

The healthcare sector in Poland is characterized by significant level of employment, which results directly from the wide range of medical services provided in both public and private facilities. According to the data from the Central Statistical Office (as of 31 December, 2023), the sector employs approximately 720,270 people. This number covers a wide range of professions - from key medical personnel, through diagnostic and technical staff, to administration and management staff of healthcare facilities (Report INDORO, p. 8).

Organizational and cultural barriers

Hospitals often have deeply rooted organisational cultures and hierarchies that can hinder the implementation of soft skills. These cultural barriers can manifest themselves as resistance to changes when the staff is reluctant to move away from the established practices. A lack of consistency between activities can further complicate the digitisation efforts, since differ priorities and communication breakdowns make cooperation difficult. Furthermore, a lack of support from management can stall initiatives, as leaders play a key role in promoting technology adoption and creating an environment conducive to changes. Rigid organisational structures can create obstacles, hindering the implementation of the flexible processes necessary for effective digital transformation. Overcoming these cultural and structural barriers is essential for the successful development of digitalisation in healthcare environments (Report: 27 Report 2025: EHMA, p. 27).

In this context, the question arises as to what barriers can be identified in the development of the competences we are interested in among medical personnel. Research shows that the country of origin and education has a significant impact on their educational experiences, learning styles and the intensity of their relationships with their social environment. Significant cultural differences between the country of origin and the host country/country providing medical services cause numerous difficulties in establishing social relationships (Andrade, 2006). This is due to unfamiliarity with the codes of the host culture, a lack of shared biographical experiences, and a lack of language skills (Kamara, 2017). In the source literature, there are many factors that block or slow down the development of competences. It is worth emphasising that the study of this negative impact is not a simple, one-sided relationship, but a circular one. This means that a low level of specific competences (independent variable) affects an individual's functioning in the social environment, limiting access to material, social and institutional resources (dependent variable), and this limitation has a slowing down or blocking effect.

An example of such a cyclical relationship is the social alienation and sense of alienation often experienced by patients and medical staff (Sakurai, McCall-Wolf, Kashima, 2010). Research shows that even if patients form their own groups within the "patient" community, they will not have as much access to resources as they would in the case of contact with

residents of the host country, especially in these cities where foreigners constitute a very heterogeneous group (Sawir, Marginson et al., 2008). Social isolation hinders the development of competences, primarily social, cultural, and linguistic ones, and a low level of these competences deepens alienation. On the other hand, researchers indicate that resource limitations can also have a mobilizing effect and, by breaking the circular relationship, lead to the development of competences in a multicultural environment, encourage students to reflect on their own cultural identity and its positive assessment, and strengthen their self-esteem (Starr-Glass, 2014, 2016).

Model of medical personnel social competences management

In the healthcare sector, soft skills are a key element ensuring effective and professional patient care and legal cooperation between medical teams. Due to the specific nature of the sector - requiring constant communication, interdisciplinary collaboration and handling emotionally challenging situations - soft skills are crucial to the proper functioning of medical facilities.

The most important soft skills in the healthcare sector include:

- interpersonal communication,
- empathy and emotional intelligence,
- ability to work in a team,
- stress management and mental resilience,
- conflict management,
- professionalism and professional ethics,
- ability to organize own work and manage time.

Research carried out in this area in many countries indicates an increase in the importance and role of soft skills (social skills, predispositions, personality traits, internal motivation) in proper medical care that is in line with the medical practice and patient expectations. Employees possessing these competences contribute to a higher level of healthcare services and greater patient satisfaction. Unfortunately, to date, medical personnel managers in many healthcare facilities have not paid sufficient attention to the need to strengthen the social competencies of their employees.

According to experts: “There may be reservations about the scope of competences in “competence profiles” due to their practical usefulness. Profiles are treated by management specialists as a tool supporting high quality at work, in this case health services. Although many specialists involved in occupational studies participated in the work on the methodology, the competence profile preferred in the EU was chosen mainly to assess the level of competence of societies in relation to lifelong learning. As a consequence of this approach, the descriptions

of professions lack key competence profiles that are important in every medical profession". (Czajka, 2019, p. 60).

Due to the fact that each medical facility provides a specific range of services and employs specialists in various fields, it seems necessary to create a model of competencies essential in today's world. A tool for diagnosis, needs assessment and support options would enable a more efficient response to social needs. Furthermore, such needs should be reported by employees themselves and they should be provided with opportunities to receive support in their individual development and in fulfilling their professional roles (Czajka, 2019, p. 60).

Contemporary patient

„The modern patient is a patient who, more than ever before, desires to participate in the treatment process, co-creating it rather than following orders. This is a patient who wants to engage in dialogue with a physician (medical facility staff), to create contact, which should be interactive – engaging both parties that are motivated to establish a constructive relationship. A patient who makes conscious choices is not condemned to "mediocrity", as he or she has access to facilities with varying levels of service both near their home and throughout the entire local, national, and even international space available to them" (Łaska-Formejster, 2015, p. 138). Currently, we also speak of an *electronic virtual patient*, a concept referring to interactive computer programs that simulate real patients and real-world clinical scenarios. The term "e-patient" (electronic patient record, electronic health record) is also used, which functions in two contexts: the first one refers to a specific patients' electronic data, containing a description of their overall health situation, the other one encompasses the description of a patient using the internet (Łaska-Formejster, 2015, p. 139; Dudzikowa, 1993). More and more information about difficulties occurring in the relationship between patients and physicians is appearing in the source literature" (Gordon, Edwards, 1999; Barański 2002; Więckowska, 2005, p. 259; Łaska-Formejster, 2002, p.150; Grabowska, 2019).

„Effective communication is now more desirable than ever before", in times of increasing complexity of knowledge, there is a growing need to explain and interpret the effects of new therapeutic solutions to patients. Persons struggling with a disease want their doctors to explain why they are recommending certain tests and why others, which they learn about from the media, are being omitted. An additional challenge is the unsatisfactory public perception of issues related to the medical environment, which is partly due to the inability to quickly and accessibly disseminate important medical information (Goleman, 1997; Stangierska, Horst-Sikorska, 2007, p. 58).

4. Conclusions

Anticipated changes in the healthcare sector and growing public expectations with respect to the quality of medical services mean that it will be necessary to develop new skills among employees in the sector. Among the skills that will become increasingly important in the coming years, the following are particularly essential:

- digital and telemedicine competences,
- skills of using artificial intelligence and Big Data,
- competences in personalized medicine,
- competences related to innovation management,
- green competences related to environmental protection,
- soft competences related to patient care and stress management, which will become even more important due to the increasing patient expectations regarding service quality and the need to prevent burnout among the medical staff,
- competences related to long-term and geriatric care,
- interdisciplinary collaboration skills (INDORO Report, p. 23).

Due to the communication between different medical environments and different types of patients (e.g., in situations of acute or long-term illnesses, or in a health crisis), communication skills are particularly valued and the following competences are required:

- express yourself clearly, objectively, and understandably,
- listen actively,
- repeat the most important information,
- demonstrate understanding and acceptance,
- explain, ask questions, and respond,
- be sensitive to the recipients and follow their needs,
- avoid insincerity,
- adopt an individual and flexible approach,
- be interested in the patients, not just their illness,
- take into consideration the situational context,
- do not abandon them in difficult moments,
- provide rational hope and emotional support (Stangierska, Horst-Sikorska, 2007, p. 67).

Empathy, emotional intelligence and interpersonal communication will be of key importance here. The social dimension of health means the ability to perform tasks within individuals and groups according to the social expectations and in the reality of the changing world (Tobiasz-Adamczyk, 2015, p. 85). Currently, the rapid pace of economic development, new information technologies, the digital society, and new types of relationships between

patients and the medical community also make it necessary to draw attention to building human capital resources (medical staff), including in the area of soft skills.

Interdisciplinary research conducted in the field of humanistic sociology, particularly medical sociology, and other sciences such as psychology and management sciences, would allow for a comprehensive approach to the issue of social competences. The result would be a common model serving to verify the level of social competence among medical staff and the application of specific forms of support in the professional development process among medical and paramedical personnel both in Poland and abroad. The high balance of migration of medical staff for the purpose of improving hard skills is also part of the development trend in the context of soft skills strengthening.

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STATISTICAL ANALYSIS OF THE COMPLIANCE OF THE DISTRIBUTION OF STOCK EXCHANGE DATA FROM THE MAIN MARKET OF THE WSE WITH THE NEWCOMB-BENFORD LAW

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Purpose: The aim of the study is to verify the compliance of the empirical distribution of closing prices of companies listed on the Main Market of the Warsaw Stock Exchange (GPW) with the theoretical Newcomb-Benford law. In addition, it was investigated whether the degree of conformity with the Benford distribution differs between companies with high and low liquidity. The analysis aimed to identify potential statistical anomalies in market data that may indicate irregularities in price formation or signal potential manipulations of stock prices.
Research limitations/implications: The research sample included a total of 1.456.671 observations (real numbers representing the daily closing price of 421 analyzed companies listed on the main market of GPW between 1991-2022). To verify whether the empirical distribution of data representing the daily closing prices of shares listed on the Main Market of GPW conforms to the theoretical Newcomb-Benford distribution, first-digit, second-digit and first-two-digit tests were applied. To quantitatively assess the degree of fit of the empirical distribution to the theoretical one, statistical tests and the mean absolute deviation (MAD) measure were used. The research focuses on the Polish market. Future research suggests conducting a comparative analysis of foreign exchanges.
Practical implications: The results may be used by financial market regulators, auditors, and market analysts as a tool to support the detection of anomalies in stock trading.
Social implications: The research findings are important for society because a properly functioning stock market can attract more investors and issuers. In turn, any market anomalies, especially those involving manipulation, can lead to a decline in trust in capital market institutions. Furthermore, they can lead to asset mispricing and, in extreme cases, to losses for market participants.
Originality/value: This study represents one of the first applications of the Newcomb-Benford law to analyze long-term closing price data of companies on the Main Market of GPW in Warsaw (Central and Eastern Europe). The originality of the study lies in combining multiple tests of empirical-theoretical distribution fit and considering the liquidity differentiation of companies.
Keywords: Newcomb-Benford law (distribution), Main Market GPW, distribution conformity tests, MAD.
Category of the paper: Research paper.

1. Introduction

Modern finance requires comprehensive methods to detect irregularities and verifying data reliability. In this context, the Newcomb-Benford law is considered a useful mathematical tool, connected to big data analysis and statistical methods. The Newcomb-Benford law describes the relative frequency distribution of the leading digits in data sets. For individual datasets, the distribution of digits in certain significant positions aligns with the theoretical distribution known as the Newcomb-Benford law, Benford's law, or the law of the first significant digits.

In 1881, the Canadian astronomer and mathematician S. Newcomb discovered that the frequencies of first digits in randomly selected numbers are not uniformly distributed but follow a natural logarithmic decreasing pattern. While in the United States Naval Observatory library, Newcomb observed that the earlier pages of logarithmic tables were more worn than the later ones. Based on this observation, Newcomb hypothesized that users of logarithmic tables more frequently consulted numbers beginning with lower digits, which appeared at the start of the tables (Newcomb, 1938). However, his discovery did not initially attract much attention. Only in 1938 did Frank Benford, unaware of Newcomb's previous work, independently observe the same regularity by examining the wear on logarithmic tables. Empirically testing this thesis, he found that numbers in various datasets more often start with lower digits. Benford analyzed the first-digit distribution in approximately 300 data sets from different scientific fields and confirmed the pattern. Applications of the Newcomb-Benford law include natural sciences (e.g., river areas), mathematics and statistics (e.g., numerical data in newspapers or statistical yearbooks) and economics and finance (e.g., transaction prices, market data) (Benford, 1995). It is also applied in market data analysis and auditing (Corazza et al., 2010; Grammatikos, Papanikolaou, 2021). In the literature, the Newcomb-Benford law is used, among other things, to detect financial anomalies, accounting fraud, and analyze capital market data in various countries. Previous research has focused primarily on the American and Western, and Southern European markets, while analysis of long-term data from the Warsaw Stock Exchange (WSE), accounting for differences in company liquidity, remains limited.

The aim of this article is to verify the consistency of the empirical distribution of closing prices of companies listed on the Main Market of the Warsaw Stock Exchange (WSE) with the theoretical distribution of the Newcomb-Benford law. Additionally, we examined whether the degree of consistency with the Newcomb-Benford law varies depending on the companies' liquidity. The following research question was formulated: Does the empirical distribution of the first, second, and first two significant digits of the daily closing prices of companies listed on the Main Market of the Warsaw Stock Exchange (WSE) correspond to the theoretical distribution of the Newcomb-Benford law? Based on this, a research hypothesis was formulated: the empirical distribution of daily closing prices of companies listed on the Main Market of the Warsaw Stock Exchange differ significantly from the theoretical distribution of Newcomb-Benford law.

The article has a classic structure, consisting of an introduction, a literature review, including the strengths and weaknesses of the mathematical method of the Newcomb-Benford distribution discussed by the authors, a description of the research methodology, a presentation of the results, and a summary containing the main conclusions and limitations of the research, as well as future directions for potential analyses.

2. Literature Review

The Newcomb-Benford law is relatively rarely applied in Polish literature. Regarding the capital market, one study applied the first-digit test to daily trading volumes of 774 companies listed on GPW and NewConnect. A lack of conformity with the Newcomb-Benford distribution was observed in 37.38% of the public company stocks (Lesiak, 2024). Digit analysis is applied more frequently to foreign markets. Research on daily returns of the S&P 500 index from March 21, 1988, to March 21, 2018 (7,561 observations) provided empirical evidence of compliance with the Newcomb-Benford law. Short-term deviations (1 year) were associated with low risk periods and positive trends, and χ^2 test p-values relative to the Newcomb-Benford distribution showed some predictive ability for average market returns and risk levels, suggesting that deviations could serve as market risk indicators (Cerqueti, Maggi, Riccioni, 2024).

Analysis of closing prices on the Istanbul Stock Exchange showed generally significant deviations (Karavardar, 2014), as did studies on the Chinese stock market. Daily returns were more in line with the law, suggesting they may be better candidates for the Newcomb-Benford test than prices alone (Fang, 2024). Studies on daily returns of indices from selected developed and developing countries (Europe, North Africa) indicated that daily returns often corresponded to the Newcomb-Benford distribution, revealing natural regularities in financial market dynamics. Deviations from Benford's law (χ^2 p-values) were correlated with low-risk periods and positive market trends, highlighting its potential as a short-term market risk indicator (Hamida, de Peretti, Belkacem, 2024).

Riccioni and Cerqueti noted that the Newcomb-Benford analysis could serve as a market stability barometer, as deviations between empirical and theoretical distributions were correlated with periods of increased market instability (eg, crises, sharp declines or increases) (Riccioni, Cerqueti, 2018). Studies on credit default swap (CDS) prices showed that daily first-digit distributions were more stable in developed countries (USA, Germany, France), but deviations were significant in countries affected by debt crises (Greece, Ireland, Portugal) (Ausloos et al., 2016). Cano-Rodríguez found that while market-based asset valuations better comply with Newcomb-Benford law than expert valuations, differences were minor, indicating both approaches have high conformity, and digit analysis can be a useful tool for monitoring

valuation quality (2025). However, some authors point out that mathematical analysis using the Newcomb-Benford distribution can produce both false positives and false negatives. The specificity and type of the data and whether the basic conditions are met, such as a large data set and the absence of arbitrary constraints, are crucial for effectiveness (Diekmann, Jann, 2010).

Literature review demonstrates the growing application of digit analysis using Newcomb-Benford properties in economics and finance, supporting the potential for developing procedures to detect anomalies in large financial datasets. In the literature, the Newcomb-Benford law is used, among other things, to detect financial anomalies, accounting fraud, and analyze capital market data in various countries. Previous research has focused primarily on the American, Western, and Southern European markets, while analysis of long-term data from the Warsaw Stock Exchange (WSE), accounting for differences in company liquidity, remains limited. The literature review showed that the application of the Newcomb-Benford law as an analytical method is quite broad. Recent studies also show that deviations from the theoretical distribution, measured, for example, by the chi-square test, can be used as indicators of unusual market activity and predict future stock returns. At the same time, however, the authors emphasize that not every data set, including financial data, must or should satisfy the Newcomb-Benford law, suggesting caution in treating this method as a universal tool. Some studies indicate that deviations from the Benford distribution correlate with unusual market activity and can serve as a screening tool for detecting potential manipulation. At the same time, significant criticism of this mathematical method has been raised, suggesting that the Newcomb-Benford law is, at best, a screening tool and that results should be verified using other methods and contextual analysis.

3. Methods

In 1995, Hill provided a proof confirming that the Newcomb-Benford distribution can be used to identify distortions in aggregated data sets (Hill, 1995). It should be noted that this law is conceptually flexible, allowing the application of various tests, e.g. first-digit, second-digit, and first-two-digit tests (Hill, 2009).

The formulas for the distributions of the first, second, and first-two digits are as follows (Nigrini, 1996, 2012):

Probability that the first significant digit is d, where d ∈ {1, 2, 3, …, 9}:

$$P(D_1 = d) = log_{10}\left(1 + \frac{1}{d}\right) \quad (1)$$

The probability of each first significant digit is 30.10% for 1, 17.60% for 2, 12.49% for 3, 9.69% for 4, 7.99% for 5, 6.69% for 6, 5.79% for 7, 5.11% for 8, and 4.57% for 9.

Probability that the second digit (following the first significant digit) is d, where d ∈ {0, 1, 2, …, 9}:

$$P(D_2 = d) = \sum_{k=1}^{9} log_{10}\left(1 + {}_{10k+d}^{1}\right) \quad (2)$$

where k represents the first digit (from 1 to 9). The probability of each second significant digit decreases with increasing value, from 11.97% for 0 to 8.50% for 9.

Probability that the first two digits of a number are d_1, d_2, where $d_1 \in \{1, 2, \ldots, 9\}$ and $d_2 \in \{0, 1, \ldots, 9\}$:

$$P(D_1 D_2 = 10d_1 + d_2) = log_{10}\left(1 + {}_{10d_1+d_2}^{1}\right) \quad (3)$$

For the first two-digit distribution, the range of possible values is larger, including combinations from 10 to 99. The highest probability is 4.14% for pair 10, and the lowest is 0.44% for the pair 99.

This article presents a statistical analysis applying the Newcomb-Benford law to verify whether the real numbers representing the daily closing prices of the Main Market of GPW conform to the theoretical law. The objective is to detect significant deviations, which could indicate anomalies in stock prices, potentially signaling speculative behavior or price manipulations on the Polish regulated market. In the study sample, closing prices were represented as real numbers, so the analysis considered the full range of price precision, which increases the reliability of the study.

The analysis used historical GPW stock price data from 1991 to 2022, sourced from www.stooq.pl. Data from 421 companies were analyzed, totaling 1 456 671 observations (real numbers representing daily closing prices). First-digit, second-digit, and first-two-digit tests were applied to verify compliance with the Newcomb-Benford distribution at the following aggregation levels:

- Daily closing prices of GPW companies for the entire period and comparison between the first full year analyzed (1992) and the last (2022).
- Daily closing prices of GPW companies grouped by high and low liquidity (low-liquidity program classification).

Based on the literature review, the article reports results of statistical tests, including (Jianu, Jianu, 2021):

- Chi-square test.
- Kolmogorov-Smirnov test.
- Chebyshev distance-based test.
- Euclidean distance-based test.
- Freedman–Watson U^2 test.
- Joenssen correlation test.
- Hotelling T^2 "joint digit" test.

The use of these tests allows for a more comprehensive picture of the data's compliance with the Newcomb-Benford law, minimizing the risk of misinterpretation of the results. The selection of multiple tests is justified by the literature review, as the literature lacks a uniform methodological approach, and the selection of tests is not clear-cut. Using a set of complementary tests allows for results that are more comparable to previous studies and increases their reliability. These tests assess the null hypothesis that the distribution of digits (or digit combinations) conforms to the Newcomb-Benford distribution versus the alternative hypothesis of nonconformity. Statistical significance levels of $p = 0.05$, $p = 0,01$, and $p = 0,001$ were used; p values below 0,001 are reported as $p < 0,001$. In large samples (as in this study), even small deviations may be statistically significant; therefore, analyzes are complemented by visual comparisons of empirical and theoretical distributions (Kossovsky, 2021).

In addition, the mean absolute deviation (MAD) measure was used to evaluate the fit between empirical and theoretical distributions (David, 1998; Wilcox, 2003; Larsen, 2017). Critical values to identify significant deviations are (Nigrini, 2012):

- First-digit test: MAD exceeds 0,015.
- First-two-digit test: MAD exceeds 0,0022.

Nonconformity with the theoretical Newcomb-Benford distribution may indicate market anomalies such as potential speculative or manipulative actions during the analyzed period or reflect the presence of heuristics in the market.

Visualizations were created to show the values taken from the distributions of daily closing prices over the subsequent years. In Chart 1, the y-axis represents the stock closing price (PLN), and the x-axis represents the year.

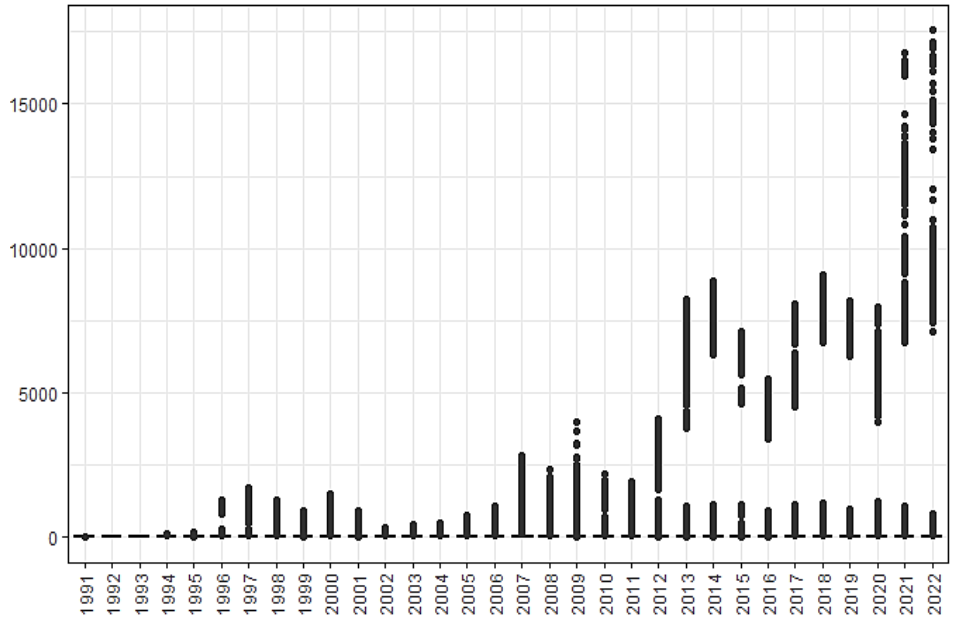


Figure 1. Distribution of closing prices from 1991 to 2022.

Source: own elaboration based on www.stooq.pl

An upward trend in closing prices can be observed over the analyzed period. Furthermore, as the market developed, the dispersion (spread) of prices increased, especially after 2010, when the range of prices (interquartile range and number of outliers) expanded. Some companies exhibited occasionally exceptionally high prices. The lower bound of closing prices remained relatively low throughout the study period, which may indicate the persistence of a segment of low-capitalization and low-liquidity companies.

4. Research Results

4.1. Tests of Empirical Data Conformity with the Newcomb-Benford Distribution: Entire Study Period

The hypothesis of conformity between the empirical data distribution (daily closing prices of companies listed on the Main Market of GPW) and the theoretical Newcomb-Benford distribution was tested, similarly to other studies, using several different tests as described in the methodology section.

Table 1.
Results of tests for Conformity of Empirical Data with the Newcomb-Benford distribution

Distribution Type	Chi^2 Test	Kolmogorov-Smirnov Test	Chebyshev Distance Test	Euclidean Distance Test	Friedman U Test	Joenssen Correlation Test	Hotelling T^2 Test
First Digit	<0,001	<0,001	<0,001	<0,001	<0,001	0,999	<0,001
Second Digit	<0,001	<0,001	<0,001	<0,001	<0,001	0,999	<0,001
First Two Digits	<0,001	<0,001	<0,001	<0,001	<0,001	0,992	<0,001

Source: own elaboration based on www.stooq.pl.

As shown in Table 1, most of the tests for the conformity of the digit distributions with the Newcomb-Benford law indicated deviations from the expected distribution, except for the Joenssen correlation test. This test only checks the consistency of the sign of the correlation between empirical data and the theoretical distribution. For the complete data set, the MAD value was 0,001 for the first digit and below 0,001 for the first two digits. This indicates that although statistical tests formally showed significant differences between the compared distributions, which, as noted in the methodology section, may result from the large sample size, the practical level of these differences is marginal and does not indicate a substantial distortion of the data. This is also confirmed by figure 2, which shows that the largest differences occur in the frequencies of higher digits, which may reflect the relatively small number of high closing prices.

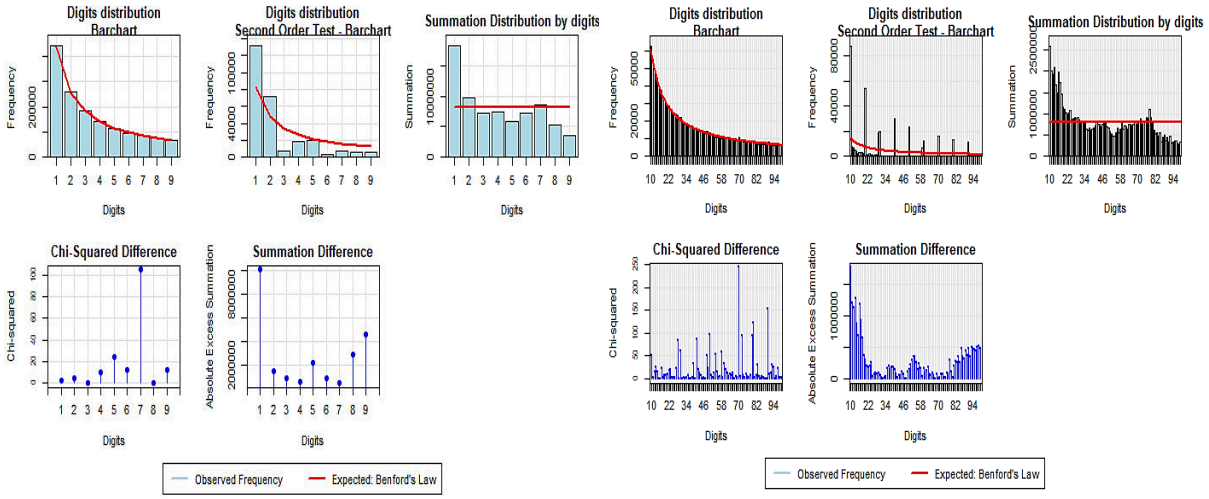


Figure 2. Visualization of the Conformity of Closing Prices with the Newcomb-Benford Distribution for the First Digit Second Digit, and First Two Digits.

Source: own elaboration based on www.stooq.pl.

A comparison of results was also made for the initial and final periods, namely 1992 (the first full year) and 2022. In the case of 1992, for closing prices, the MAD value was 0,107 for the first digit and 0,013 for the first two digits.

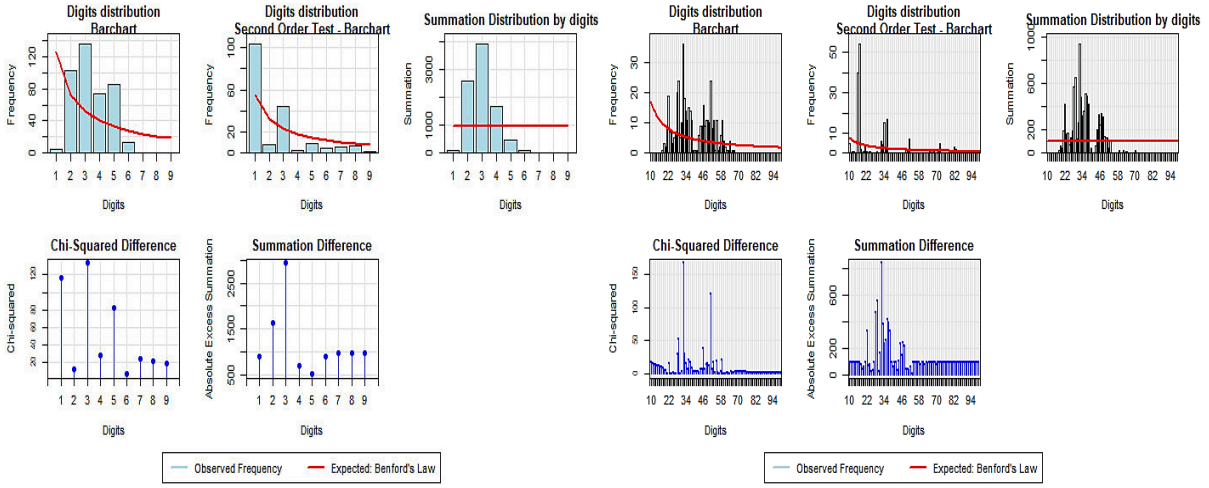


Figure 3. Visualization of the Conformity of Closing Prices with the Newcomb-Benford Distribution for the First Digit, Second Digit, and First Two Digits in 1992.

Source: own elaboration based on www.stooq.pl.

These results were compared with those from 2022. In the case of 2022, the MAD value was 0,008 for the first digit and 0,001 for the first two digits.

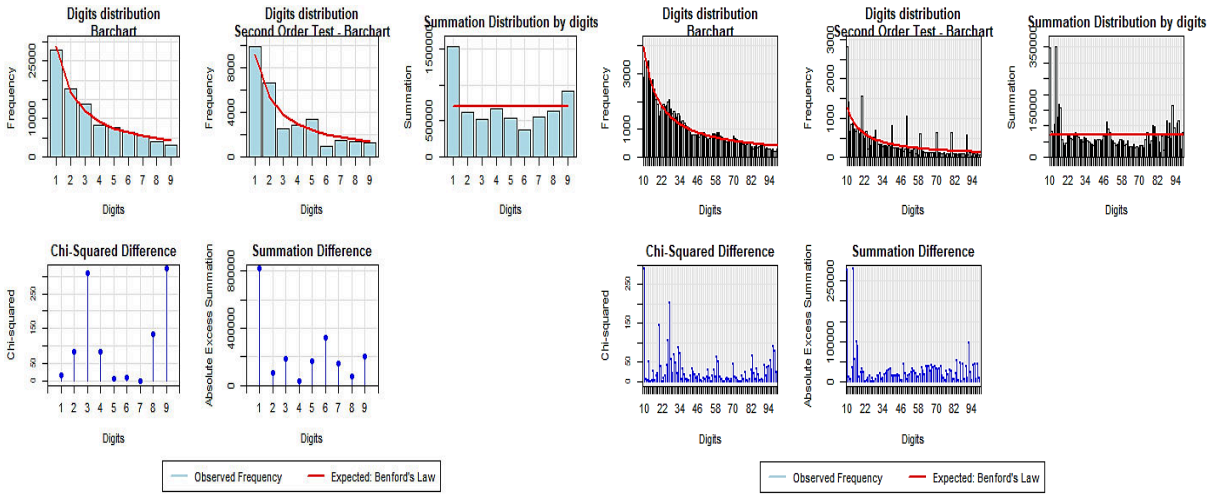


Figure 4. Visualization of the Conformity of Closing Prices with the Newcomb-Benford Distribution for the First Digit, Second Digit, and First Two Digits in 2022.

Source: own elaboration based on www.stooq.pl.

Based on graphs 3 and 4, it was observed that, compared to 2022, in the early period of the modern stock exchange (1992), there were significant deviations of the empirical data from the theoretical distribution. This can probably be attributed to the low efficiency, limited liquidity, and the small number of listed companies (16) (www 1). A substantial decrease in the MAD value - from 0,107 to 0,008 for the first digit and from 0,013 to 0,001 for the first two digits - indicates an increase in the conformity of the stock closing prices with the Newcomb-Benford distribution for three decades of the Main Market of the Warsaw Stock Exchange (GPW).

4.2. Tests of Conformity with the Newcomb-Benford Distribution: Low- and High-Liquidity Companies

In the next stage of analysis, the research sample was divided into two groups. The aim was to determine, based on stock price data, whether companies classified as belonging to the low-liquidity segment exhibit higher deviations from the theoretical distribution than those outside of this segment. According to the assumption adopted, low-liquidity companies are defined as those whose closing price does not exceed 1 PLN (www 2; www 3). The purpose was to compare these two groups. Therefore, the hypothesis of conformity between the closing price distribution and the Newcomb-Benford distribution was also tested for this company division.

Table 2.
Results of Goodness-of-Fit Tests for Empirical Data Distributions of Low- and High-Liquidity Companies Compared to the Newcomb-Benford Distribution

High-Liquidity Companies							
Distribution Type	**Chi² Test**	**Kolmogorov-Smirnov Test**	**Chebyshev Distance Test**	**Euclidean Distance Test**	**Friedman U Test**	**Joenssen Correlation Test**	**Hotelling T² Test**
Second Digit	<0,001	<0,001	<0,001	<0,001	<0,001	0,999	<0,001
First Two Digits	<0,001	<0,001	<0,001	<0,001	<0,001	0,999	<0,001
First Digit	<0,001	<0,001	<0,001	<0,001	<0,001	0,999	<0,001
Low-Liquidity Companies							
Distribution Type	**Chi² Test**	**Kolmogorov –Smirnov Test**	**Chebyshev Distance Test**	**Euclidean Distance Test**	**Friedman U Test**	**Joenssen Correlation Test**	**Hotelling T² Test**
First Digit	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Second Digit	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
First Two Digits	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001

Source: own elaboration based on www.stooq.pl.

The results indicate that the low- and high-liquidity company groups exhibit similar deviation patterns from the Newcomb-Benford distribution. For low-liquidity companies, the MAD value for closing prices was 0,081 for the first digit and 0,008 for the first two digits. Both values exceed the critical thresholds specified in the methodological section, suggesting a lack of conformity between the compared distributions. On the contrary, for high-liquidity companies, the MAD value for closing prices was 0,008 for the first digit and 0,001 for the first two digits. These results fall below the critical thresholds, indicating that the structure of the closing price digits in the group of more liquid companies is closer to the theoretical Newcomb-Benford distribution. Charts 5 and 6 allow for verification of whether the deviations from the Newcomb-Benford distribution are indeed substantial and identify in which cases these discrepancies occur.

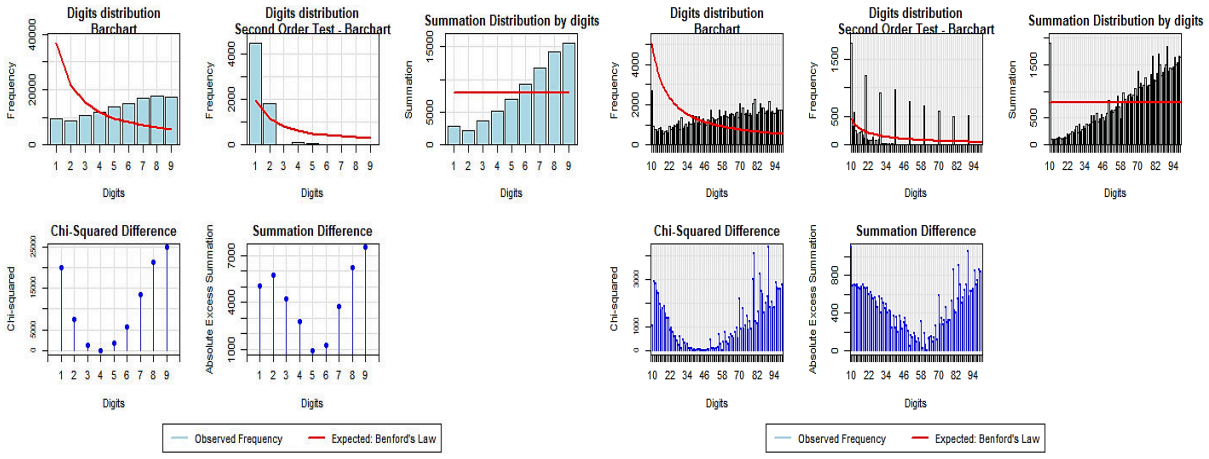


Figure 5. Visualization of the Conformity of Closing Price Distributions for Low-Liquidity Companies with the Newcomb-Benford Distribution for the First Digit, Second Digit, and First Two Digits.

Source: own elaboration based on www.stooq.pl.

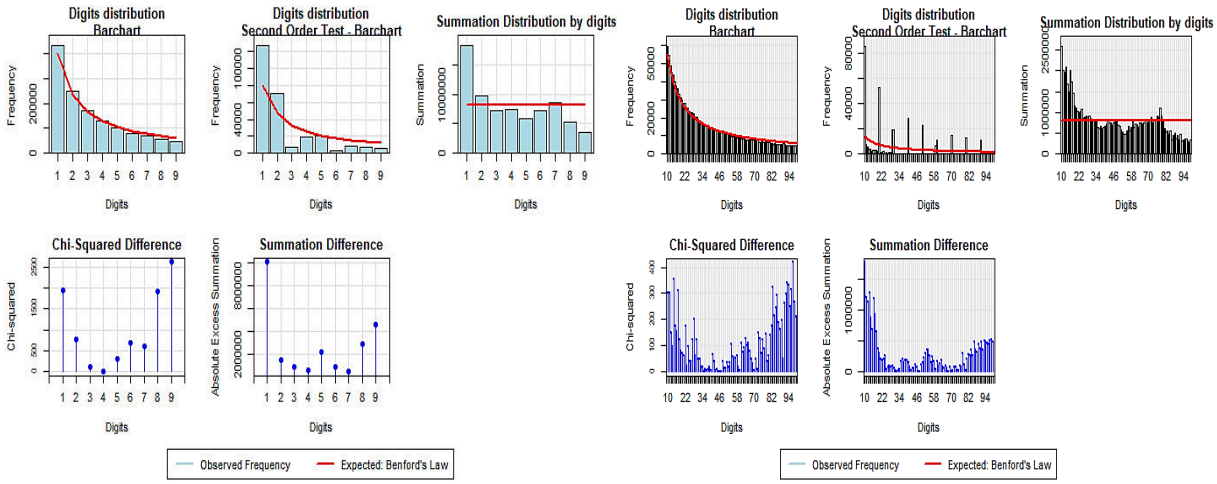


Figure 6. Visualization of the Conformity of Closing Price Distributions for High-Liquidity Companies with the Newcomb-Benford Distribution for the First Digit, Second Digit, and First Two Digits.

Source: own elaboration based on www.stooq.pl.

The visualizations presented in graphs 5 and 6 confirm the conclusions drawn from the statistical tests and the MAD measure. They indicate that a clear deviation between the compared distributions is observed for low-liquidity companies, where the discrepancies appear significant and more pronounced in closing prices compared to high-liquidity companies.

5. Summary

There are studies in the literature indicating that deviations from the Benford distribution correlate with unusual market activity and can serve as a screening tool for detecting potential manipulation. At the same time, there is also significant criticism of this mathematical method, indicating that the Newcomb-Benford law is, at best, a screening tool and that the results should be verified with other methods and contextual analysis.

In this statistical analysis, the combination of statistical tests, visualizations, and the MAD measure enabled a comprehensive assessment of the conformity of stock market data from the Main Market of the Warsaw Stock Exchange (GPW) with the Newcomb-Benford distribution. The results indicate that the Newcomb-Benford law can serve as a useful tool for supporting financial data analysis, assess market efficiency, and identifying potential anomalies in stock quotations.

The results of the statistical test suggest that the structure of the digits in integer values representing daily closing prices is not entirely random, therefore, the research hypothesis was positively verified. This stems from the specific mechanisms of market price formation, which are influenced by regulations, supervisory decisions, and investor behavior. At the same time,

the visualizations and MAD results revealed a more nuanced picture of the conformity between the compared distributions.

The findings provide grounds for concluding that deviations from the theoretical Newcomb-Benford distribution are greater in the early stages of market operation (1992 compared to 2022) and among low-liquidity companies. These deviations may result from limited investor activity, a low number of transactions, and the specific characteristics of stock quotes. The results are consistent with previous research, confirming that low-liquidity markets are characterized by a higher risk of data anomalies, which in practice may increase susceptibility to speculative or manipulative behavior. The research focuses on the Polish market. Future research suggests conducting a comparative analysis between each country. The obtained results are significant from both theoretical and practical perspectives. Theoretically, the study demonstrates that the long-term closing prices of companies listed on the WSE Main Market exhibit statistically significant deviations from the Newcomb-Benford distribution, regardless of the companies' liquidity category. This means that the classical assumption of the universality of the Newcomb-Benford distribution for a range of stock market data is not fully met in the case of the Polish stock market. From a practical perspective, the observed deviations cannot be automatically interpreted as evidence of market manipulation, as the Newcomb-Benford law primarily serves as a screening tool. These observations open an interesting avenue for further research, involving the analysis of the relationship between deviations from the Newcomb-Benford distribution and periods in which market manipulation or abuse were actually detected by the supervisory authority.

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THE USE OF ARTIFICIAL INTELLIGENCE (AI) BY BUSINESSES AS MEASURED BY POLISH PUBLIC STATISTICAL DATA

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Purpose: This study aims to conduct a comprehensive analysis of the level of AI adoption by Polish businesses in 2021, 2023 and 2024 based on public statistical surveys. This article focuses on the scale, structure, and conditions of the use of artificial intelligence technology in Polish businesses.
Design/methodology/approach: The analysis is based on data from the study conducted by the Central Statistical Office on the use of information and communication technologies in businesses. A quantitative approach based on secondary data analysis (desk research), supplemented by a review of the literature on the subject. The study investigated the overall percentage of companies using AI, as well as the typology of the technologies implemented.
Findings: Empirical analysis reveals apparent disparities in the use of artificial intelligence across Polish companies, both by region and by industry. AI technologies are much more often implemented in areas with highly developed technological and educational facilities. Industries related to digital technologies, particularly the information and communication sector, show the highest activity in AI. Their advantage lies in the great potential for process automation, the use of large data sets, and the availability of specialised personnel. Variation is also apparent at the level of ownership. Businesses with foreign capital implement AI more often than those funded domestically. The technologies used primarily include automatic learning systems, image analysis, and natural language processing. The conclusions drawn from the study are unambiguous. Despite the growing importance of AI in the economy, its use by companies in Poland remains limited and uneven. Such a situation may deepen the existing developmental divisions, which is why it is essential to take systemic action. Investments in education, the dissemination of knowledge about the possibilities of using AI, and the strengthening of innovation ecosystems should play a key role.
Research limitations/implications: The analysis is based solely on data from 2021, 2023 and 2024. The lack of data for 2022 limits the ability to accurately capture the dynamics of change.
Originality/value: The study should be seen as a contribution to the scientific discussion on the development of artificial intelligence and the level of its adaptation by enterprises in Poland.
Keywords: artificial intelligence, enterprises, public statistics.
Category of the paper: research paper.

1. Introduction

Artificial intelligence is rapidly advancing as a leading force in digital transformation, reshaping how social and economic structures operate. Despite the imperfections which still exist, the technology continues to replace humans. It is increasingly responsible for the technological transformation of businesses. In fact, artificial intelligence is a requirement of the modern world and a condition for the survival of companies (Bielińska-Dusza, 2022, p. 193).

AI is used by companies, among others, in production (automation of tasks, improvement of quality control, optimisation of production processes), in retail trade (personalisation of consumer purchasing experiences, the use of recommendation engines, automation of customer service) or in the financial industry (detecting fraud, risk management, supporting investment decisions). The implementation of such solutions reduces costs, creates conditions for innovation, improves customer satisfaction and loyalty, increases security, profitability and, in turn, the competitiveness of enterprises (Polish Agency for Enterprise Development, 2023, p. 46).

This study aims to conduct a comprehensive analysis of AI adoption levels among Polish businesses in 2021, 2023, and 2024, based on public statistical surveys. In particular, the study focuses on identifying the scale, structure and conditions for the use of AI, taking into account regional variables (by Voivodeships), sectoral, business size and ownership structure. In addition, the analysis covers the dominant types of AI solutions and the barriers to their implementation identified by companies.

2. Genesis and methods of defining the concept of artificial intelligence

When considering the use of artificial intelligence by companies in Poland, it is essential to have prior knowledge of its background and architecture. The history of artificial intelligence has its origins in human attempts to understand the nature of the mind and its ability to reproduce it in artificial systems. The breakthrough occurred with the publication of Alan Turing's 1950 article “Computing Machinery and Intelligence”. He introduced the Turing Test to answer the question: *Can machines think?* Instead of trying to define thinking itself, Turing proposed a thought experiment to assess the machine’s ability to manifest intelligent behaviours indistinguishable from those of human beings (Małyska, 2025, p. 140). Later in 1956, the term *artificial intelligence* (AI[1]) was coined by John McCarthy, and it is now one of the key concepts in debates over technological development. The first works on artificial intelligence focused on

[1] Acronym for *artificial intelligence*. Within the article, it is used interchangeably with the full expression ‘artificial intelligence.’

using cognitive models to simulate and explain human ability to process information, using *'logical'* systems which implement reasoning based on common sense and expert rationale, as well as on robots which perceive the environment and interact with it. The works were funded by the *Defence Advanced Research Projects Agency* (DARPA) and the *Office of Naval Research* (ONR) in the USA. Wide-scale research on AI began in the early 1960s of the 20th century. It has led to theoretical progress and the development of practical technologies to address information processing in the military, science, medicine, and industry (Waltz, 1996). Due to technological constraints, AI has been depicted mainly in pop culture narratives for decades before it found practical application. Today's AI penetrates virtually all areas of social life, ranging from science and humanities to legal systems (Czapska, 2018, p. 15). The reason why AI has gained such popularity in recent years lies in the availability of large amounts of data, advanced algorithms, and increasing computing and data storage capabilities. Figure 1 depicts the historical timeline of artificial intelligence.

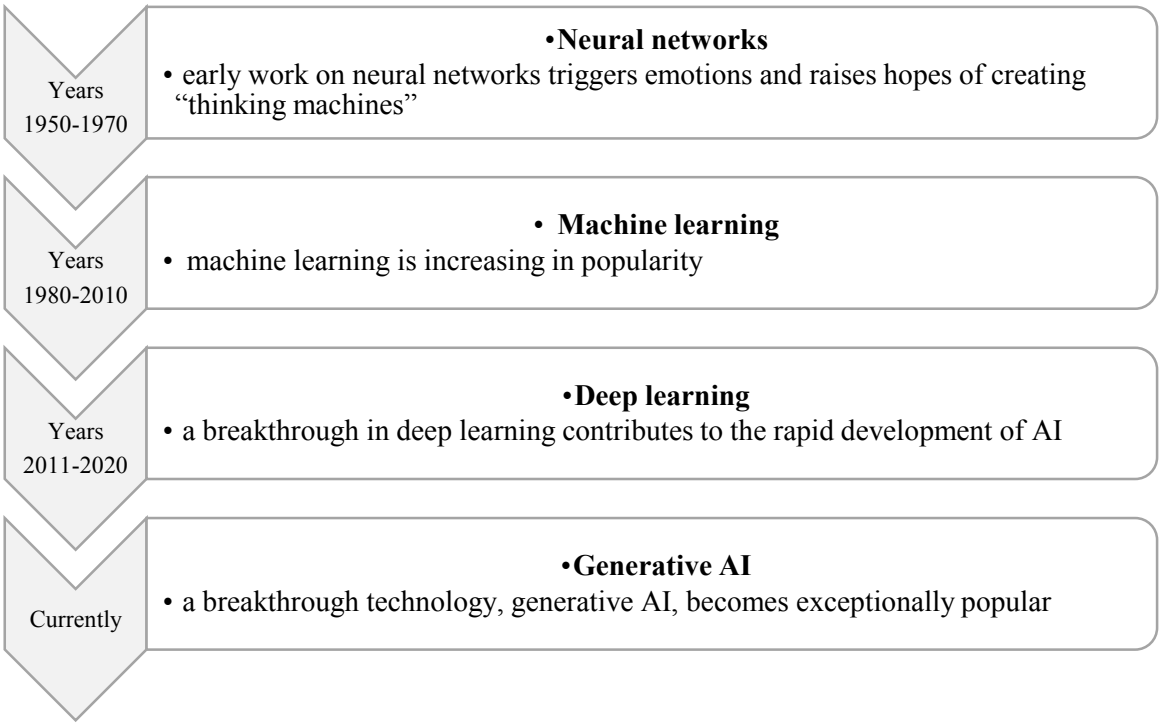


Figure 1. The historical timeline of artificial intelligence.

Source: own development based on SAS Institute Inc., 2025.

The literature contains dozens of attempts to define the concept of artificial intelligence. This is due to historical developments and to the lack of consensus on the scope and subject matter of the idea (Flasiński, 2024, p. 325). Therefore, it seems reasonable to learn about the essence of the concept. The selected definitions of artificial intelligence are depicted in Table 1.

Table 1.
Selected definitions of artificial intelligence

Source	Definition of artificial intelligence
(Nilsson, 2010, p. 13)	Artificial intelligence is the process of making machines intelligent, and intelligence is a feature that enables an object to function predictably and adequately in its environment.
(Stone et al., 2016, p. 4)	Artificial Intelligence (AI) is a science and a set of computing technologies that, however, operate completely differently from how humans use their nervous systems and bodies to feel, learn, reason, and take action.
(OECD, 2019, p. 7)	An artificial intelligence system is a machine-based system capable of formulating forecasts and recommendations, or making decisions, that affect a real or virtual environment for a specific set of objectives defined by humans.
(Statistics Sweden, 2019)	Artificial intelligence refers to systems that demonstrate intelligent behaviour by analysing their environment and taking action with a certain degree of autonomy to achieve specific objectives. AI-based systems can be implemented either as software or built into hardware.
(European Commission, 2019, p. 2)	Artificial intelligence allows machines to learn and make decisions without human involvement. Artificial intelligence is not an end in and of itself, but rather a tool that must serve humans to improve human well-being.
(Warszycki, 2019, p. 115)	Artificial intelligence is a scientific field that brings together fields, methods, tools, and techniques to create and develop a complete computer program that accurately reflects the model of human functioning and mind.
(U.S. Congress, 2020, p. 1137)	An artificial intelligence system is a machine-based system capable of formulating forecasts and recommendations, or making decisions, that affect a real or virtual environment for a specific set of objectives defined by humans. Artificial intelligence systems use machine and human input data for: (A) perceiving real and virtual environments; (B) transforming these insights into models through automated analysis; and (C) using model reasoning to formulate options for information or actions.
(Zalewski, 2020, p. 3)	Artificial intelligence is a system that enables the execution of tasks that require learning and that takes into account new circumstances when solving a specific issue; it may act autonomously and interact with the environment to varying degrees, depending on its configuration.
(Oracle, 2021)	Artificial intelligence is a term that describes applications that perform complex tasks, such as online communication with customers or chess games that previously required human participation.
(Polish Agency for Enterprise Development, 2023, p. 5)	Artificial intelligence is a sub-discipline of computer science which develops information systems which can learn and act autonomously.
(Sheikh et al., 2023, p. 15)	Artificial intelligence is the simulation of human intelligence by computers.
(Bar, 2024, p. 21)	AI, or AI systems, are computer software operating at different levels of autonomy. Having clear or implied objectives at its disposal, it can generate output data in the form of forecasts, recommendations, or decisions that affect the physical or virtual environment.
(Flasiński, 2024, p. 325)	1. Artificial intelligence is a common area of computer science and robotics, where research is carried out on developing systems designed to perform activities requiring human intelligence. 2. Artificial intelligence means a feature of artificial systems which allows them to perform actions which require human intelligence.
(McKinsey & Company, 2024)	Artificial intelligence is the ability of a machine to perform cognitive functions typically associated with the human mind.
(National Statistical Institute of the Republic of Bulgaria, 2024)	Artificial intelligence refers to systems using technologies, such as text analysis, image and speech recognition, natural language generation, machine learning, deep learning, etc., for the collection and/or use of data for the purposes of making predictions, recommendations or for decision-making, at varying levels of autonomy to suggest the best actions to be taken to achieve specific objectives.

Cont. table 1.

(NASA, 2024)	Artificial intelligence refers to computer systems that can perform complex tasks that are usually performed by human reasoning, decision-making, and creativity.
(European Parliament and Council of the EU, 2024, p. 46)	Artificial intelligence system is a machine system which is designed to operate at different levels of autonomy after it has been implemented, and which may demonstrate the ability to adapt after its implementation, and which infers on how to generate results based on the obtained input data, such as predictions, content, recommendations or decisions which may affect the physical or virtual environment to achieve clear or implied purposes.
(Statistics Austria, 2024)	Artificial intelligence refers to technologies which mimic intelligent behaviour and have a certain degree of autonomy in performing specific tasks.
(The National Conference of State Legislatures, 2024)	Artificial intelligence involves the use of computer systems to perform tasks which usually require human intelligence, such as learning and decision-making. It has the potential to transform the economy and the way people live and work.
(Central Statistical Office, 2025)	Artificial intelligence refers to systems that use technologies such as text exploration, machine learning, or deep learning to collect or use data to predict, recommend, or make decisions at different levels of autonomy.
(Central Statistical Office, 2025)	Artificial intelligence includes software systems that use technologies such as text mining, computer vision, speech recognition, natural language generation, machine learning, deep learning, and data collection or processing for the purpose of making predictions, recommendations, or decisions. They may be part of computer software or be built into devices.
(Central Statistical Office, Ireland, 2025)	Artificial intelligence refers to systems that use technologies such as text analysis, machine learning, or deep learning to collect or use data to predict, recommend, or make decisions at varying levels of autonomy.
(Information Commissioner's Office, 2025)	Artificial intelligence is a set of technologies based on algorithms that solve complex tasks and perform functions previously performed by humans.
(International Organization for Standardization, 2025)	Artificial intelligence is an area of computer science that creates systems and software capable of performing tasks considered exclusively human.
(SAS Institute Inc., 2025)	Artificial intelligence enables machines to learn from experience, adapt to new data, and perform human-specific tasks.
(Statistics Netherlands, 2025)	Artificial intelligence describes machine-based systems that can generate output data for specific purposes based on provided input data. These systems are capable of developing forecasts, giving advice, or making decisions that affect the physical or virtual environment to a specific degree of autonomy.

Source: own elaboration based on the publication above.

A review of the definition shows that the vast majority of them create a comprehensive terminological structure. They primarily relate to machine-based systems that perform tasks that require human skills. The remaining companies constitute the minority that emphasise AI as a scientific field, creating the conditions for equipping artificial machines with features that allow them to perform tasks typically requiring human intelligence. Regardless of the differences in wording, all the definitions relate to activities that create added value by saving time and reducing human workload.

It should be stressed that AI is interdisciplinary. Artificial intelligence is not pure science (explaining section), and it is merely the basis of an engineering discipline (emulating section). Both matters are included in the statement that artificial intelligence aims to understand intelligence for practical applications (Kwaśnicka, 2000, p. 15). Artificial intelligence relates to several scientific disciplines. It crosses issues in computer science, statistics, mathematics, humanities, philosophy, social sciences, and management (Karski, 2022, p. 206). Research on artificial intelligence covers a wide range of methods and techniques from various scientific

areas. The most critical areas of research are data exploration, algorithmics, machine learning, mechatronics, cognitive science, logic, statistics, and knowledge management (Goczyła, 2018, p. 13).

3. Key areas of artificial intelligence

The following main sub-disciplines may be distinguished within the research and technological approaches developed in the area of artificial intelligence (Bar, 2024, p. 21; Piwowar et al., 2023, pp. 6-7; Warszycki, 2019, p. 115):

- Machine learning focuses on developing algorithms which are capable of learning based on data. Machine learning algorithms are usually trained on large datasets and later used to make predictions and support decision-making. The following areas may be distinguished within ML: deep learning and reinforcement learning. Deep learning involves teaching computers to think and learn like the human brain. It is used to recognise images, process natural language, recognise speech, or translate languages. Reinforcement learning is a method in which an agent (e.g., a robot or software) learns to make decisions through interaction with its environment.
- Natural Language Processing (NLP) focuses on understanding and generating human language. NLP algorithms are used for speech recognition, machine translation and summarising text.
- Computer vision focuses on understanding and interpreting images. Computer vision algorithms are used, among others, in autonomous vehicles, facial recognition and medical image analysis.
- Neural Networks, i.e. computing models which are inspired by the structure of the brain and try to mimic its mode of action.
- Problem solving and reasoning concerns the application of computer systems and algorithms capable of performing tasks which would require human intelligence. Algorithms enable data analysis, pattern recognition, experience-based learning, decision-making, and the generation of new solutions.

The literature contains numerous descriptions of AI typology. One of the most frequently cited and widely used is the division based on functional criterion (Table 2). The functional criterion is based on AI systems' ability to perform specific tasks.

Table 2.
AI typology by functional criterion

Artificial intelligence	
General functionality	Specific functionality
Machine Learning	Deep Learning, Supervised Learning, Unsupervised Learning
Natural Language Processing	Classification, Machine Translation, Answering Questions, Text Generation, Content Extraction
Planning	Not identified
Image Processing	Image Recognition, Machine Vision
Speech Processing	Speech-to-Text, Processing, Text-to-Speech processing
Robotics	Not identified
Expert Systems	Not identified

Source: own elaboration based on IAB Polska 2024, p. 13; Karski 2022, p. 208.

In addition to the aforementioned sub-sections of utilitarian AI, attention should be paid to technologies which automate processes or assist decision-making. *Robotic Process Automation* (RPA) is an example of such a solution. This software simulates human activities on the computer, i.e. clicking, typing and navigating systems to perform tasks automatically. Artificial intelligence interprets, while RPA performs precise, repeatable actions in various systems. The task of RPA bots is to execute a set of instructions. They do not analyse data or make decisions. RPA and AI are automation technologies, but they operate under different principles. RPA executes instructions while AI generates output data based on context (Kargwal, 2025).

4. Research methods

The dynamic development of technology, including artificial intelligence, has a significant impact on how modern companies operate. The increasing availability of AI-based solutions offers new opportunities to automate processes, optimise costs, analyse data, and develop innovative business strategies and models. Their implementation is not only an element of increased competitiveness but also a response to changing market conditions and growing customer expectations. Empirical data that allow for assessing the actual level of implementation of artificial intelligence in companies in Poland gain particular importance. They provide the basis for analysing the directions of technological transformation, the scale of AI applications and the willingness of companies to adopt such solutions.

The analysis is based on statistical data published by the Central Statistical Office. Since 2004, it has been publishing the results of regular surveys on the use of information and communication technologies in enterprises, which are available online[2]. Since 2021, these surveys have included a module dedicated to the application of artificial intelligence solutions.

[2] The CSO also publishes information on the use of ICT by households and public administration bodies.

This study uses data from 2021, 2023, and 2024[3] from Polish companies employing at least 10 people. The scope of the analysis is limited solely to issues related to the use of artificial intelligence technology, excluding other areas covered by the study. The thematic narrowing results from the adopted research objective.

5. Results

To illustrate the dynamics of implementation of artificial intelligence technology by companies by territory, Figure 2 presents data on the percentage of businesses using AI by Voivodeships in 2021, 2023 and 2024. This analysis identifies overall development trends at the national level and regional differences in the pace of AI technology implementation.

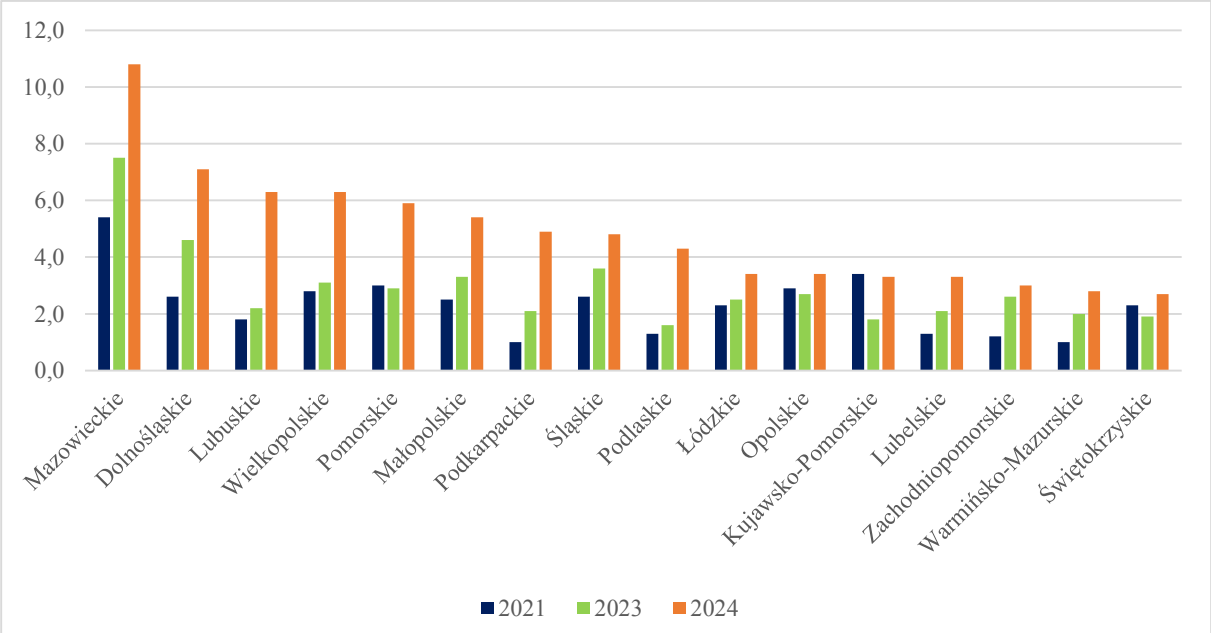


Figure 2. Percentage of businesses which utilise artificial intelligence technologies by Voivodeships in Poland in 2021, 2023 and 2024.

Source: own development based on data from the Central Statistical Office.

In 2024, businesses increased their use of artificial intelligence technology across all Voivodeships compared to 2021. The most significant increase in AI adoption was recorded in the Mazowieckie Voivodeship (from 5.4% in 2021 to 10.8% in 2024, i.e., by 5.4 percentage points). This confirms its dominant position as a Polish centre of innovation and technology. A significant increase in the surveyed indicator was also observed in the Dolnośląskie, Lubuskie and Wielkopolskie Voivodeships (approximately four percentage points over 3 years). Despite the overall upward trend, data analysis reveals regional variations in

[3] No data for 2022.

AI implementation levels. In certain Voivodeships of Eastern and Northern Poland, such as Warmińsko-Mazurskie (2.8% of enterprises using AI in 2024) or Świętokrzyskie (2.7%), the level of AI use remains relatively low, and the change dynamics seem low. The analysis indicates an increasing interest in artificial intelligence technologies among businesses in Poland, though their intensity is strongly influenced by regional factors. These include, in particular, the level of urbanisation, the availability of technological infrastructure, the presence of Research and Development institutions and the general maturity of innovation ecosystems.

The level of AI technology use varies not only by region but also by business type. To capture these differences, Figure 3 shows the percentage of enterprises using AI solutions across selected business sections/areas in 2021, 2023, and 2024. This summary identifies the most technologically advanced sectors and those where the pace of AI implementation remains relatively low.

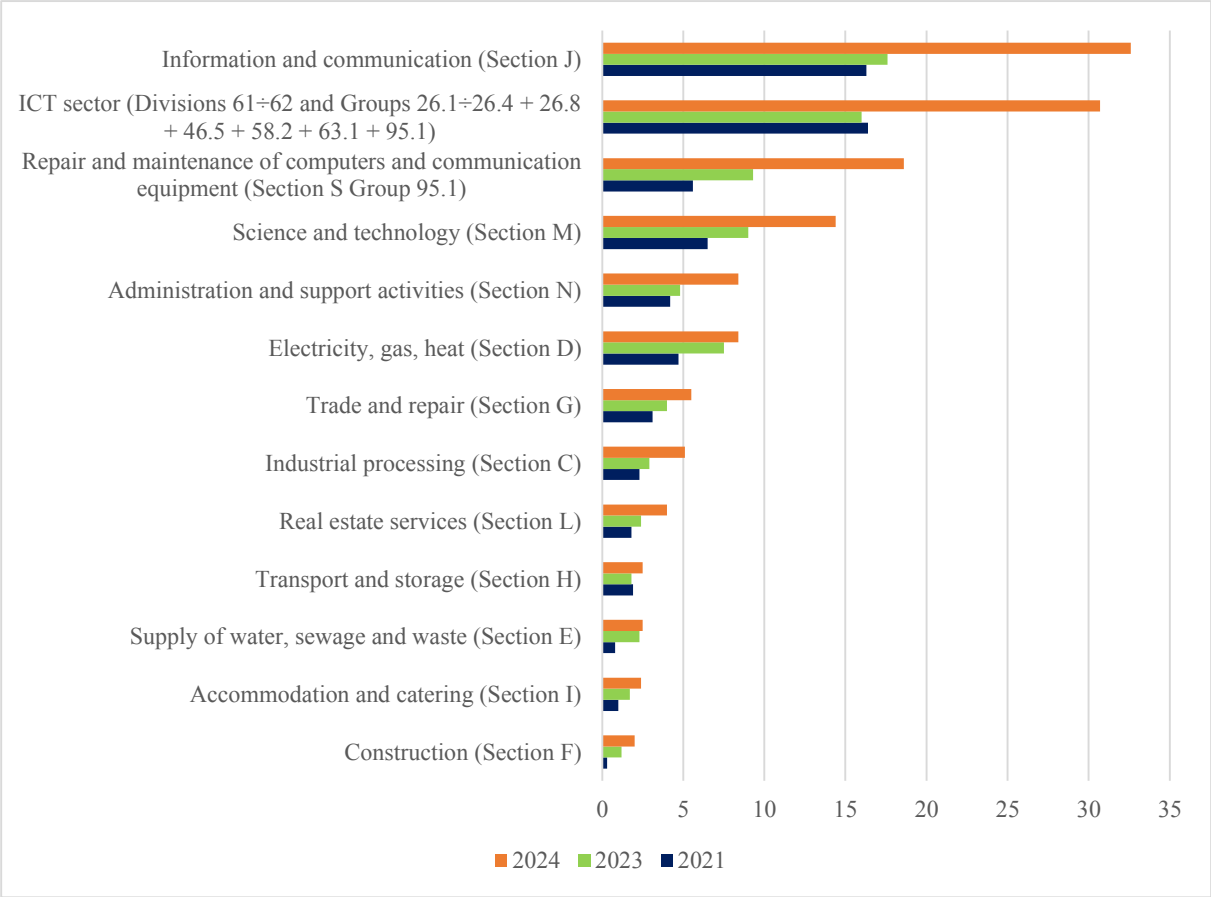


Figure 3. Percentage of businesses which utilise artificial intelligence technologies by type of business activity in 2021, 2023 and 2024.

Source: own development based on data from the Central Statistical Office.

In 2024, the percentage of businesses implementing artificial intelligence technologies across all activities under analysis increased compared to 2021. The highest degree of AI use in 2024 was observed in the Information and Communication section – 32.6%, an increase of 16.3 percentage points from 2021. A similar increase was observed in the broadly defined ICT

sector, where the percentage of enterprises using AI increased from 16.4% to 30.7% (i.e. by 14.3 percentage points). Significant growth was also noted in activities related to the repair and maintenance of computer and communication hardware (13.0 percentage points) and in the scientific and technical sector (7.9 percentage points). The lowest AI adaptation in 2024 occurred in industries such as construction (2.0%), accommodation and gastronomy (2.4%), and transport and storage (2.5%). However, a relative increase in the ratio was also observed in the industries analysed compared with 2021. Variation in AI implementation across companies from different sectors suggests a strong link between their technological advancement and the nature of their operations. The greater intensity of AI applications in the information and communication sectors stems from their specific activities. It is based on data processing, process automation and the integration of digital solutions. In traditional sectors, barriers may be posed not only by technological constraints but also by lower awareness of AI application potential and limited access to adequate human capital and financing.

Figure 4 shows changes in the percentage of companies using artificial intelligence technologies in 2021, 2023, and 2024, accounting for company size and ownership.

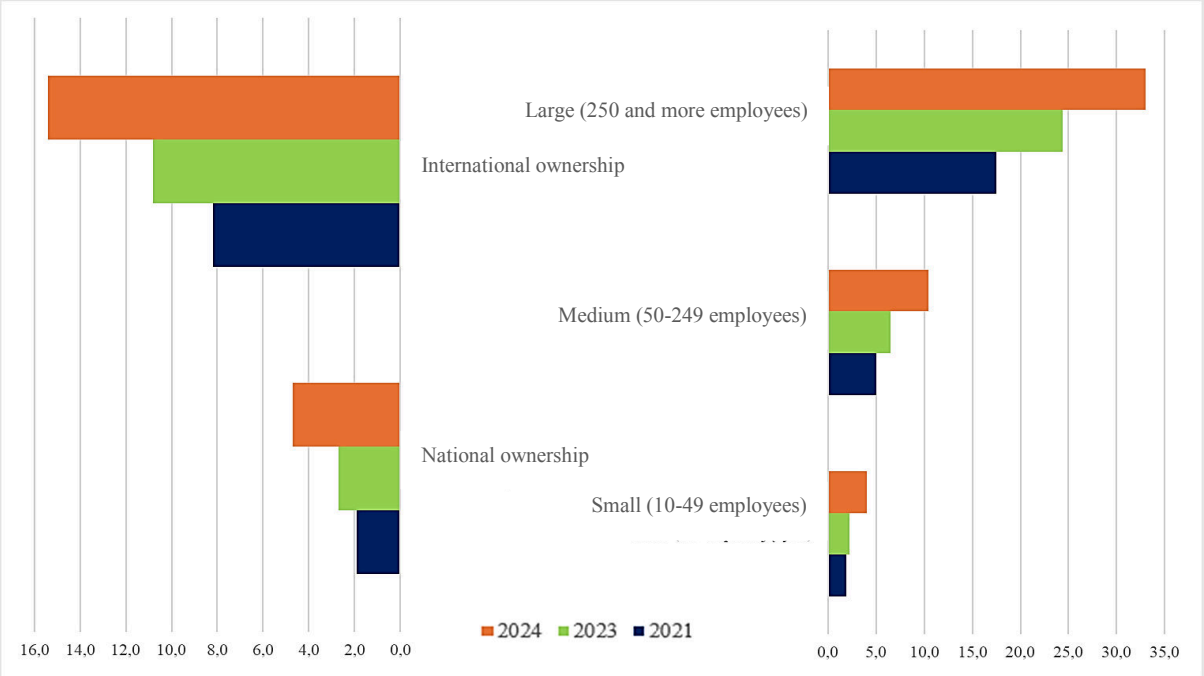


Figure 4. Percentage of businesses which utilise artificial intelligence technologies by business size and ownership in Poland in 2021, 2023 and 2024.

Source: own development based on data from the Central Statistical Office.

The data presented in Figure 4 indicate a systematic increase in the percentage of companies using artificial intelligence technologies across all categories analysed over 3 years. The most significant increase in the indicator analysed was observed among large enterprises – from 17.5% in 2021 up to 33.0% in 2024 (i.e. by 15.5 percentage points). In the group of medium-sized enterprises, this percentage increased by 5.4 pp. (from 5.0% to 10.4%), while in the group of small enterprises, by 2.1 pp. (from 1.9% to 4.0%). This indicates a greater capacity

for large companies to invest in advanced technologies. The analysis by form of ownership shows a clear differentiation between entities with domestic and foreign capital. In 2024, the percentage of foreign capital companies using AI technologies was 15.4%, whereas the percentage among Polish companies amounted to 4.7%. The difference was 10.7 percentage points. In 2024, compared to the base year, the increase in the percentage rate under examination was 7.2 pp., respectively for foreign companies (from 8.2% to 15.4%) and 2.8 pp. for domestic companies (from 1.9% to 4.7%). Therefore, companies with foreign capital implement AI technology at a faster pace. This may be the result of better access to know-how, greater experience in digital transformation processes, and often belonging to international corporate networks.

Continuing the analysis of the use of artificial intelligence technology in Polish companies, Figure 5 illustrates the percentage of entities implementing specific types of AI solutions in 2021, 2023 and 2024. The list below allows you to determine which AI technologies are most frequently adopted.

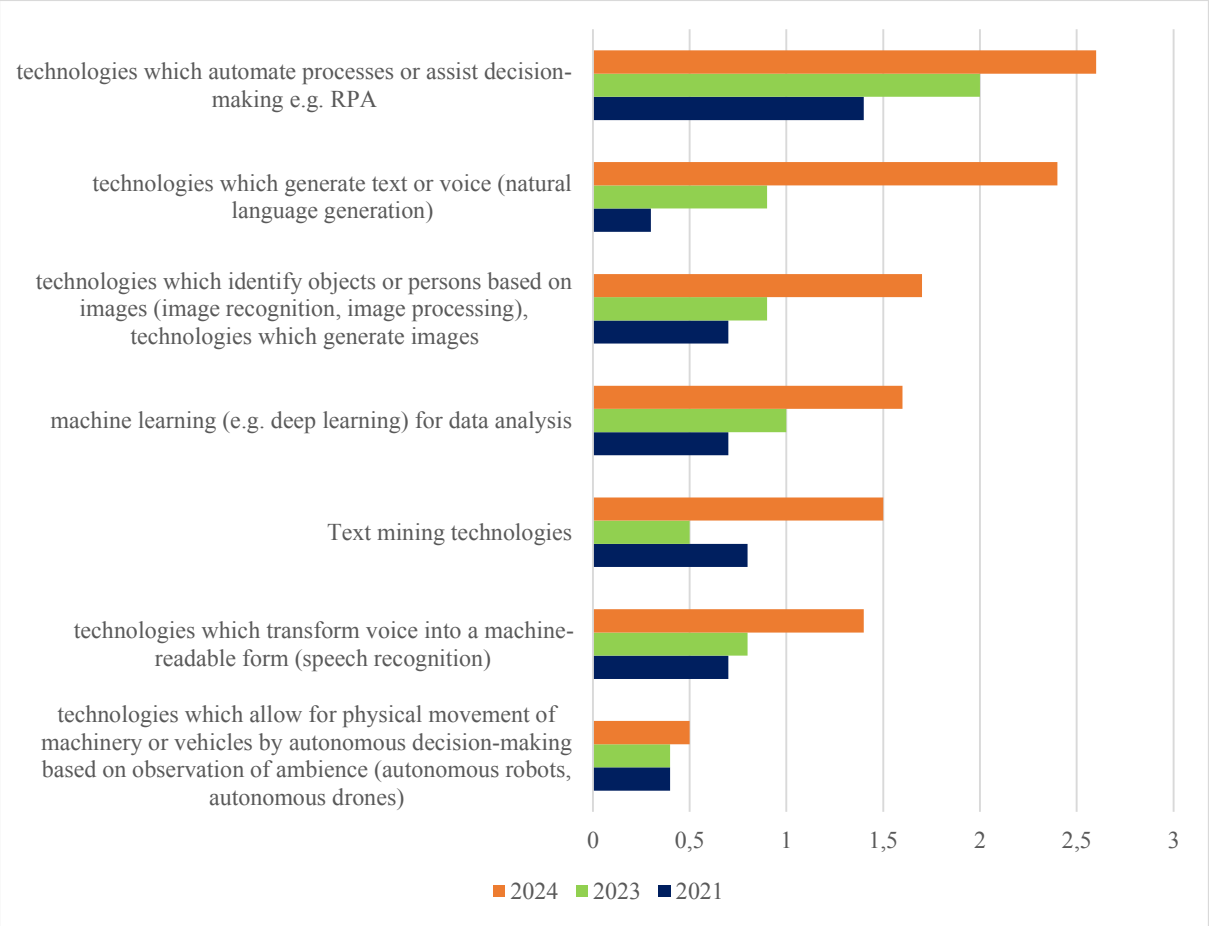


Figure 5. Percentage of businesses which utilise artificial intelligence technologies by technology type in 2021, 2023 and 2024.

Source: own development based on data from the Central Statistical Office.

Compared to 2021, 2024 saw a significant increase in the percentage of companies implementing various artificial intelligence technologies, with a varying growth rate, depending on their type. The most significant increase was recorded in the case of technologies that generate text or voice (natural language generation), where the percentage increased from 0.3% in 2021 to 2.4% in 2024 (i.e., by 2.1 percentage points). The relatively high growth of the examined indicator was also observed for technologies that recognise and process images, which were used by 1.7% of companies in 2024, up from 0.7% in 2021 (an increase of 1.0 pp). Process automation or decision-making technologies have been used relatively frequently during the period under analysis. The percentage of companies benefiting from these solutions increased from 1.4% in 2021 to 2.6% in 2024 (i.e. by 1.2 percentage points). This may indicate a high degree of maturity of such technologies and their usefulness in business processes. In turn, the lowest level of implementation concerns technologies enabling the autonomous movement of machinery or vehicles. Over 3 years, the increase in their use was marginal - 0.4% to 0.5% (i.e., 0.1 pp.). This may result, inter alia, from the limited availability of its applications and relatively high implementation costs.

In addition to previous analyses of the scale of artificial intelligence implementation in Polish companies, Figure 6 depicts the barriers that limited its implementation in 2021, 2023, and 2024. This makes it possible to understand better the structural, technical and organisational challenges of digital transformation and to identify areas requiring support from institutions and/or support in terms of competences.

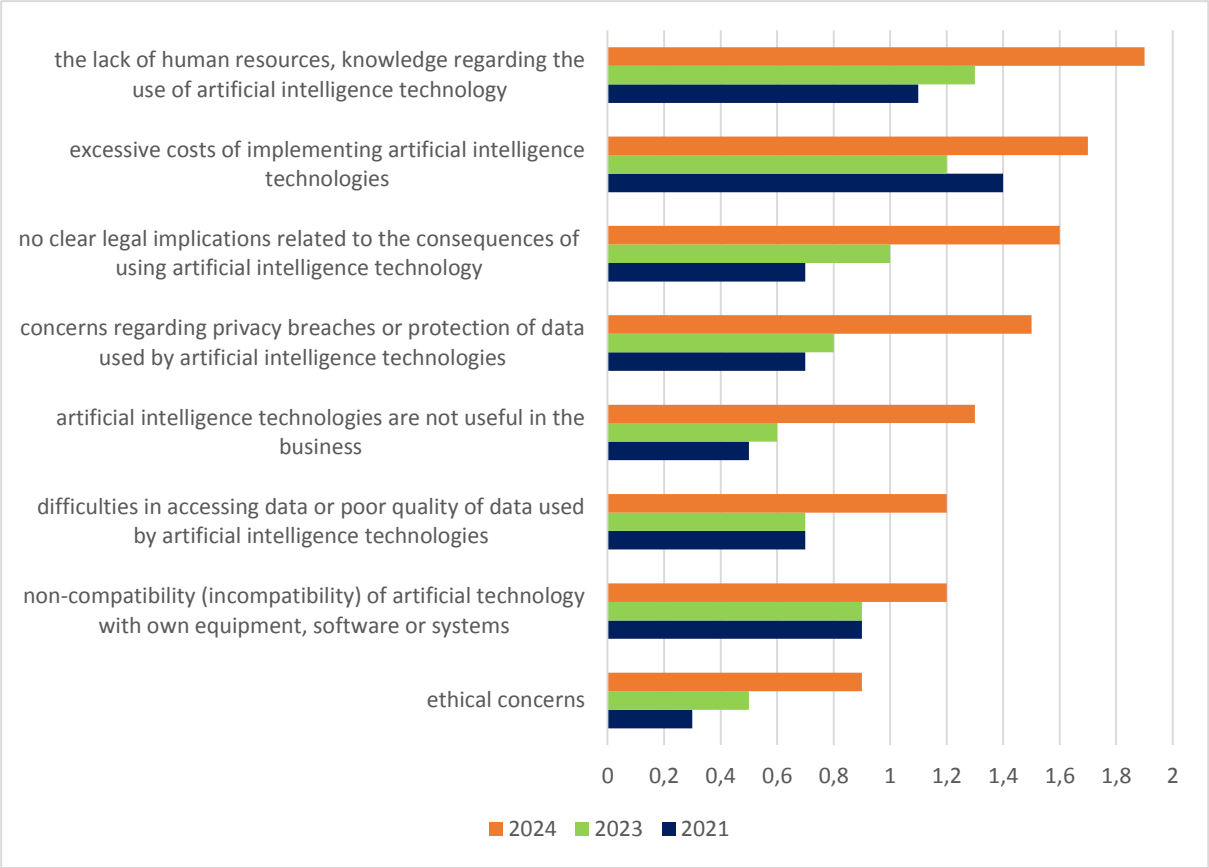


Figure 6. Percentage of enterprises which do not use artificial intelligence technologies due to their non-use in Poland in 2021, 2023 and 2024.

Source: own development based on data from the Central Statistical Office.

The figures shown in Figure 6 indicate that in 2021, 2023, and 2024, the main barriers limiting the use of artificial intelligence technology in enterprises were financial, human, and legal. In 2024, the most common barrier was the lack of human resources and knowledge of AI use. This factor was identified by 1.9% of companies, an increase of 0.8 percentage points from 2021. A similar increase was observed in the case of excessive costs related to implementing AI technology, which became a barrier for 1.7% of operators in 2024 (a rise of 0.3 pp.). The importance of privacy and data protection concerns also increased significantly from 0.7% in 2021 to 1.5% in 2024 (i.e., by 0.8 pp). At the same time, confusion about the possible legal consequences of AI implementations has increased. This factor was a barrier for 1.6% of enterprises in 2024, up from 0.7% three years earlier. There is also an increase in the importance of the technical obstacles: the incompatibility of AI technology with existing infrastructure was indicated by 1.2% of enterprises in 2024 (an increase from 0.9% in 2021), and the difficulty in accessing data or their low quality, also by 1.2% (an increase from 0.7%). Ethical concerns (growth from 0.3% in 2021 to 0.9% in 2024) and the belief that AI technologies are not helpful to the company (from 0.5% to 1.3%) were among the least frequently identified barriers.

In order to provide a summary of the diversity of AI technology use in enterprises in 2024, table 3 lists the maximum and minimum values broken down by region, industry, enterprise size, ownership type, and type of technology used. These results allow for quick identification of areas with the highest and lowest levels of AI adoption.

Table 3.
Summary of results

No.	Category	Maximum (data for 2024)	Minimum (data for 2024)
1	Percentage of businesses which utilise artificial intelligence technologies by Voivodeships	Mazowieckie	Świetokrzyskie
2	Percentage of businesses which utilise artificial intelligence technologies by type of business activity	Information and communication	Construction
3	Percentage of businesses which utilise artificial intelligence technologies by business size	Large	Small
4	Percentage of businesses which utilise artificial intelligence technologies by ownership	International ownership	National ownership
5	Percentage of businesses which utilise artificial intelligence technologies by technology type	Technologies which automate processes or assist decision-making e.g. RPA	Technologies which allow for physical movement of machinery or vehicles by autonomous decision-making based on observation of ambience (autonomous robots, autonomous drones)
6	Percentage of enterprises which do not use artificial intelligence technologies due to their non-use	The lack of human resources, knowledge regarding the use of artificial intelligence technology	Ethical conerns

Source: own elaboration.

Data analysis indicates that the use of AI technology is most widespread in the Mazowieckie Voivodeship, in the information and communication sector, in large enterprises and in companies with international capital. The lowest level of AI adoption is observed in the Świętokrzyskie Voivodeship, in the construction industry, in small enterprises and in companies with domestic ownership. Technologies that automate processes and support decision-making are used much more frequently than autonomous machine and robot technologies. The lack of AI use is primarily due to staffing constraints and knowledge gaps, while ethical issues play the smallest role in this regard.

6. Conclusion

The analysis shows that the level of artificial intelligence use in Polish companies is relatively low and highly diverse across regions and industries. The most significant activity in this area is displayed by entities located in highly urbanised, technologically developed regions,

as well as companies operating in the information and communication sector with a share of foreign capital. In turn, smaller businesses operating in traditional industries and less developed regions are much less likely to implement AI solutions. Data from the Central Statistical Office shows that financial constraints, a lack of qualified personnel, and a low level of technological awareness remain the key barriers to the implementation of artificial intelligence. In light of these findings, it is necessary to intensify efforts to support the development of digital competences, to promote knowledge of the possible applications of AI, and to stimulate innovation in less advanced industries and regions of Poland. Factors such as state policy, strengthening local innovation ecosystems and creating conditions conducive to investing in modern technologies should play a key role.

If Poland aims to compete effectively in the so-called knowledge-based economy, a systematic approach to digital and technological transformation is required, taking into account both the potential and the constraints faced by various groups of companies in this area. Artificial intelligence can therefore play a key role in building resilience, flexibility and competitive advantage of Polish businesses.

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OPPORTUNITIES AND BARRIERS TO ESG REPORTING IN SMALL AND MEDIUM-SIZED ENTERPRISES

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Purpose: The implementation of ESG (Environmental, Social, Governance) principles in the group of small and medium-sized enterprises (SMEs) is currently one of the key challenges for the development of sustainable economies at the local, national and international level. Although the idea of sustainable development has been promoted for years at the level of European Union policies and on the global arena, its effective implementation among SMEs faces a number of unique difficulties, but at the same time creates opportunities that can contribute to improving the competitiveness and long-term stability of companies.
Design/methodology/approach: The inference was based on the results of a systematic literature review. It was found that the management of environmental, social and corporate governance aspects creates an opportunity to accelerate advanced development or increase competitive advantage.
Findings: In the literature on the subject, it has been pointed out that expanding disclosures is essential for companies to maximize returns on ESG investments. This allows creditors, investors, and other stakeholders to gain deeper insights into a company's ESG assessment in a timely and timely manner, facilitating greater support for their continued growth and success. Various proposals are discussed in the research to ensure the best way to implement the upcoming mandatory ESG reporting. The need for systematic, regulated and measurable ESG-focused disclosures is highlighted. There is a crucial need for SMEs to gain an understanding, awareness and recognition of the importance of ESG and its reporting.
Originality/value: The implementation of ESG (Environmental, Social, Governance) principles in the group of small and medium-sized enterprises (SMEs) is currently one of the key challenges for the development of sustainable economies at the local, national and international level. Although the idea of sustainable development has been promoted for years at the level of European Union policies and on the global arena, its effective implementation among SMEs faces a number of unique difficulties, but at the same time creates opportunities that can contribute to improving the competitiveness and long-term stability of companies.
Keywords: ESG reporting, small, medium – sized enterprises. Financial statements, ESG regulations.
Category of the paper: research paper.

Introduction

Financial statements are a structured set of information on the property, financial situation, financial result and cash flows of a business entity, prepared at the end of the reporting period. According to IAS 1, financial statements are a structured presentation of the financial position and transactions made by an enterprise. The purpose of the financial statements is therefore to provide information on the financial situation, achievements and cash flows in the company, which is useful for a wide range of decision-making users, but also the purpose is to present the results of the fiduciary function performed by the management over the resources transferred to it (Kumor, 2013). According to M. Smejda (Smejda, 2006), financial reporting is a synthetic picture of the effects of managerial actions occurring in the process of managing a given business entity. These activities express the multiple economic relationships of current and potential economic partners, such as owners, contractors, managers, employee teams, and society (Pfaff, Messner, 2012).

The financial statements are the final product of the accounting system and are the main source of information on the property and financial situation of a business entity. The financial statements have a formalized form specified in the Accounting Act and in the International Financial Reporting Standards. The final effect of financial reporting is that all the information contained therein comes directly from the accounting books, previously confirmed by the results of the inventory. In accordance with the Accounting Act, financial statements should be prepared in a reliable, clear and consistent manner with the actual state of affairs in order to enable their recipients – including owners, investors, creditors, tax authorities or other stakeholders – to properly assess the financial condition of the entity.

Financial statements can be considered in a static as well as dynamic approach. In static terms, financial reporting can be understood as a set of numerical statements prepared periodically or occasionally, taking into account legal requirements and the expectations of the recipient. On the other hand, in a dynamic approach, financial reporting is understood as the creation and transformation of information characterizing the property and financial situation of a business entity and showing the effectiveness of its operations in the indicated reporting period. In this approach to financial reporting, in addition to the indicated values, the procedures, valuation methods and processes leading to the estimation of this value should also be taken into account.

The financial condition of business entities can be assessed not only with the help of financial results, which are determined on the basis of financial statements. Stakeholders also expect an assessment of the impact that economic entities exert outside the economic sphere (Śnieżek, Wiatr, 2014; Świderska Bek-Gaik, 2016; Dratwińska-Kania, Ferens, Szewieczek, 2021). ESG reporting was the answer to these needs.

Thus, ESG covers three areas:

a) Environmental – environmental protection through sustainable development, reduction of greenhouse gas emissions and energy consumption, use of renewable energy sources, reduction of waste and harmful chemicals.
b) Social responsibility – ESG investments focus on social responsibility, i.e. the impact of companies' operations on employees, consumers, and the local community. Companies investing in ESG are committed to protecting workers' rights, preventing discrimination and promoting diversity, occupational health and safety.
c) Governance – ESG investments include ethical and effective financial management, including issues related to transparency, accountability, ethics and compliance.

The ESG concept itself is based on the idea of CRS, i.e. corporate social responsibility.

Literature review

The idea of corporate social responsibility, commonly known as CSR (Corporate Social Responsibility), means the responsibility of a company for its impact on society and the environment. Initially, it was understood primarily as a charitable activity carried out by individual entrepreneurs, but over time it has transformed into an extensive, strategic management concept, important not only for the company's image, but also for long-term success reflected in the company's financial results and market value.

CSR derives from the philosophical assumptions according to which freedom carries responsibility for actions. Already at the turn of the eighteenth and nineteenth centuries, philanthropic entrepreneurs appeared in the United States, such as Andrew Carnegie, who in his essay "The Gospel of Wealth" argued that the rich should treat themselves as stewards of the common good, fulfilling their moral duty to societies (Kaczocha, 2009). At that time, such activities were usually of a personal philanthropic nature, but were not directly related to the operational activities of the company. The breakthrough came in the mid-twentieth century – in the 1950s, Howard Bowen published the book "Social Responsibilities of the Businessman", which was the first comprehensive synthesis of the idea that companies should act in accordance with social goals and values, because their activities affect ordinary people (Visser, 2008). At the same time, Peter Drucker, considered one of the fathers of modern management, emphasized the need to take into account the social context of companies' activities, thus laying the foundation for the further development of CSR (Drucker, 1966). The sixties and seventies brought significant development impulses. Social and environmental movements have raised public awareness of the impact of corporations on the environment on the one hand, and on workers' rights on the other. Archie Carroll, on the other hand, developed the famous CSR pyramid, in which the responsibility of the company is divided into the following levels:

economic, legal, ethical and philanthropic (Caroll, 1991). The eighties and nineties brought the institutional sanctioning of CSR. Occupational health and safety management systems were introduced, as well as further codes – e.g. "Responsible Care". During this period, the ISO 14001 standards for environmental management and SA 8000 for social standards were created, as well as the guidelines for social reporting – the Global Reporting Initiative (GRI) – which contributed to the institutionalization of the idea of CSR (Visser, 2008). In 1994, John Elkington introduced the idea of the Triple Bottom Line, which assumed that the performance of a company should be evaluated through the prism of three areas: economics (profit), ecology (planets) and social issues (people) – 3P (World Commission on Environment and Development (1991) [1987]. Our common future. Oxford University Press). In Europe, at the turn of the century, CSR has gained importance as part of a sustainable development strategy. At the Lisbon Summit in 2000, the EU set itself the goal of making the EU economy the most competitive and knowledge-based, while ensuring sustainable, sustainable development and social cohesion. In 2001, the European Commission published the "Green Paper on Corporate Social Responsibility", which was intended to stimulate a public debate on responsible business[1].

In 2004, the completion of the "Who Cares Wins" report – prepared by the UN Global Compact – initiated the use of the term ESG. This was a clear shift from the moral values of CSR to a structurally defined and measurable approach, integrating environmental, social and corporate governance factors (Kiziukiewicz, Jaworska, 2017; Lerner et al. 2015). This report indicated that ESG is a value for investors and financial markets and should be treated as an element of assessing their stability and long-term value[2].

In 2011, the EU updated its approach to CSR, adopting a strategic definition as "the responsibility of companies for their impact on society", with a focus on integrating CSR into the competitiveness of companies[3]. The next phase of development was related to the departure from the CSR approach to more advanced concepts. In 2006 and 2011, Michael E. Porter and Mark Kramer proposed the concept of "Creating Shared Value" (CSV), which postulates that business activities can simultaneously increase a company's competitiveness and improve social conditions – in other words: combining value creation with responsibility (Porter, Michael, Kramer; 2011).

Undoubtedly, the development of CSR was related to the increase in the importance of legal regulations related to its reporting. In 2010, ISO published ISO 26000 – a guide to the principles of responsible business, covering areas such as governance, human rights, industrial relations, the environment, fair practices, consumer relations and social engagement[4]. From a theoretical perspective, the development of CSR can be observed as an evolution from CSR 1.0 (defensive,

[1] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2001:0366:FIN:EN:PDF, 1.09.2025.
[2] https://www.icl-group.com/blog/the-evolution-from-csr-to-esg/, 1.09,2025.
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0681, 1.09.2025.
[4] https://www.parp.gov.pl/csr#csr, 1.09.2025.

charitable, promotional and strategic) to CSR 2.0, understood as a transformational, integrated approach, based on values such as creativity, scalability, globality (combining global and local activities) and circularity; its goal is value creation, good governance, social contribution and environmental integrity (Visser, 2010).

CSR has played an important role in shaping corporate and social awareness for decades, but is now giving way to ESG, which offers a more transparent, measurable and strategically integrated approach. The transformation began to gain momentum in the early 21st century. In 2022-2023, the European Union adopted the CSRD (Corporate Sustainability Reporting Directive) and ESRS standards, and is currently consulting the Corporate Due Diligence Directive (CSDDD) – entering CSR as part of a broad ESG (environmental-social-governance) approach.

The CSRD (*Corporate Sustainability Reporting Directive*) is a European Union directive that aims to increase the transparency of doing business in the field of sustainable development. It introduces the obligation to report information in accordance with the ESRS (*European Sustainability Reporting Standards*).

The CSRD modifies sections of Directive 2013/34/EU (the 'Accounting Directive') with regard to non-financial disclosures initially introduced by the Non-Financial Reporting Directive (NFRD). The sustainability reporting mandates set out in Article 1 of the CSRD are assumed to be phased in between 2024 and 2028 for four different categories of companies.

In the literature, the term ESG refers to a strategy, concept, principle, standard, tool, pattern, system, or model that combines three types of governance aspects: environmental, social, and governance and includes interactions between them. ESG refers to the non-financial aspects of governance that have a material impact on the performance and value of entities (Gemza et al., 2024; EBA, 2021; Ling, Wang, Sueyoshi, Wang, 2021).

Therefore, several key thematic areas can be identified in the literature on the subject (Giemza et al., 2024):

1. Sustainable supply chain (Koberg, Langoni, 2019; Cousins, Lawson, Petersen, Fugate, 2019; Tseng, Wu, Lim, Wong, 2019; Becerra, Mula, Sanchis, 2021; Feng, Lai, Zhu, 2023).
2. Measurement, collection and exchange of data.
3. Impact on business efficiency (Abdallah, Alfar, Alhyari, 2021; Rupa, Saif, 2022).
4. Managing relationships with business partners in the supply chain (Muzaffar, Khurshid, Malik, Azhar, 2019.
5. Decarbonization challenges (Zhang, Alvi, Gong, Wang, 2022).

ESG Regulations

ESG issues are regulated by two cross-cutting standards:

- ESRS 1 – general requirements,
- ESRS 2 – general disclosures.

In addition to the above standards, non-financial reporting will be regulated by ten thematic standards, respectively concerning the environment (ESRS E1-E5), employee and social affairs (ESRS S1-S4) and business conduct rules (ESRS G1).

ESRS Environmental Standards:

- ESRS E1 Climate Change.
- ESRS E2 Pollution.
- ESRS E3 Water and Marine Resources.
- ESRS E4 Biodiversity and Ecosystems.
- ESRS E5 Resource use and circular economy.

ESRS standards in the field of social policy and corporate governance:

- ESRS S1 Employees managed by the organization.
- ESRS S2 Employees in the value chain.
- ESRS S3 Affected Communities.
- ESRS S4 Consumers and end-users.
- ESRS G1 Running a business.

It was also assumed that in addition to universal (baseline) standards, industry (sectoral) standards would be created. It is estimated that there will be about forty of them. Work on these standards will last until mid-2026 and their introduction is expected to reduce the burden on companies obliged to prepare a sustainability report – mainly because there will be clear guidelines for given industries and it will be easier to meet the requirements resulting from the ESRS. Currently, companies are obliged to report on material issues, as the cross-sectional and thematic standards are assumed to apply to all companies that are subject to the CSRD Directive – regardless of the sector in which a given entity operates.

European Sustainability Reporting Standards

The European Sustainability Reporting Standards change the way and, above all, the scope of reporting, focusing on the topics that are relevant, i.e. those through which a given company exerts the greatest impact on the environment or society. At the same time, companies are obliged to identify the key risks and opportunities that may arise for the company from climate change or social issues. For the topics of material and key risks, the financial dimension should

also be estimated. This concept is defined as double materiality and is unique from other non-financial reporting standards currently in force in the world. ESRSs also require, like other global standards, to look at both relevant topics and risks not only through the prism of one's own organization, but also from the perspective of the value chain.

It is these issues concerning the assessment of dual materiality, as well as the value chain perspective, that are described in ESRS 1 – General requirements. ESRS 1 together with ESRS 2 forms the foundation on which all other standards are based.

The ESRS 1 standard contains the most important guidelines concerning, among other things, the structure and content of sustainability reporting. It also defines the most important terms used in all other standards. The ESRS 1 standard requires entities to report in accordance with the principle of double materiality. It also imposes an obligation of consistency with other legal regulations, such as the EU Taxosome and the CSRD, and highlights the role of transparency and reliability of data, e.g. through requirements for the verification of information and the use of appropriate indicators and metrics. Undoubtedly, a useful element of ESRS 1 are the individual add-ons that are at the end of the standard.

ESRS No. 1 defines the qualitative characteristics of the information of the published data. These features should be consistent with the features indicated by the Accounting Act. These are:

- usefulness,
- faithful reflection,
- comparability,
- verifiability,
- intelligibility.

Definitions of the above features are contained in Appendix B to the above Standard. When analysing these features, it should be pointed out that the information will be useful if it influences the decisions of users – in accordance with the principle of materiality.

This information can be divided into two groups: concerning the future and concerning the past. Future data will be used to make your own predictions, while historical data will be used to confirm feedback.

Only information that is neutral, complete and accurate will be a faithful reflection of reality. Another feature mentioned is comparability, which concerns the comparability of different entities, but also the comparability of subsequent periods. Verifiability, in turn, consists in the possibility of confirming information in source documents or output data.

Non-financial reporting obligation

The first solution assumed that for the financial year starting on 01.01.2024, large public-interest entities exceeding the average number of 500 employees in the financial year as of the balance sheet date would be subject to the reporting obligation. The obligation to report ESG in the first year was imposed on the following entities:

- public interest, i.e. listed on the stock exchange,
- more than 500 employees in the financial year,
- meeting at least one of two conditions:
  a. balance sheet total of more than EUR 20 million,
  b. net sales revenues of more than 40 million euros.

On the other hand, for the financial year beginning on 01.01.2025, the obligation applies to other large enterprises and other parent companies of a large group.

That is, the obligation to submit a report is imposed on:

1. Entities that are not public-interest entities, but meet at least two of the three conditions:
   - balance sheet total of more than EUR 20 million,
   - net sales revenues of EUR 40 million,
   - average number of employees 250 people.
2. entities that are public-interest entities but employ fewer than 500 people, but meet two of three conditions:
   - balance sheet total of more than EUR 20 million,
   - net sales revenues of EUR 40 million,
   - average number of employees 250 people.

For the financial year starting on 01.01.2026, the reporting obligation also covers small and medium-sized enterprises of public interest and not being micro-entities:

- some issuers defined as small and non-complex institutions,
- some issuers defined as in-house insurance undertakings and in-house reinsurance undertakings.

For the first two years, small and medium-sized public-interest entities will be able to opt out of sustainability information in their activity reports if they provide a reason for their resignation.

The European Union has introduced regulations that are primarily aimed at ensuring transparency in companies. From 2024, ESG reporting was to become a key obligation for many companies in Europe. In June 2025, the Council of Ministers adopted a deregulatory solution regarding ESG reporting for companies. The draft provides for postponing the ESG reporting obligation for companies by two years. The solution adapts Polish law to the regulations of the European Union. Thus, the ESG reporting obligation for companies is postponed by 2 years.

This obligation also applies to companies that were supposed to start reporting in 2026 and 2027, respectively.

Thanks to the postponement of reporting deadlines, companies will have more time to prepare for the new obligations. The solution is also intended to reduce excessive administrative burdens for companies, especially in the face of increasing competition from companies from outside the European Union.

At the same time, the European Union is working intensively on further changes in ESG reporting, including a significant narrowing of the scope of entities obliged to report. At the same time, a new proposal was introduced in 2025 whereby only companies with more than 1000 employees and either revenues of more than €50 million or a net turnover of more than €25 million would be included in the CSRD, removing around 80% of companies from sustainability reporting requirements[5].

Economic activities can make an important contribution to the environmental objective of protecting and restoring biodiversity and ecosystems in a number of ways, including by protecting, preserving or restoring biodiversity and ecosystems, and thus through the development of ecosystem services. Such services fall into four categories: supply services (food and water supply):

- regulation services (climate and disease control),
- support services (nutrient cycles and oxygen production),
- cultural services (providing spiritual and recreational benefits).

Reporting in the field of society concerns: own employees, employees in the value chain, communities, consumers and end users.

With regard to issues concerning people and society (workers, suppliers, customers, users, etc.), including information on:

- equal opportunities for all, including gender equality and equal pay for equal work or work of equal value,
- training and skills development, as well as employment and integration of persons with disabilities,
- working conditions, including a safe working environment, wages, social dialogue, collective bargaining,
- respect for human rights, fundamental freedoms, democratic principles and norms.

In terms of corporate governance, the ESG report should include information on:

- the role and composition of the administrative, management and supervisory bodies of the entities, including with regard to sustainable development issues,
- business ethics and corporate culture, including anti-corruption and bribery,

[5] The European Commission has announced the publication of the first 'Omnibus' package, which contains a number of proposals to reduce sustainability reporting requirements for companies, including plans to remove 80% of companies from the scope of the Corporate Governance Directive (CSRD) and to limit the sustainability information that large companies and banks can request.

- the political involvement of the entity, including its lobbying activities,
- managing relationships with business partners and their quality, including payment practices,
- the entity's internal control and risk management systems, including in relation to the entity's reporting process.

Among the indicators in each of the three internal factors appear:

a) Uniform indicators for all actors,
b) uniform indicators for industry players,
c) indicators specified for a given entity.

Metrics are a key part of the ESG reporting process, as they enable you to measure, monitor, and communicate your company's sustainability performance. Their proper selection and use allows for the presentation of reliable, comparable and detailed data that is relevant both for internal management objectives and for stakeholders, including investors, regulators, clients and local communities. When choosing indicators, it is necessary to take into account several basic criteria. Firstly, the indicator must reflect issues relevant to the company's operations and its stakeholders, which is related to the materiality assessment. Secondly, it should be possible to measure precisely, based on available data and standards. Thirdly, the indicator must allow for time-over-time comparisons and with other players in the industry, which requires the use of recognised and well-defined methodologies.

The breakdown of indicators within ESG reports can be made based on their functions and thematic areas. Environmental indicators (E) focus on aspects related to environmental protection. The most commonly used environmental indicators include the level of carbon dioxide emissions per unit of production (e.g. t CO_2/kg of product), the consumption of electricity and other raw materials per unit of production, the waste recycling rate, the share of renewable energy sources in total energy consumption, or the water consumption rate per unit of product or service. Social (S) indicators relate to relationships with workers, communities, human rights and working conditions. Social indicators commonly include the level of employee turnover, the employment rate of women and men, the number of training days per employee, diversity and equality policy, the rate of reported cases of human rights violations or the percentage of suppliers meeting the criteria of responsible production. Corporate governance (G) indicators cover aspects of governance, governance structure, ethics and transparency. Among the corporate governance indicators, the risk management indicator (e.g. the number of reported corruption incidents), the ownership and management structure, the number and qualifications of supervisory board members, the anti-corruption policy, or the transparency index in financial and non-financial reporting are important.

To ensure the reliability and comparability of data, there is an increasing emphasis on the use of standardised indicators developed by international organisations and initiatives. Examples of such standards are the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), or the European ESRS Standards. It is important to

choose metrics that best reflect key aspects of your business and ESG risks, as well as those that are relevant to stakeholders. The selection of indicators should support transparency, credibility and the ability to compare between companies and industries. In the context of ESG reporting, there are imposed or standard indicators that have been developed by international organizations and regulations to ensure the consistency, comparability, and reliability of data. The implementation of these indicators is intended to help stakeholders assess the sustainability performance and performance of companies. Organizations such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), the Climate Disclosure Standards Board (CDSB), and more recently the European ESRS Standards, have developed sets of indicators that can be mandatory or recommended in ESG reports. In the case of GRI, the guidelines offer a wide catalogue of indicators on various aspects of ESG, with the possibility of choosing the right ones for the specifics of the company's operations. The reports include those that are most relevant, but in some jurisdictions or sectors there may be reporting obligations for a specific set of indicators. European law, in particular the CSRD and ESRS directives, indicates the relevant indicators that companies must report. Although the indicators themselves are defined within the standards and may vary depending on the industry, examples of key areas and values that must be included in the reports are indicated. For example, in a climate context, companies may be required to disclose CO_2 emissions according to certain methodologies, such as Scope 1 (direct emissions), Scope 2 (indirect emissions associated with energy purchases) and Scope 3 (other indirect emissions from the supply chain).

Table 1.
Catalogue of indicators that cover various aspects of sustainability

Organizations	Assumptions	Indicators
Global Reporting Initiative (GRI)	GRI offers a wide catalogue of indicators that cover various aspects of sustainability, and are available under the GRI Standards. These indicators are divided into thematic categories and refer to quantitative and qualitative data. GRI emphasizes reporting with numerical values, measurement methodology, and quality of information.	CO2 emission (GHG)**:** GRI 305-1 (Scope 1), GRI 305-2 (Scope 2), GRI 305-3 (Scope 3) – emissions in tons of CO_2e. **Energy consumption**: GRI 302-1 – total energy consumption in kWh. **Water consumption**: GRI 303-1 – total water consumption in m^3. Environmental failure rate**:** The number of environment-related breach incidents. **Working conditions**: employee turnover rate, absenteeism, accident rate at work.
Sustainability Accounting Standards Board (SASB)	SASB has developed industry standards that contain specific indicators suitable for different sectors of the economy. SASB metrics are particularly useful for investors and focus on ESG risks and opportunities that can impact financial results. Industry standardization makes SASB allow for comparing indicators between companies in the same industry.	Energy**:** Average CO_2 emissions per megawatt/h (MJ/power output) – energy sector. **Cosmetics**: The percentage of products certified as organic or cruelty-free. **Mining**: Hazardous waste rate per unit of production. **Technology**: Percentage of products recyclable.

Cont. table 1.

Climate Disclosure Standards Board (CDSB)	The CDSB has developed a reporting framework related mainly to climate issues, particularly in the field of disclosure of information on emissions and climate risk, which have a direct impact on the company's operations. An important aspect here is attention to the quality and comparability of information on emissions and climate risks.	CO_2 emissions per unit of activity. The value of potential financial losses related to climate risk. The share of renewable energy in the company's energy capital. Impact resulting from extreme weather phenomena – number of interruptions in operations, material damage.
European ESRS Standards	The European ESRS Standards, developed under the CSRD Directive, include detailed guidelines and key indicators to be reported by companies operating in the EU. These standards are based on the latest trends and best practices, combining elements of global standards and local requirements.	Net CO_2 emissions**:** the total emissions of both Scope 1, 2 and 3, expressed in tonnes. Renewable and non-renewable energy consumption**:** percentage of total energy consumption. Impact on the local community**:** number of social initiatives or supported projects. Working conditions and diversity**:** the percentage of women on the board, the diversity index. ESG risk management

Source: own study based on **Global Reporting Initiative (GRI)**: GRI Standards. https://www.globalreporting.org/ **Sustainability Accounting Standards Board (SASB)**: SASB Standards, https://www.sasb.org/ **Climate Disclosure Standards Board (CDSB)**: Framework and Guidance, https://www.cdsb.net/ **Europejskie Standardy ESRS**: Draft standards developed by EFRAG, available on the official EFRAG website https://www.efrag.org/ and in the European Commission's materials on the CSRD Directive.

ESG for small and medium-sized enterprises

The implementation of ESG (Environmental, Social, Governance) principles in the group of small and medium-sized enterprises (SMEs) is currently one of the key challenges for the development of sustainable economies at the local, national and international level. Although the idea of sustainable development has been promoted for years at the level of European Union policies and on the global arena, its effective implementation among SMEs faces a number of unique difficulties, but at the same time creates opportunities that can contribute to improving the competitiveness and long-term stability of companies.

According to the European Commission, the CSRD increases transparency and accountability, including by expanding its scope to include large and listed companies while modernising and strengthening reporting rules[6]. The new requirements ensure that stakeholders have access to the information they need to assess the impact that companies have on people and the environment. Companies subject to reporting obligations must comply with the European Sustainability Reporting Standards (ESRS).

[6] https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en, 11.09.2025.

The mandatory draft standard – ESRS for Small and Medium-sized Enterprises Exposure Projects (ESRS LSME) – applies to listed SMEs, comprising entities with transferable securities traded on regulated markets in the EU, as well as small and non-complex institutions, internal insurers and reinsurers. At the same time, a voluntary standard for non-listed SMEs is being developed. This standard is a draft of the voluntary European Sustainability Reporting Standard (VSME ESRS), and is drafted explicitly for SMEs not listed on a regulated market in the European Union. It serves as a simple reporting tool to help these SMEs respond to requests for information on sustainability from a variety of stakeholders, including banks, investors and larger companies – for which they serve as suppliers.

While non-listed SMEs are not directly covered by the CSRD, they are likely to be de facto required by their business partners and investors to report accordingly. In other words, even if the CSRD does not explicitly apply to unlisted SMEs, market pressures and stakeholder expectations may prompt them to adopt sustainability reporting practices.

For SMEs, the path to ESG integration is fraught with challenges related primarily to limited resources, lack of expertise and perceived focus on short-term goals, which are different from those of large enterprises, scale of operations, human, capital and organizational resources that often distinguish small companies from large corporations, which is part of the specific challenges related to the implementation of ESG policies. SMEs often operate in limited financial conditions, lack sustainability professionals, and have limited access to competence and knowledge in the latest ESG standards. However, despite these challenges, implementing ESG can be seen as an investment for the future, opening up long-term opportunities for small businesses. In the context of ESG, SMEs typically do not have dedicated sustainability departments, and their activities are often carried out on an ad hoc basis or as part of broader development strategies. This situation means that elements of sustainable development are not always an integral part of the main business goals, and their implementation requires not only a change in organizational culture, but also significant investments, which can be a financial burden for these companies.

Not only will early and voluntary CSRD compliance help SMEs maintain business relationships with their existing customers, but ESG compliance in general presents significant growth opportunities for smaller businesses. Potential benefits include:

- Sustainability-linked loans that tie financial incentives to ESG goals.
- Attracting new customers.
- Positioning ourselves for regulatory benefits.

In addition, the commitment to sustainability reporting provides SMEs with valuable insights into non-financial indicators related to their business activities. This understanding reveals cost-saving opportunities (such as optimizing energy consumption) and potential innovations, as well as increasing clarity on how to comply with mandatory regulations.

CSRD compliance makes organizations more agile and future-proof, giving them a competitive advantage. Therefore, SMEs are encouraged to proactively monitor their sustainability practices as soon as possible in order to include customers and prevent potential contract losses.

Given the growing preference for sustainable businesses, early voluntary compliance by SMEs can provide a competitive advantage, contributing to their forward-looking and environmentally conscious image.

Undoubtedly, the implementation of ESG principles in SMEs brings numerous benefits. Above all, SMEs that engage in ESG initiatives can gain a competitive advantage in the market. Consumers are increasingly choosing products and services from companies that demonstrate social and environmental responsibility, as well as attach importance to the quality of management. ESG activities can also reduce operating costs, for example by optimizing energy and water consumption or reducing waste, which is especially important for companies with limited financial resources. In addition, companies implementing ESG policies can benefit from various forms of public and EU support, which are increasingly available at the national and European level. Financing investments in energy-efficient technologies, environmental certifications, training and development of employee competences in the area of CSR – these are just some of the instruments that are conducive to the development of responsible business in SMEs. For many companies, ESG implementation is also a form of building lasting relationships with stakeholders, which in turn fosters the development of the company's long-term value. The growing importance of ESG in the context of the availability of financing is also an important opportunity – banks, investment funds and other institutions are increasingly requiring small and medium-sized entities to report and be transparent about ESG policies. This, in turn, motivates SMEs to develop a sustainable development strategy as part of building trust and opportunities to raise capital.

Barriers to ESG implementation in SMEs

The barriers to implementing ESG principles in the small and medium-sized enterprises (SMEs) sector are multidimensional and result from various organizational, financial, legal and cultural conditions. Understanding them is crucial for developing effective strategies to support these companies in the process of implementing sustainable practices.

One of the main barriers is the limited knowledge of SME owners and managers about the ESG concept, its scope and the benefits of implementation. Many companies, especially those operating at the local or regional level, are not familiar with the latest international or national frameworks, standards and guidelines for reporting and responsible management. Lack of awareness means that pro-environmental, social and corporate governance activities are not

treated as an element of the development strategy, but as additional obligations or costs, which discourages their introduction. Additionally, owners often do not recognize the direct financial benefits, which affects the limited incentive to invest in these areas.

Another significant challenge is the lack of qualified staff or available ESG specialists who would be able to help develop and implement a sustainable development strategy. SMEs most often do not have their own HR or CSR departments to deal with these issues, which forces them to outsource services or search for knowledge on their own, often to a limited extent. Lack of competence in the measurement, reporting and interpretation of ESG indicators means that the company may not carry out its activities in a consistent, methodologically correct and reliable manner, which weakens their credibility and resistance to criticism or controls.

Implementing ESG policies often involves upfront costs, such as investments in green technologies, certifications, training, infrastructure upgrades, or operational process improvements. For many SMEs, especially those with limited equity or borrowing financing on the basis of short-term liabilities, these are major financial barriers. In addition, access to funding sources targeting ESG-related projects, such as EU funds or loans with preferential pathways, is often limited or requires complex application procedures, which is difficult for smaller companies that do not have their own finance departments or advisors specializing in green and social accounting.

SMEs face difficulties related to the lack of uniform, widely accepted and tailored ESG reporting standards. International frameworks such as the GRI or SASB are mainly aimed at large corporations and generate complex, time-consuming documentation that may be beyond the capabilities of a small or medium-sized enterprise to complete. As a result, many SMEs are concerned that reporting will require a lot of work and at the same time will not bring direct economic benefits, resulting in delays or no action altogether.

Summary

The implementation of ESG principles in the group of small and medium-sized enterprises is a key challenge for the development of sustainable economies. ESG is a response to the expectations of stakeholders regarding the assessment of the impact of economic entities outside the purely economic sphere. The concept of ESG is based on the idea of Corporate Social Responsibility (CSR), but it should be more transparent, measurable and strategically integrated than CSR.

Implementing ESG in SMEs is a key challenge, but it also presents significant opportunities. Among the barriers to implementing ESG in SMEs, it is necessary to point out limited knowledge and lack of awareness, which makes ESG treated as an additional cost, and not an element of the strategy. Lack of qualified staff or ESG specialists and the need to incur start-

up costs (technologies, certifications, training), which are a serious financial barrier for companies with limited capital.

Another problem is access to dedicated sources of funding (e.g. EU funds), which is hampered by complicated application procedures or the lack of adapted standards, as international reporting frameworks (GRI, SASB) are aimed mainly at large corporations and generate time-consuming documentation that exceeds the capabilities of SMEs.

When analysing the chances of implementing ESG in SMEs, it is necessary to point out the competitive advantage, as engaging in ESG allows you to gain an advantage in the market, as consumers prefer socially and environmentally responsible companies. ESG measures can lead to lower operating costs, e.g. by optimizing energy consumption and reducing waste.

In the literature on the subject, it has been pointed out that expanding disclosures is essential for companies to maximize returns on ESG investments. This allows creditors, investors, and other stakeholders to gain deeper insights into a company's ESG assessment in a timely and timely manner, facilitating greater support for their continued growth and success. Various proposals are discussed in the research to ensure the best way to implement the upcoming mandatory ESG reporting. The need for systematic, regulated and measurable ESG-focused disclosures is highlighted. There is a crucial need for SMEs to gain an understanding, awareness and recognition of the importance of ESG and its reporting.

Recommendations for the implementation of ESG principles in the group of small and medium-sized enterprises

In recent years, the ESG concept, which includes environmental, social and corporate governance issues, has become one of the key trends shaping the practice of managing business organizations. Small and medium-sized enterprises are increasingly faced with the need to adapt to new regulatory requirements, investor expectations and stakeholder pressure. The implementation of ESG in this group of entities is not only a response to external obligations, but can also be the basis for building a sustainable competitive advantage. The aim of this study is to present recommendations for the effective implementation of ESG in the SME sector, taking into account the specifics of their scale of operation, organizational structure and available resources. A major challenge in the process of implementing ESG in small and medium-sized enterprises is the reduction of capital, human resources and technological resources. Unlike large corporations, these entities are less likely to have specialized units responsible for sustainable development. Therefore, it is crucial to integrate ESG issues into the overall strategy of the company, so that the responsibility for their implementation is not seen as a separate project, but as an integral part of operational activities. This process should begin with a diagnosis of the current situation, covering both environmental, social and organizational aspects. Only on this basis is it possible to formulate realistic goals, adequate to the scale of the activity and the nature of the industry.

In the environmental area, the identification of key sources of the company's impact on the environment is of particular importance. For many SMEs, the basic issue is the consumption of energy, materials and waste generation. Implementing energy-saving solutions, circular economy or optimization of production processes can bring both environmental and financial benefits. It is important that these activities are based on measurements and data, so that progress can be monitored and future initiatives can be rationally planned. In the absence of internal competencies, it is worth using advisory support or cooperation within clusters and industry organizations.

The social dimension of ESG in SMEs primarily includes relations with employees, the local community and contractors. Building an organizational culture based on respect for employee rights, transparency and equal opportunities is conducive to employment stabilization and increases team engagement. In the conditions of staff shortage, competent management of human resources becomes a decisive factor for competitiveness. At the same time, companies can strengthen their position in the local environment through responsible relationships with suppliers and customers, as well as by participating in initiatives supporting regional development.

The third pillar of ESG is corporate governance, which takes a different form in SMEs than in listed companies. Despite less formalization, transparency of decision-making processes, a clear division of responsibilities and business ethics are crucial. Owners and management should create a governance framework that allows ESG factors to be systematically incorporated into strategic and operational decisions. This includes, but is not limited to, the introduction of compliance procedures, the prevention of conflicts of interest, and the development of a culture based on accountability and trust.

The implementation of ESG is also associated with the need to report on activities and results. In the case of SMEs, proportionality should be sought so that reporting obligations do not impose an excessive burden. The development of a simplified but consistent reporting framework allows for transparent communication with stakeholders and facilitates access to finance, especially in the context of the growing role of sustainable instruments. Reporting should be based on reliable data, which strengthens the company's credibility on the market.

It is also worth emphasizing that the implementation of ESG in SMEs is not a one-time process. It is evolutionary and requires continuous improvement. The involvement of top management and building employee awareness are crucial. Education in the field of sustainable development and sensitivity to ethical and environmental issues are conducive to the permanent rooting of ESG principles in everyday business practice. It is also important to create partnerships between companies, public institutions and social organisations, which allows for the exchange of experiences and reduces the costs associated with the implementation of new solutions.

In conclusion, implementing ESG in the SME sector is both a challenge and an opportunity. A properly designed and implemented process can lead to increased efficiency, improved reputation and increased resilience to changes in the market and regulatory environment. Recommendations for ESG implementation should take into account the proportionality of actions, integration with the company's strategy and systematic monitoring of the effects. In the long term, ESG adaptation can become an important element of building a sustainable model for the development of SMEs, while contributing to the achievement of social and environmental goals at the level of the economy as a whole.

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PRINCE2 RISK MANAGEMENT IN FDM PROTOTYPING MANUFACTURING: CASE STUDY

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Purpose: The aim of this study is to identify, assess, and classify key risks that arise at various stages of prototype development—planning, implementation, and testing—when using additive manufacturing techniques. It was determined, how structured project management practices, implemented in accordance with the PRINCE2 methodology, can enhance the predictability, quality, and efficiency of rapid prototyping processes. By analysing the technological, organizational, and operational risks, the study also explores how risk mitigation strategies can support decision-making and improve overall project outcomes.
Design/methodology/approach: The study employs a case-study approach supported by qualitative analysis of risk management procedures within the PRINCE2 framework. Particular emphasis is placed on identifying uncertainties specific to 3D printing with FDM technology, such as material performance, parameter selection, equipment limitations, and iteration-related delays. A full risk register was developed, alongside risk response plans and periodic reviews, demonstrating how PRINCE2 tools can be directly applied to a rapid prototyping environment.
Findings: The findings show that the structured PRINCE2 approach enhances control over both technological and organizational uncertainty. The method enables more effective planning of printing processes, improves communication between project stakeholders, and supports early identification of critical risks. As a result, organizations can achieve shorter project cycles, reduced costs, and higher-quality prototype outputs. The analysis of the printed stabilizer also revealed five significant opportunities—both realized and potential—related for example to print-time optimization, pre-print quality improvement or the prospective commercialization of medical-grade prints.
Research implications: During the risk analysis of the printed prototype, five opportunities were identified that have already occurred and those that are likely to occur if the concept of further research is accepted, and which will have a significant impact on obtaining/increasing profits: optimization of parameters to reduce printing time, the possibility of improving the quality of the prototype before printing, reduction of filament costs, acquisition of additional research data, the possibility of automating the preparation of the prototype model, commercialization of medical prints.
Practical implications: The presented case confirms that PRINCE2 risk management mechanisms—when embedded into rapid prototyping processes—can be effectively used by organisations of varying scale to improve predictability, efficiency, and product value.

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Originality/value: The article emphasizes the importance of systematic risk management in innovative additive manufacturing environments and offers practical recommendations for enhancing project management practices in FDM-based prototyping.
Keywords: risk management, 3D printing, PRINCE2, medical prototype.
Category of the paper: Research paper / Case study.

1. Introduction

In 1901, A.H. Willet stated that risk is an objective phenomenon indirectly related to uncertainty. This definition is somewhat tautological and proves to be imprecise today, because uncertainty is not only ambiguous, but also difficult to define. F.H. Knight published his concept of uncertainty in 1921, dividing it into measurable and immeasurable. He called the former risk and the latter uncertainty in the strict sense. This division is still considered appropriate today.

In 1966, two further definitions of insurance risk were published in the United States. These were (Chong, Brown, 2001):

- risk defined as uncertainty about the occurrence of a specific event in conditions where there are two or more possibilities,
- in the second definition, insurance risk was understood as an insured person or object.

The above definitions became the subject of discussion, on the basis of which four fundamental conclusions were identified regarding the nature of risk:

1. risk is not a homogeneous phenomenon, which makes it impossible to provide a single universal and unambiguous definition of risk,
2. risk occurs in at least two forms – objective and subjective,
3. risk can be studied from different perspectives, as danger, gambling, uncertainty, or the probability of a specific phenomenon or set of phenomena occurring,
4. finally, risk is something variable and periodic, i.e. it is a variable process rather than a stable state of the environment.

The motivation for conducting a risk analysis is primarily the consequences that may occur when implementing a risky project or undertaking. An undertaking is any activity or task that can be undertaken. In a developed society, business activity in the general sense deserves special mention, because functioning in this space involves the continuous implementation of successive projects, which make up the process of project implementation. The responsibility of those who implement them, in turn, forces them to seek ever better methods that ensure not so much better results in the implementation of these projects, but above all the best possible predictability of the effects. Therefore, after defining the project, it is crucial to analyze the possible consequences of its implementation as deviations of the results from a certain assumed model.

Contemporary companies implementing small-batch, single-unit, or individual projects operate in conditions of increased uncertainty resulting from both the uniqueness of orders and the high variability of customer requirements. Such projects are characterized by limited process repeatability, which naturally hinders the use of standard planning and control methods. As a result, the importance of effective risk management as a tool to support decision-making, improve the predictability of results, and minimize the likelihood of costly deviations is growing (Dudziak, 2014).

One of the main applications of 3D printing in medicine, which is personalized orthopedic devices, belongs to this type of project. 3D modeling allows for understanding the individual conditions of the patient and adapting the treatment strategy to the specific case. The ability to quickly create prototypes leads to immediate testing and refinement of new medical solutions, which accelerates the research and development process. In addition, printed models can also be used for educational purposes, enabling students and young doctors to learn through practical exercises.

The literature on the subject emphasizes that individual projects generate specific categories of risk, including technological, design, scheduling, and communication risks, resulting from the need for close cooperation between many specialists and the adaptation of solutions to the individual expectations of recipients. Thus, classic approaches to risk management need to be adapted to the context of low-volume projects, where flexibility, iterative planning, and rapid identification of deviations play a key role (Jajuga, 2005; Jedynak et al., 1977; Kaczmarek, 2010).

The article presents the practical application of the PRINCE2 (Projects IN Controlled Environments) methodology in the field of risk management in a project to develop an individual prototype of a thumb stabilizer printed on a 3D printer. The structure of risk management and the main strategies for responding to risk are discussed, and a sample risk register is created. The aim of this article is to present the specifics of risk management according to the PRINCE2 method, taking into account small-batch projects based on 3D printing. The presented considerations provide valuable guidance for companies, enabling them to effectively reduce uncertainty in such projects, as well as a basis for further research on improving risk management processes in highly customized project environments.

2. Risk management methodology according to PRINCE2

Risk management, as defined in ISO 31000 "Risk management – Principles and guidelines", can be defined as coordinated activities aimed at directing and controlling a project in terms of risk. Project risk management is not optional: it is essential for effective project management. It should be applied to all projects and included in project plans and operational documents,

becoming an integral part of every aspect of project management (ISO 31000, 2018; Pacana, 2017).

The risk management process according to PRINCE2

The project risk management addresses the uncertainty associated with project estimates and assumptions. In the early stages of a project, the level of risk exposure is highest, but information about project risk is minimal. PRINCE2 is based on seven principles, compliance with which ensures that the project is conducted in an orderly and controlled manner from the very beginning. One of the fundamental topics according to this methodology is risk management.

Risk management in PRINCE2 consists of the following stages (Ligarski, 2014; Wolniak, 2010):

- Risk identification – recognizing potential threats and opportunities that may affect the project's objectives. Identified risks are recorded in *the Risk Register*, forming the basis for further analysis. Various techniques are used in the process, such as brainstorming, document analysis, review of historical project data, and expert consultation.
- Risk assessment – determining the likelihood of occurrence and the potential impact of risks on the project. The purpose of this stage is to understand which risks require active measures and which can remain within the project tolerance.
- Risk response planning – selecting appropriate actions to minimize negative effects or take advantage of emerging opportunities.
- Implementing the risk management plan – carrying out the planned actions and monitoring their effectiveness.
- Risk monitoring and control – continuously updating the risk register and reporting on the status of risks at each stage of the project. PRINCE2 emphasizes clear and regular exchange of information on risks through periodic reports, stage reviews, and consultations with stakeholders.

Adapting PRINCE2 to small projects

Single-series projects with a short life cycle, such as the development of a prototype of an individual thumb stabilizer made using 3D printing technology, require the adaptation of the PRINCE2 methodology to the specific nature of small project teams and a limited scope of activities. PRINCE2 emphasizes the principle of tailoring to the project situation, which assumes the possibility of consciously simplifying processes, documentation, and tools without sacrificing their key functions. In practice, this means reducing formal procedures in favor of lightweight, iterative mechanisms that allow for quick responses to changes and emerging risks (Wróblewski, 2015).

Table 1.
Comparison of Full PRINCE2 Methodology and Tailored PRINCE2 for prototype development projects (e.g., a 3D-Printed Thumb Stabilizer)

PRINCE2 Area / Element	Full PRINCE2 Methodology	Tailored PRINCE2 for prototype development projects
Project scope	Clearly defined and formally documented; stable requirements approved at initiation	Broad, flexible scope allowing iterative adjustments as the prototype evolves
Roles and responsibilities	Multi-layer structure (Project Board, Project Manager, Team Manager, Delivery Team)	Combined roles; often one person performs management and technical tasks; simplified decision paths
Project documentation	Extensive documentation including PID, Quality Management Strategy, Risk Management Strategy, Communication Plan	Minimal documentation: short project brief, basic product specification, simplified risk register
Risk management	Formal risk register, structured analysis, periodic risk reviews at stage boundaries	Light, operational risk register; frequent short reviews; immediate response to emerging risks
Project stages (Stage management)	Project divided into multiple controlled stages supervised by the Project Board	Typically one or two stages: design/modeling and 3D printing + functional testing
Change control	Formal change management with impact assessment and authorization by the Project Board	Dynamic, on-the-spot changes; documented through brief notes or updated CAD versions
Product quality	Quality requirements defined in a formal Quality Plan; acceptance testing following standards	Quality assessed through rapid functional and visual checks; iterative refinements during prototyping
Schedule and progress control	Detailed schedules (e.g., Gantt charts), formal progress reporting, structured checkpoints	Short, flexible timelines reflecting the experimental and iterative nature of prototyping; daily or continuous monitoring
Communication management	Formal communication channels, regular reports, structured meetings	Direct, fast, informal communication; reporting limited to essential milestones
Project objectives	Delivery of a final product meeting predefined technical and functional criteria	Production of a functional prototype meeting minimum requirements for testing or validation
Stakeholder engagement	Regular interactions with multiple stakeholders; formal review sessions	Collaboration focused on one or two key stakeholders (e.g., user, designer, technician)
Benefits management	Formal Benefits Management Plan and post-project benefit review	No formal plan; benefits assessed through the prototype's practical usefulness and test outcomes

Source: own work based on: Kaczmarek, 2010; Wróblewski, 2015.

In the case of prototype projects, it is important to reduce formal artifacts—such as extensive quality plans, detailed role descriptions, or multi-stage approvals—in favor of agile, operational documentation, e.g., in the form of a shortened risk register or a checklist covering key technological, organizational, and quality risks (Table 1). Regular, brief risk reviews conducted during the preparation of the CAD model, configuration of print parameters, or physical tests enable ongoing monitoring of significant factors affecting the project outcome, while minimizing the time required (Budzik, et al., 2022).

This approach is fully consistent with the logic of PRINCE2, which emphasizes the need to deliver a product in a controlled but not overly formalized manner. Simplified tools allow for transparency in the decision-making process, ensure communication between stakeholders,

and maintain basic mechanisms for assessing and responding to risks without burdening the project with unnecessary administration. As a result, even small individual projects – such as the production of an orthopedic stabilizer prototype using the FDM method – can benefit from the advantages of the PRINCE2 structural approach, while maintaining the efficiency typical of experimental and iterative projects (Brahma et al., 2025)

3. 3D printed prototype project

The study involved designing and printing a functional prototype of a personalized thumb stabilizer for the right hand using an FDM 3D printer. The team consisted of two people: the author of the article, acting as a CAD designer, printer operator, and project manager, and an assistant, who was a potential customer. The project was scheduled to take four weeks, and the budget was limited to the funds allocated by the Kielce University of Technology for research activities at the Faculty of Management and Computer Modeling in the Department of Quality Management and Intellectual Property, of which the author is a member.

During the project, the following stages were planned:

- development of a 3D model,
- preparation of files for printing,
- performing material tests and calibrating the printer,
- production of a prototype,
- quality assessment and possible corrections.

A Shining3D EinScan-SP V2 rotary scanner was used to develop the 3D model, which was used to take a three-dimensional image of the customer's hand. Next, using SolidWorks software, a customized stabilizer model was designed (Fig. 1). After converting the stl file to g-code format in PrusaSlicer, the printing and 3D printer parameters were determined, in this case Prusa i3 MK3. The most important settings are (Kristiawan, 2021; Ngo, 2018):

- infill: 100%,
- head temperature: 200℃,
- table temperature: 60℃,

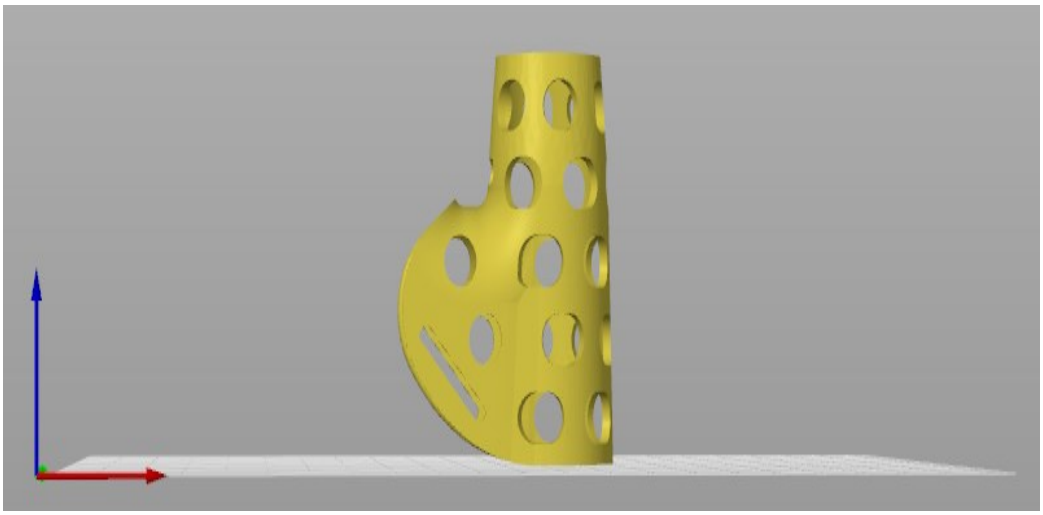


Figure 1. Thumb stabilizer model placed on the virtual printer table.

Source: own work.

Due to the fact that the stabilizer will be in direct contact with the skin, it was decided to use PLActiv filament to print the actual model, which is a combination of high-quality PLA with a patented and scientifically proven non-copper additive with antibacterial properties. The prototype used to validate the geometric parameters was made of standard PLA filament, which is significantly cheaper than PLActiv filament.



Figure 2. Printed stabilizer on the client's thumb.

Source: own work.

The prototype printing process took 1 hour and 16 minutes and ran smoothly. 4.14 meters of material from a 330-meter spool were used. Since the stabilizer test showed that no modifications were necessary, printing of the actual model began immediately after changing the filament. No difference was noticed between the printing processes. The printed stabilizer fit well and completely prevented thumb movement (Fig. 2), and thanks to the additional security provided by a non-elastic fabric strap, it will provide solid support.

4. Implementation of risk management in the project

Table 2.
Register and analysis of risks that may occur during the project

ID	Risk	Causes /sources	Possible consequences	Probability	Impact	Response strategy	Actions	Responsibility
R 01	3D printer failure	Mechanical damage, motor jam	production interruption, delay	3	3	Reduction	Arranging for a backup device or access to another printer	PM
R 02	Power outages	Network failure	Design interruption, production interruption, delay	1	3	Avoidance	Establishment of a backup power source	PM
R 03	Errors in the STL file or CAD model	Insufficient verification, incorrect scaling	print deformations, incorrect dimensions	2	3	Reduction	test print, model validation, slicer simulations	D
R 04	Lack of material or unsuitable filament	poor inventory planning, delivery problems	printing interruption	2	2	Avoidance	advance orders with buffer, alternative suppliers	PM
R 05	Problems with layer adhesion — peeling from the table	uneven heating table, contamination, lack of primer	deformation, print loss	3	2	Reduction	testing adhesives, adjusting temperatures, using raft/brim	PO
R 06	Delays in delivery of parts for assembly	incorrect orders, supplier fails to meet deadlines	delays in assembly and project completion	2	2	Transfer /Reduction	contract with deadline guarantee, selection of local suppliers	PM
R 07	Inappropriate design ergonomics	lack of end-user consultation	user dissatisfaction, need for modification	2	3	Reduction	early user consultation, partial prototypes	D
R 08	Overheating or print deformation	improper cooling, excessive speed	Surface defects, layers separating	2	2	Reduction	use of fans, cooling tests, speed reduction	PO
R 09	Damage to prototype during testing	operator errors, vibrations	need to repair or replace the printer	1	3	Acceptance / Reduction	compliance with procedures, offline testing, insurance	PO
R 10	Absence of a key team member	illness, other commitments	Delays in tasks	1	3	Reduction	documentation, substitution plan, cross-training	PM

Note: PM – project manager, D – designer, PO – printer operator.

Source: own work.

Ten key risks were identified at the planning stage (Table 2), including technical (e.g., printer failure), design (errors in the CAD model), logistical (lack of materials), and organizational risks. Each risk was assigned a probability and impact assessment, and a response strategy (e.g., reduction, avoidance) was developed.

For each defined risk, the response priority was calculated using the formula (Eq. 1):

$$\text{Priority} = P \times W \tag{1}$$

where:
probability (P): scale 1-3,
impact (I): scale 1-3.

The highest probability of occurrence combined with a high impact on the project's success was recorded for risk no. 01. A 3D printer failure—given that its correct operation is fundamental to the execution of the printing process—was identified as the most critical risk, as its occurrence would prevent the project from being carried out altogether. To mitigate this threat, appropriate actions were implemented, including obtaining permission to access an FDM 3D printer located at the Faculty of Mechatronics and Machine Design at the Kielce University of Technology, ensuring process continuity in the event of equipment malfunction.

A slightly lower response priority was assigned to risks no. 03, 05, and 07. Notably, risks 03 and 07 are associated with the same stage of project execution, as both directly relate to the design of the product. This stage is therefore crucial for the subsequent success of the project, as any design inaccuracies may propagate into later phases and significantly affect final quality. To address these risks, the stabilizer was printed early in the process in the form of a prototype using basic PLA filament. This preliminary print allowed for verification of the model's geometry, early detection of design flaws, and informed adjustments before committing to production using the final material.

5. Summary

Thanks to the development of a detailed register of risks that may occur throughout the project and the effective risk management approach—including risk analysis and, consequently, the preventive printing of a stabilizer prototype using a cheaper equivalent of the final material (PLActiv)—the risk of dimensional incompatibility between the printout and the customer's hand structure was significantly minimized. This preventive strategy allowed to eliminate one of the most critical technical risks at an early project stage, ensuring higher confidence in the final prototype's performance.

In addition, preparing the project according to the PRINCE2 methodology encouraged the author to undertake proactive actions aimed at identifying market and technological opportunities. As a result, several opportunities were recognized that are highly likely to occur and can substantially increase profitability if a strategy is implemented to further capitalize on the knowledge gained during the research. These opportunities include optimization of printing parameters to reduce production time, the possibility of improving prototype quality before

final manufacturing, the use of lower-cost filament alternatives, acquisition of additional research data, automation of prototype model preparation, and commercialization of the final products derived from the developed methodology.

Collectively, these opportunities highlight the broader potential of integrating structured project management with additive manufacturing technologies. They demonstrate not only the advantages of systematic risk management but also the capacity of PRINCE2 to support entrepreneurial thinking and continuous improvement in rapid prototyping processes. Ultimately, the findings suggest that the combined use of disciplined project governance and iterative 3D printing workflows can significantly enhance both the technical outcomes and the business viability of future development projects.

6. Conclusions

3D printing (additive manufacturing) has revolutionized the prototyping process, enabling the rapid production of complex geometries without the need for molds or complex tools. Its use is growing in the industrial, medical, aerospace, education, and research sectors. Despite its popularity, this technology still faces numerous challenges: material limitations, printing precision, mechanical properties of layers, adhesion to the working platform, thermal stability, and many others.

Projects involving new technologies and prototyping carry a high degree of uncertainty. Although widely available, 3D printing requires experience in technical parameters, materials, and spatial design. Therefore, it is crucial to implement an effective risk management system that allows you to identify and mitigate the impact of undesirable events, as well as take advantage of emerging opportunities.

Technology projects, even smaller ones, are characterized by significant uncertainty. Technical problems, design errors, delivery delays, or limited budgets can significantly affect the success of a project. In such an environment, a formal approach to risk is crucial—identifying, controlling, and monitoring potential threats and opportunities. The PRINCE2 methodology, although often used in large organizations, can be effectively adapted to smaller-scale projects, providing a framework for logical, predictable risk management. Its versatility allows the approach to be adapted to the characteristics of both large corporate ventures and smaller technical projects. The application of the PRINCE2 methodology has made it possible to systematize the approach to risks in the project. Formalization of the risk management process:

- increased the predictability of project implementation,
- enabled faster response to technical problems,
- improved the quality of communication between the designer and the potential customer.

The risk analysis conducted in this single-series project provides a valuable knowledge base for future initiatives of a similar nature and opens the door to further research in several important directions. One promising area is the comparison of the PRINCE2 methodology with agile approaches, such as Agile or Scrum, specifically in the context of risk management for technical and prototyping projects. Such a comparison can help determine which methodology is more effective in mitigating uncertainties, ensuring that project objectives are met, and adapting to rapidly changing technological or organizational conditions. Another critical direction is assessing the impact of different risk strategies on both the cost and timeline of prototyping projects. Understanding how various approaches influence resource allocation, project duration, and potential bottlenecks allows organizations to optimize processes, reduce delays, and better anticipate challenges, ultimately improving overall project efficiency. Additionally, empirical studies comparing the effectiveness of PRINCE2 and PRINCE2 Lite in projects with similar characteristics could provide practical insights into whether a simplified version of the methodology can deliver comparable benefits in smaller-scale or less complex initiatives.

By pursuing these research directions, future studies can build on the lessons learned from this project, improving project management practices and supporting the more effective implementation of innovative additive manufacturing solutions. Ultimately, these investigations have the potential to contribute not only to the theoretical understanding of risk management methodologies but also to provide actionable guidance for practitioners seeking to integrate structured and iterative approaches into prototyping processes, enhancing both quality and efficiency in real-world applications.

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FROM RED TO TEAL – GENERATION Z AND ORGANIZATIONAL COLOR MODELS

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Purpose: The study aims to analyze Generation Z's preferences regarding organizational characteristics and their relationship with the type of work environment. The study seeks to determine which values and organizational features are most important to young people, and to what extent their declared preferences correspond to their perceptions of how these characteristics are implemented in various organizational models (red, amber, orange, green, and teal). Additionally, the study aims to understand how Generation Z combines aspirations toward idealistic work models (e.g., teal organizations) with realistic professional needs and employment stability.

Design/methodology/approach: The study was conducted in the form of a survey in May 2025 among students of the Faculty of Management at the University of Gdańsk. Respondents indicated their preferred type of organization and assessed the level of implementation of specific organizational characteristics that they consider important for their work environment. The analysis included calculating consistency indicators between the preferred type of organization and the preferred degree of implementation of particular characteristics, as well as interpreting the results in the context of the classification of organizational types: red, amber, orange, green, and teal.

Findings: The analysis of preferences among Generation Z participants shows that in evaluating organizational characteristics, students are guided by both aspirations and realistic needs. The highest value was attributed to *mutual respect*, aligning respondents most closely with the teal organizational model, while other traits related to collaboration and autonomy point toward green organizations, and procedural and efficiency-oriented features are associated with orange organizations. *Job stability*, on the other hand, most often corresponds to amber organizations, reflecting a need for predictability and structured order. The analysis of consistency between the preferred organizational type and the perceived level of implementation of individual characteristics indicates that the overall level of alignment is generally low. The highest consistency values were observed in areas such as cooperativeness, innovativeness, self-management, autonomy, and efficiency, while the lowest were found in stability, sense of security, procedurality and loyalty. These results suggest that the respondents consciously distribute their preferences across different organizational models, selecting features that best match their current needs and experiences. In doing so, they combine aspirations toward teal and collaborative work models with the realistic demands of the labor market, such as structure, procedures, and security.

Research limitations/implications: The study is limited to a sample of students from a single faculty of the University of Gdańsk, which may affect the generalizability of the results. In the future, it would be worthwhile to conduct research involving a broader population of Generation Z representatives from various educational or professional backgrounds to determine whether the observed patterns are representative.
Practical implications: The results may help in designing programs for the onboarding and adaptation of young employees in the workplace, particularly in companies with a partnership-based or self-organizing structure. Employers can better tailor training processes, talent management, and organizational culture-building strategies to the expectations of Generation Z.
Social implications: The study indicates the need to educate young people about different types of organizations and corporate values, which may contribute to better functioning of the labor market and increased satisfaction and engagement in the workplace.
Originality/value: The article offers a new perspective on analyzing Generation Z's preparedness to function within different types of organizations, with particular emphasis on teal, green, and orange organizations. The value of this study lies in demonstrating how young people's declared preferences regarding the work environment correlate with their assessment of the implementation of key organizational characteristics. The research identifies gaps between Generation Z's aspirations and their practical alignment with organizational types, highlighting areas where greater awareness, education, and adaptation are needed—both on the part of employees and employers. Additionally, the study reveals that young people combine idealistic expectations related to teal models and collaboration with realistic needs connected to procedures, structure, and a sense of security, which may have significant implications for designing talent management strategies.
Keywords: Generation Z, Organizational Color Theory, Teal organizations, Organizational types.
Category of the paper: Research paper.

1. Introduction

The contemporary labor market is undergoing dynamic changes, with increasing emphasis on flexible forms of employment, employee autonomy, and a focus on values and meaningful work. Of particular interest is Generation Z, entering the workforce with a strong need for self-realization, work–life balance, and participation in decision-making processes. Young employees expect work environments that support collaboration, trust, and creativity. In this context, Teal organizations, which emphasize self-management, partnership-based relationships, and shared responsibility, are particularly relevant. Understanding the extent to which the values and preferences of Generation Z align with the principles of Teal management can help organizations better prepare for changes in team functioning.

In this article, it is hypothesized that, despite expressing appreciation for the values characteristic of teal organizations (autonomy, collaboration, mutual respect), Generation Z respondents most often choose work environments that do not fully embody these values in practice. This article aims to analyze the preferences of Generation Z regarding organizational

characteristics and their relationship with the type of work environment. The study focuses on the alignment between the declared attitudes of students at the Faculty of Management, University of Gdańsk, and the preferred type of organization (Red, Amber, Orange, Green, and Teal), as well as the extent to which respondents identify with the key characteristics associated with these models. The article seeks to identify areas where respondents' expectations align with organizational characteristics, as well as areas where discrepancies occur, to understand how attitudes toward specific organizational features shape perceptions of different types of firms.

Based on this framework, the following research questions were formulated:

1. Which organizational characteristics are considered most important by Generation Z, and to which type of organization do they correspond most closely?
2. To what extent does the preferred type of organization align with the perceived implementation of these characteristics in practice?
3. Which areas of values and organizational traits show the highest consistency between declared organizational preferences and the assessment of the extent to which these traits are realized?
4. Which areas exhibit the lowest consistency, potentially indicating flexibility or pragmatism in choosing a work environment?
5. How do young respondents balance aspirations for idealistic organizational models, such as Teal, with realistic expectations of work environments represented by Orange, Green, or Amber models?

Modern organizations need to continuously monitor the labor market to respond effectively to changes in employee values, attitudes, and expectations. Understanding the needs of current and future team members enables the adaptation of organizational structures, decision-making processes, and workplace culture. Recognizing the concerns and aspirations of Generation Z facilitates the creation of environments that foster engagement, creativity, and shared responsibility. Only organizations that respond proactively can maintain competitiveness and innovation, highlighting the relevance of this topic for the implementation of modern and flexible management models.

2. A Literature Review on Organizational Color Theory and Generation Z

Entrepreneurship has long been a subject of interest across multiple scientific disciplines, including economics, psychology, sociology, and management studies. Despite numerous efforts, no universal theory of entrepreneurship has been established, which can be attributed to its complexity and interdisciplinary nature (Carree, Thurik, 2010; Pablo-Lerchundi et al., 2015). In the literature, two main approaches are distinguished: entrepreneurship as a set of

individual traits and entrepreneurship as a process of creating and developing new ventures (Daszkiewicz, 2014). A classical contribution was made by Joseph Schumpeter, who regarded entrepreneurship as a driving force of economic development and innovation, introducing the concept of "creative destruction" (Schumpeter, 1960). Frank Knight emphasized the role of risk and uncertainty, noting that profit rewards decisions made under conditions of uncertainty (Jajuga, 2019). Entrepreneurs, endowed with the spirit of creative destruction, dismantle inefficient solutions and initiate new ones (Bławat, 2003). The Austrian School (Mises, Kirzner) focuses on the individual, subjective preferences, entrepreneurship, and market processes. It treats entrepreneurship as a process of discovery, while the market is seen as a learning and adaptive system. Ludwig von Mises highlighted the subjective theory of value and criticized state interventionism, whereas Israel Kirzner concentrated on detecting market opportunities and coordinating supply with demand (Gaweł, 2007). Contemporary theories link entrepreneurship with economic development (Lukas, Kihlstrom, Laffont) as well as with the theories of the firm and the learning organization. Today, entrepreneurship is defined in two ways: as a set of traits and behaviors (activity, innovativeness, risk-taking propensity, and opportunity recognition) and as a process of creating new value, where both individual predispositions and actions leading to the implementation of changes and generation of market benefits are essential (Janowski, 1998). Current perspectives also emphasize the impact of entrepreneurship on society and the environment, including social entrepreneurship, sustainable development, women's initiatives, and inclusive regional development (Scartozzi et al., 2024). Research indicates that the social impact of entrepreneurship receives the most attention, while its environmental impact remains underexplored. Thus, entrepreneurship can be understood as a process integrating personality traits, managerial functions, and market activities - identifying opportunities, creating innovations, organizing resources, and undertaking risk - which collectively contribute to organizational and economic development (Gartner, 1988). The significance of entrepreneurship in this context lies in its role in preparing employees to actively participate in organizational life, develop innovative solutions, and make decisions in uncertain environments. Entrepreneurial skills, such as initiative, creativity, self-discipline, and the ability to collaborate, form the foundation for building modern organizational models based on autonomy, trust, and responsibility. As a result, employees not only perform their assigned tasks but also become active participants in decision-making processes and co-creators of organizational value.

Contemporary organizations operate in conditions of increasing competition and dynamic market changes, which necessitate the creation of environments conducive to innovation, employee engagement, and effective utilization of market opportunities. Understanding the mechanisms of entrepreneurship and the ways in which it is implemented within organizational structures allows managers to better align management strategies with market needs. One framework that aids in understanding organizational evolution is Frederic Laloux's „Reinventing Organizations" theory, which distinguishes five types of organizations -

Red, Amber, Orange, Green, and Teal - reflecting levels of structural maturity, leadership style, and decision-making processes (Laloux, 2015). A Red organization represents an authoritarian model based on the power of the leader and employee loyalty, commonly observed in small family businesses. In such organizations, decisions are made rapidly, often impulsively, and employee initiative is limited, which facilitates flexibility in crises but constrains innovation. Amber organizations are characterized by stability, formal hierarchy, and adherence to procedures; examples include public institutions, administrative bodies, and religious organizations. In these structures, roles are clearly defined, and predictability and discipline enable efficient functioning, though often at the expense of creativity. Orange organizations focus on efficiency, growth, and results, offering employees greater autonomy and rewarding individual achievements, typical of corporations, banks, and technology firms. This model fosters a performance- and competition-oriented culture, where innovation is supported through recognition of creative solutions and initiatives. Green organizations emphasize values, collaboration, democratic decision-making, and employee development, placing people at the center of organizational priorities. Examples include cooperatives, creative organizations, educational institutions, and non-governmental organizations (NGOs). In such environments, relationship-building, dialogue, and a sense of belonging are central, and decisions are made collectively within a culture of trust and mutual support. Teal organizations represent the most advanced model, based on self-management, trust, and collective decision-making without traditional hierarchical positions. Employee motivation arises from a sense of purpose and influence on organizational outcomes, with a focus on long-term development and the common good. Examples include Morning Star, Buurtzorg, and Marco. In Teal organizations, engagement in the organization's mission, continuous learning, and adaptation to changing market conditions are prioritized, and accountability for results is distributed among all team members (Blikle, 2016; Gałat, 2018; Kalwa-Rojczyk, 2018; Borowiecki et al., 2021; Łyszkowska, 2023; El Khoury et al., 2024). To better understand the evolution of organizational consciousness, Laloux draws on Clare W. Graves's Spiral Dynamics framework, which describes the development of values and modes of thinking across eight color-coded levels. This model facilitates the analysis of how individuals and organizations progress from simple power-based systems to complex structures founded on collaboration, self-organization, and social responsibility (Graves, 2005; Rutkowska, 2020; Wasiluk, 2022).

The contemporary world of work is changing dynamically, and Generation Z, entering the labor market, is gradually shaping new standards for organizational functioning. Generation Z typically includes individuals born after 1989, sometimes after 1995 or even 2000 (Biernacki, 2014; Papież, 2016; Dolot, 2018; Titko et al., 2020). However, the precise year of birth is less important than the shared social experiences that shape an individual's values and behaviors. Some employees may not meet the age criteria yet still exhibit characteristics typical of Generation Z. A defining feature of this generation is a high level of familiarity with new technologies. Having grown up in a digital environment, they naturally utilize virtual tools and

online solutions (Muster, 2020). At the same time, they acknowledge that daily functioning without technological support is challenging (Żarczyńska-Dobiesz, Chomątowska, 2014). Generation Z operates within groups but often settles for virtual interactions, and their well-being at work is considered as important as in their personal life. Respect for authority depends primarily on competence and achievements, rather than age or seniority (Ozkan, Solmaz, 2015). Individuals from Generation Z are characterized by high tolerance and social responsibility, making decisions quickly based on practical experience. They are capable of deep, specialized knowledge, though often find it difficult to place this knowledge in a broader context. Growing up in a world of computer games has fostered risk resilience and a willingness to experiment, treating work almost like a game, where failures are opportunities for learning. For young people, not only stable income but also meaningful work, autonomy, authentic relationships, and opportunities for personal development are important (Żarczyńska-Dobiesz et al., 2014; Warwas et al., 2018). They expect flexibility, remote work, equal opportunities, and real influence over organizational decisions (Papież, 2016). Their values partially align with the principles of Laloux's teal organizations, based on trust, partnership, and self-organization, where traditional hierarchical structures diminish and employees gain genuine autonomy in decision-making. However, the question arises whether Generation Z is truly ready to work within such a model. On one hand, young people have a natural need for autonomy, shared responsibility, and self-expression, but on the other hand, they may lack experience in self-discipline and self-leadership competencies required for full self-organization (Ragin-Skorecka et al., 2023). Implementing teal models therefore requires a gradual transformation, development of these competencies, and the creation of spaces for authentic participation, enabling Generation Z to become a catalyst for cultural change in organizations. Entrepreneurship becomes a key element in preparing Generation Z for modern organizations. It cultivates initiative, creativity, decision-making under uncertainty, and rapid problem-solving. It also develops digital competencies and the ability to collaborate virtually, which are essential in environments characterized by high autonomy and self-organization. Entrepreneurial attitudes among young employees not only allow them to effectively complete current tasks but also actively participate in creating innovations and organizational value, supporting the transformation of organizations in line with the teal models described in Frederic Laloux's theory of organizational colors.

3. Research methodology

In May 2025, a study was conducted among students of the Faculty of Management at the University of Gdańsk. The survey included 209 respondents, representing all programs and years of study. The aim of the study was to identify personality traits, stress coping strategies,

and students' preferences regarding organizational structure and workplace values, as well as their readiness to work in different types of organizations, including modern, flexible management models. The survey questionnaire was distributed electronically, with access provided via a QR code, enabling respondents to complete the form quickly and conveniently. Completion time averaged between 10 and 15 minutes.

Table 1.
Characteristics of Selected Questions in the Research Questionnaire

Questions	Characteristics
What type of organizational structure would you prefer the company you work for to have?	nominal dichotomous scale: rigid structure vs. flexible structure
In which company would you be most willing to work?	nominal scale: five management models described textually, reflecting varying levels of autonomy
How would you assess your approach to stress at work?	ordinal 5-point scale: from very poor to very good
Rate the extent to which the following organizational characteristics are important to you: sense of security within the hierarchy, stability, effectiveness, mutual respect, self-management, clear structure, creativity, employee engagement, cooperativeness, procedural adherence, loyalty, innovativeness, control and autonomy.	ordinal scale, 5-point – importance rating: from least important to most important
Gender	demographic item: nominal scale
Age	demographic item: ratio scale

Source: own elaboration.

The questionnaire comprised 12 items addressing stress-related approaches and preferences concerning organizational structure. It also included questions assessing the importance of selected organizational characteristics and workplace values, measured on a five-point Likert scale, as well as items regarding the choice of preferred company and type of organizational structure. Additionally, demographic questions were included, covering age, gender, and year of study. Some items were multidimensional, encompassing several thematic categories. The majority of the questions employed a rating scale, allowing precise determination of the importance attributed to specific traits, while single-choice closed-ended questions enabled respondents to select their most preferred option. Based on the responses, conclusions were drawn regarding stress coping strategies and the preferences of Generation Z students concerning professional values, expectations for organizational structure in the workplace, and their readiness to operate in environments characteristic of Teal, modern, and flexible organizations (Table 1). In the present study, due to the breadth of the topic and the complexity of issues related to students' organizational preferences and professional attitudes, only a portion of the questionnaire items was utilized. The focus was placed on those aspects that allow for the analysis of organizational characteristics, stress-coping strategies, and preferences regarding values and organizational structure in the workplace, with particular emphasis on readiness to function within modern, flexible, Teal organizations. The remaining questions, while representing valuable material, were omitted to enable a more precise and coherent analysis of the selected research areas.

4. Characteristics of Respondents and Their Preferred Organizational Structure

The study sample consisted of 58.9% female and 41.1% male participants. The gender composition and age distribution of the respondents are presented in Figures 1 and 2. The age distribution is bimodal, with two predominant peaks at approximately 20.4 and 23.1 years, indicating the presence of two main age groups within the sample: a younger group (undergraduate students) and an older group (graduate students).

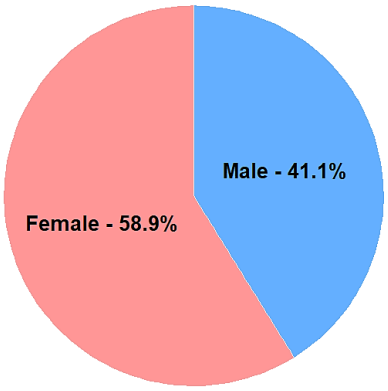


Figure 1. Distribution of respondents by gender.

Source: own elaboration.

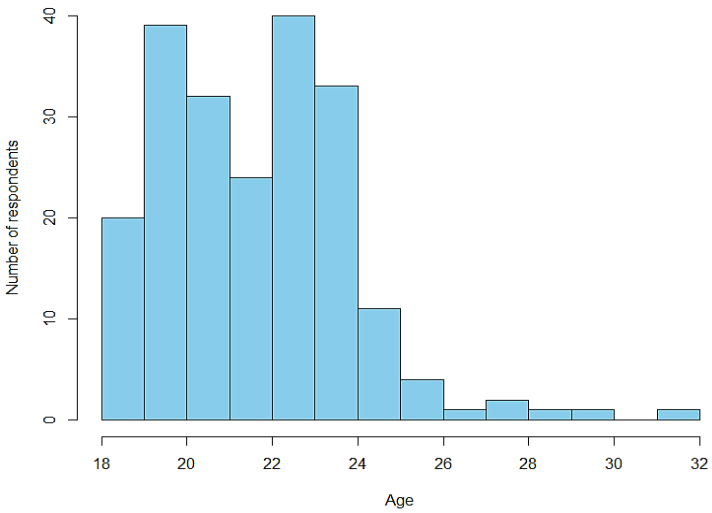


Figure 2. Age distribution of respondents (in years).

Source: own elaboration.

The largest group consisted of second-year master's students (49 individuals). Slightly fewer were third-year undergraduate students (45 individuals) and first-year master's students (42 individuals). First-year undergraduate students (40 individuals) and second-year undergraduate students (33 individuals) represented the smallest groups. In total, the study involved 118 undergraduate students and 91 master's students. The distribution of participants by year of study is relatively balanced, although there is a slightly higher representation of students from the lower years (Figure 3). Within the studied group, students predominantly prefer a flexible organizational structure (70.8%) - characterized by low levels of formalization and hierarchy, collaboration, rapid decision-making, and ease of adaptation to change. A minority (29.2%) prefer a rigid structure, with clearly defined rules and hierarchy, where decisions are primarily made at higher levels (Figure 4).

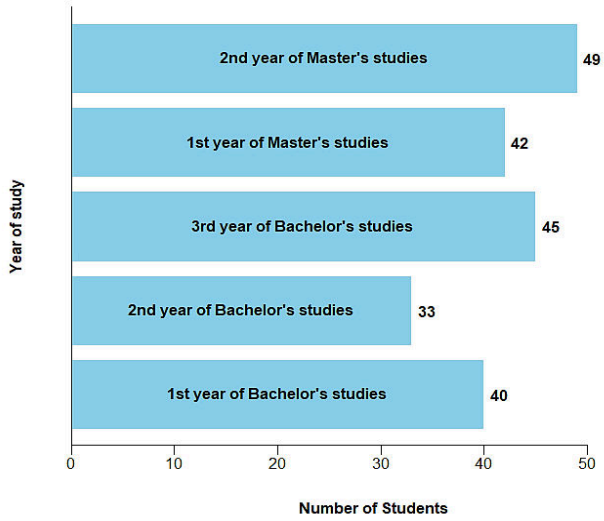


Figure 3. Distribution of respondents by year of study.

Source: own elaboration.

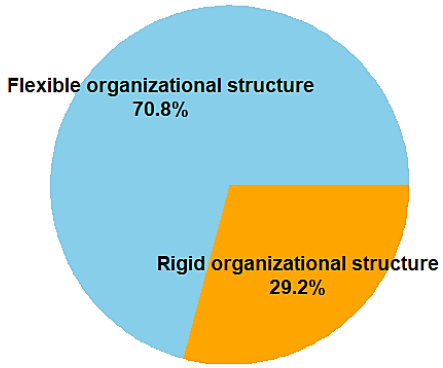


Figure 4. Preferred organizational structure.

Source: own elaboration.

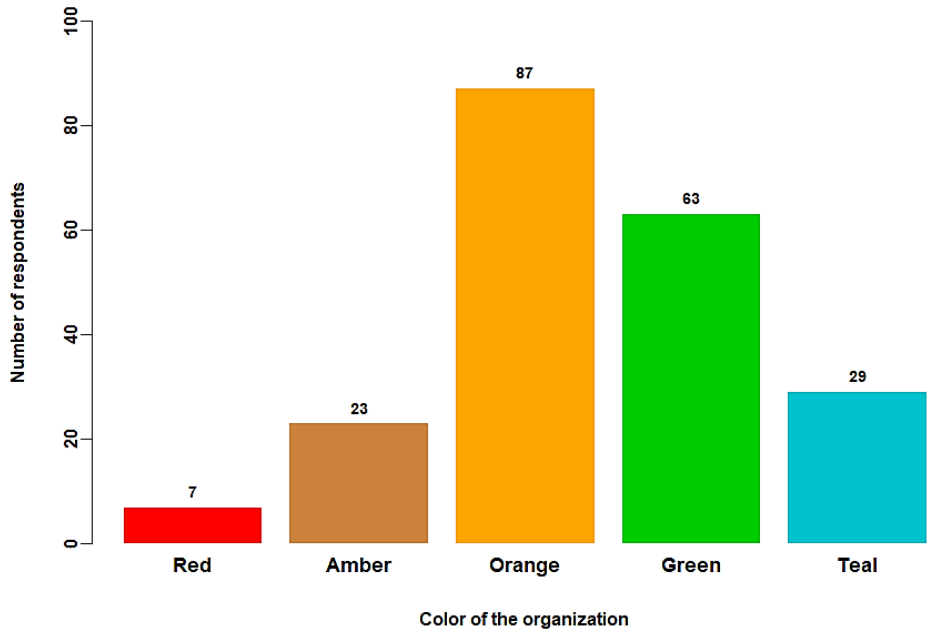


Figure 5. Distribution of students' preferences by organizational type (color-coded).

Source: own elaboration.

Participants were asked to indicate the type of organization in which they would like to work, based solely on a description of its characteristics, without being informed of the corresponding organizational „color". The analysis of students' preferences (Figure 5) shows that the largest number of respondents chose organizations of the Orange type (87 individuals) and Green type (63 individuals). These organizations are characterized by a clear structure, efficiency, and cooperativeness, while maintaining a certain degree of autonomy. Organizations of the Red type (7 individuals) and Amber type (23 individuals), characterized by stronger control, hierarchical structures, and strict adherence to rules and procedures, were selected

considerably less frequently. Teal organizations were indicated by 29 respondents, representing a relatively low level of interest. This finding may appear somewhat surprising, as the values associated with Teal organizations - such as autonomy, trust, shared responsibility, and an open work environment based on respect, collaboration, diversity, and transparent communication - are frequently highlighted in the literature as particularly important for Generation Z. These results may suggest that, despite declarative support for these principles, young people still tend to prefer organizations that offer more stable and clearly defined operational structures, rather than fully self-managed and flexible organizational models.

Table 2.
Organizational color preferences and self-reported approaches to work-related stress

		Assessment of approaches to work-related stress				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	2	1	3	0
	Amber	4	**5**	9	4	1
	Orange	3	11	**31**	40	2
	Green	6	14	27	**16**	0
	Teal	0	7	14	8	**0**
	Total	14	39	82	71	3

Source: own elaboration.

Table 2 presents the relationship between preferred organizational type and self-reported approaches to coping with work-related stress. The figures along the main diagonal indicate respondents whose declared organizational color preferences correspond with the stress-coping style typical for that type of organization. These individuals account for 25.4% of all participants. The highest congruence is observed for Orange organizations (31 individuals) and Green organizations (16 individuals), whereas the lack of alignment for Teal organizations suggests that respondents aspire to Teal values (autonomy, self-management, collaboration) but do not reflect these in their self-reported stress management approaches. Off the main diagonal, it is evident that individuals preferring Orange organizations frequently report stress-coping styles characteristic of Green organizations (40 individuals), indicating a desire for a supportive and cooperative environment despite a preference for efficient and well-structured systems. Similarly, respondents who select Green organizations report stress-coping styles corresponding to Orange organizations (27 individuals), which may reflect an intention to balance autonomy with structured processes. Generational preferences regarding workplace type and organizational style are thus multidimensional: participants may value efficiency and clearly defined structures while simultaneously requiring support, trust, and a sense of security within the work environment.

5. Analysis of Organizational Characteristics in the Context of the Organizational Color Theory

The analysis of the results concerning organizational color preferences and attitudes toward the sense of **security within hierarchical structures** indicates that, for the majority of respondents, security derived from order, rules, and predictability - values typical of Amber organizations - is of key importance (Table 3). It was the Amber sense of security that received the highest number of indications, suggesting that, regardless of the preferred work style, participants still require clear structures and hierarchies that provide them with stability. The Orange sense of security, based on efficiency, measurable principles, and a rational approach to operations, ranked second. This result suggests that respondents value not only order and stability but also fairness and transparent "rules of the game" oriented toward success. Among those who preferred Orange organizations, a tendency toward balancing stability (Amber) with autonomy (Teal) was observed, indicating that even in performance-oriented environments, elements of trust and flexibility are necessary. Individuals identifying with Green organizations, despite their focus on collaboration and relationships, also most frequently pointed to Amber sources of security. This may be interpreted as a need for clearly defined organizational frameworks that create safe conditions for open dialogue. Meanwhile, those aligned with Teal organizations - the most advanced model based on self-management and trust - often feel more secure in more structured systems, such as Amber or Orange organizations. This may stem from difficulties in fully trusting completely decentralized forms of work. A sense of security within organizations thus remains strongly associated with hierarchy and structure. Even when respondents express appreciation for modern, partnership-based organizational models, they tend to feel emotionally safer within systems that offer clear rules, defined roles, and stability. Psychological safety - characteristic of Green and Teal organizations - is acknowledged but does not constitute the primary source of security in hierarchical contexts. These findings suggest that the evolution of organizational culture toward greater maturity and self-organization does not always correspond with the emotional readiness of respondents to operate within less predictable structures.

The analysis of organizational color preferences in the context of job **stability** reveals a clear trend: the majority of respondents feel safest in an Amber environment (Table 4). Amber stability received the highest number of indications (90), confirming that people value predictability, clear rules, and durable structures, regardless of their preferred work style. The second position was occupied by Red stability, based on the leader's power and control, which is high in the short term but fragile in the longer perspective. Orange stability received 33 indications and represents a conditional model dependent on efficiency and performance outcomes. Stability within Green and Teal organizations was indicated much less frequently (12 and 3 responses, respectively), as it primarily derives from relationships, trust,

and organizational culture rather than fixed structures. In practice, this means that even in modern, partnership-oriented, and self-organizing organizations, most individuals seek a sense of security within predictable, hierarchical frameworks, while stability stemming from autonomy, trust, and a flexible culture is appreciated to a lesser extent.

Table 3.
Organizational Color Preferences and the Approach to the Sense of Security within Hierarchical Structures

		Sense of Security within the Hierarchy				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	3	3	1	0
	Amber	6	**6**	5	4	2
	Orange	13	29	**18**	10	17
	Green	9	24	11	**10**	9
	Teal	6	5	10	4	**4**
	Total	34	67	47	29	32

Source: own elaboration.

Table 4.
Organizational Color Preferences and the Approach to Job Stability

		Job Stability				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	1	3	2	1
	Amber	8	**12**	3	0	0
	Orange	33	38	**8**	7	1
	Green	21	26	13	**2**	1
	Teal	9	13	6	1	**0**
	Total	71	90	33	12	3

Source: own elaboration.

The data presented in Table 5 reveal a relationship between respondents' organizational color preferences and their perceptions of organizational **effectiveness**. The highest number of indications in the effectiveness category was attributed to Teal (71) and Green (70) organizations, whereas the lowest scores were recorded for Red (5) and Amber (19) organizations. These results suggest that students associate the highest level of effectiveness with modern organizational models grounded in trust, self-management, and shared responsibility - features characteristic of Green and Teal organizations. In contrast, traditional organizational forms based on hierarchy, control, and rigid rules (Red and Amber models) were evaluated as less effective. A noteworthy discrepancy was also observed between workplace preferences and perceived effectiveness. Although respondents frequently indicated Orange or Green organizations as their preferred work environments, the highest effectiveness was ascribed to Teal organizations. This finding may indicate that the Teal model is perceived as efficient in theory but is not necessarily associated with respondents' actual professional experiences. The overall structure of the results reflects a growing awareness of the importance

of contemporary management models emphasizing autonomy, collaboration, and trust. Respondents appear to recognize that such principles foster organizational effectiveness, even if their personal experiences are primarily linked to traditional, hierarchical structures. Consequently, the findings point toward a potential cultural shift - from control-based organizational models toward more partnership-oriented and co-responsibility-driven structures.

Table 5.
Organizational Color Preferences and the Approach to Effectiveness

		Effectiveness				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	1	3	2	1
	Amber	1	**5**	3	9	5
	Orange	3	9	**17**	27	31
	Green	1	3	12	**24**	23
	Teal	0	1	9	8	**11**
	Total	5	19	44	70	71

Source: own elaboration.

Table 6.
Organizational Color Preferences and the Approach to Mutual Respect

		Mutual Respect				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	1	2	1	2
	Amber	0	**1**	4	6	12
	Orange	1	4	**11**	10	61
	Green	0	2	5	**8**	48
	Teal	2	0	2	4	**21**
	Total	4	8	24	29	144

Source: own elaboration.

The highest number of indications in the category of mutual respect was attributed to Teal organizations (144) and Green organizations (29), whereas significantly fewer respondents associated this value with Orange (24), Amber (8), and Red (4) organizations (Table 6). These results suggest that respondents perceive the highest level of mutual respect in modern organizations grounded in trust, partnership, and self-management - characteristics typical of Green and Teal models. In such environments, respect functions as an integral element of a culture of collaboration and responsibility, independent of hierarchy or performance outcomes. It was observed that, regardless of the preferred type of organization as a workplace, respondents most frequently indicated the Teal model as the one in which mutual respect is highest. This trend was also apparent among individuals who preferred Orange or Amber organizations; for example, 61 respondents who favored the Orange model identified Teal as best representing mutual respect. A similar pattern was observed among those preferring Green organizations, who 48 times indicated the Teal type as most conducive to partnership-based relationships. These findings highlight a distinction between workplace preferences and the

perceived level of mutual respect. Respondents primarily associate this value with modern, flexible management models, while their professional experiences may involve more traditional organizational structures. In this context, the Teal model serves as a reference point for understanding structures based on trust, collaboration, and shared values, where interpersonal relationships are significant regardless of hierarchy or performance outcomes.

Table 7.
Organizational Color Preferences and the Approach to Self-Management

		Self-Management				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	0	1	2	3
	Amber	8	**6**	2	4	3
	Orange	8	10	**33**	23	13
	Green	10	15	18	**13**	7
	Teal	1	3	10	9	**6**
	Total	28	34	64	51	32

Source: own elaboration.

The analysis of the data presented in Table 7 indicates associations between respondents' organizational color preferences and their attitudes toward **self-management**. The highest number of indications in this category was attributed to Orange organizations (64). This result may be explained by the fact that respondents associate autonomy not only with formal team independence but also with the opportunity to take initiative and influence decisions within structures with which they have professional experience. Although Orange organizations are theoretically less self-managed than Teal ones, they provide space for individual initiative in achieving goals and results, which likely contributed to the high number of responses in this category. Green organizations, which promote a partnership-based approach and shared decision-making, are also perceived as conducive to self-management; however, some decisions remain under the authority of managerial staff, which may explain lower indications compared to Orange organizations. In the case of Teal organizations, the lower number of indications relative to the theoretical level of self-management may result from respondents perceiving them as more demanding in practical implementation. Respondents may recognize the potential of Teal organizations for full self-organization but do not fully associate this with their professional experience or actual work conditions. Red and Amber organizations received the fewest indications, which aligns with expectations based on Laloux's theory.

According to Table 8, only 23.4% of respondents declared an approach to **control** that aligns with their preferred organizational type, indicating a limited correspondence between preferences and the perceived role of control. The function of control varies across organizational models: in Red and Amber structures, it is dominant and constitutes the basis of hierarchy and order, whereas in Green and Teal models, control yields to autonomy, trust, and self-management. Respondents' declarations most frequently corresponded to Orange and Amber models, where control remains a significant management element, serving different

purposes: in Amber organizations, it ensures stability and adherence to rules, while in Orange organizations, it supports goal attainment and efficiency. Relatively few indications were assigned to Green and Teal models, demonstrating that values based on trust, self-management, and partnership-oriented approaches to control are not yet widely accepted by respondents. The majority of participants expect a high level of control in the workplace, reflecting the persistence of traditional management attitudes and limited familiarity with alternative, more autonomous organizational models.

Table 8.
Organizational Color Preferences and Declared Approach to Workplace Control

		Workplace Control				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	2	4	0	0
	Amber	4	**6**	6	4	3
	Orange	19	23	**26**	8	11
	Green	7	14	20	**15**	7
	Teal	2	12	10	4	**1**
	Total	33	57	66	31	22

Source: own elaboration.

Table 9.
Organizational Color Preferences and Declared Approach to Loyalty

		Loyalty				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**2**	1	2	2	0
	Amber	6	**4**	3	5	5
	Orange	28	11	**17**	17	14
	Green	15	14	12	**12**	10
	Teal	6	2	10	6	**5**
	Total	57	32	44	42	34

Source: own elaboration.

Table 9 reveals discrepancies between the declared preferred type of organization and respondents' perceptions of **loyalty**. Some participants select modern organizational models, such as Orange, characterized by goal orientation and efficiency, yet their approach to loyalty aligns more closely with traditional patterns - based on hierarchy, subordination, and the need for stability - typical of Red and Amber organizations. Individuals preferring Green and Teal organizations, where loyalty is founded on collaboration, trust, and responsibility, do not always fully identify with this approach. The results indicate that the concepts of partnership and self-organization are still less widespread among respondents, and loyalty in its modern, relational sense is only beginning to be understood and embraced. Consequently, although participants express a desire to work in more open and flexible organizations, their understanding of loyalty more frequently remains consistent with traditional models of workplace attachment, grounded in stability and hierarchy.

Approaches to innovativeness do not always align with the declared preferred type of organization. The highest number of indications in this category corresponds to the Orange type, suggesting that respondents primarily interpret innovativeness in practical and efficiency-oriented terms (Table 10). For the majority of participants, new solutions are valued primarily when they lead to improved outcomes, streamlined processes, or competitive advantage. In this perspective, innovativeness is perceived mainly as a tool for achieving goals and enhancing efficiency, rather than as an element of a culture of openness or self-organization, which is characteristic of Green and Teal organizations. Among respondents' indications, the Orange interpretation predominates: innovation is appreciated mainly when it produces measurable results. The Teal approach, in which innovativeness emerges from autonomy, self-management, and trust, appears less frequently. This indicates that values such as autonomy, self-organization, and trust-based creativity are not yet widely internalized. For individuals declaring a preference for Green organizations, responses are predominantly both Orange and Green, suggesting that while innovativeness is considered important, it is primarily perceived through the lens of collaboration and team security rather than radical change or experimentation. In Amber and Red organizations, innovativeness is marginal. These results reflect the fact that traditional structures, hierarchy, and repetitive routines dominate these models, limiting opportunities for experimentation and the implementation of new solutions.

Table 10.
Organizational Color Preferences and Declared Approach to Innovativeness

		Innovativeness				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	0	3	3	1
	Amber	3	**3**	13	3	1
	Orange	1	10	**36**	17	23
	Green	2	11	25	**15**	10
	Teal	0	2	12	8	**7**
	Total	6	26	89	46	42

Source: own elaboration.

Table 11 presents the declared significance of **cooperativeness** in relation to organizational types. The highest importance of cooperation was attributed to Teal and Green organizations, in which cooperativeness - including joint decision-making, partnership, and team collaboration - constitutes a fundamental aspect of organizational functioning. The results indicate that some respondents who prefer Orange or Green types declare cooperativeness values characteristic of Teal organizations. This suggests that, although participants choose more traditional or partnership-oriented work models, they perceive cooperativeness as an important element of organizational functioning in practice. The alignment between declared attitudes toward cooperativeness and the preferred type of organization amounts to 29.7%, indicating a limited consistency between expectations regarding collaboration and the actual preferred

organizational model. At the same time, the results highlight the importance of cooperative values among respondents, regardless of their chosen organizational type.

Table 11.
Organizational Color Preferences and Declared Approach to Cooperativeness

		Cooperativeness				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**2**	0	5	0	0
	Amber	1	**5**	2	9	6
	Orange	3	2	**17**	29	36
	Green	1	3	5	**25**	29
	Teal	0	2	7	7	**13**
	Total	7	12	36	70	84

Source: own elaboration.

Table 12.
Organizational Color Preferences and Declared Approach to Autonomy

		Autonomy				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	0	2	2	3
	Amber	3	**2**	6	8	4
	Orange	4	10	**27**	29	17
	Green	3	9	22	**20**	9
	Teal	0	3	10	7	**9**
	Total	10	24	67	66	42

Source: own elaboration.

Respondents' declarations regarding **autonomy** indicate that the greatest importance is attributed to independence in Orange, Green, and Teal organizations (Table 12). In Teal organizations, autonomy encompasses independent decision-making and team self-organization; in Green organizations, it is linked with partnership and collaboration; while in Orange organizations, it signifies freedom in achieving goals and performance outcomes. At the same time, some respondents who identify with organizations exhibiting lower levels of autonomy, such as Amber or Red, also recognize autonomy as an important attribute. This indicates that expectations regarding autonomy do not always align with the preferred type of organization. The correspondence between the declared approach to autonomy and organizational type preference amounts to 27.8%, confirming a limited correlation between these areas. The results demonstrate that autonomy is perceived as a desirable value, particularly in the context of flexible and partnership-oriented organizational models; however, the interpretation of this concept among respondents is varied and often independent of the indicated organizational type.

Among respondents, there is a strong preference for a clear structure and explicit organizational hierarchy (Table 13). The highest number of indications was attributed to Amber (61) and Orange (51) organizations, indicating a predominance of preferences for models based on formal order, clearly defined roles, and accountability, while simultaneously incorporating

elements of efficiency and competition characteristic of Orange organizations. A noticeable increase in respondents selecting Green and Teal organizations is also observed, reflecting a gradual shift in values toward collaboration, trust, and flexibility. Within Generation Z, there is a discernible need to balance clarity of rules with freedom of action. Despite the declared appreciation for values characteristic of Green and Teal organizations, such as autonomy, collaboration, and partnership-based relationships, relatively few respondents chose these models as their preferred work environment. This may result from a need for security and stability, which more structured organizational types provide. Younger respondents tend to prefer environments that combine autonomy with a clear structure, clearly defined roles, and responsibilities. They expect frameworks that ensure transparency and order while simultaneously allowing for independence and initiative. The results suggest that organizations aiming to remain attractive to younger employees should combine a clear structure with a management style that is flexible and oriented toward partnership.

Table 13.
Organizational Color Preferences and Declared Approach to Clear Structure

		Clear Structure				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**3**	4	0	0	0
	Amber	13	**5**	4	1	0
	Orange	15	27	**22**	16	7
	Green	6	21	13	**15**	8
	Teal	3	4	12	6	**4**
	Total	40	61	51	38	19

Source: own elaboration.

In the context of the declared approach to **creativity**, the highest number of indications corresponds to Green (69) and Teal (62) organizations, suggesting that respondents associate creativity with workplaces based on collaboration, autonomy, and innovativeness (Table 14). A substantial number of indications for Orange organizations (43) suggest that creativity is also valued in efficiency and results-oriented environments, although in this context it assumes a more instrumental role, serving the achievement of organizational goals. In Red and Amber models, the number of indications is considerably lower (9 and 26, respectively), indicating that in highly formalized and hierarchical structures, creativity plays a less prominent role. Among Generation Z representatives, creativity is closely linked to values characteristic of Green and Teal organizations, such as autonomy, collaboration, and flexibility. At the same time, some respondents recognize the importance of creativity in Orange organizations, where innovativeness is connected to efficiency and the achievement of results. The findings indicate that respondents perceive creativity as a critical component of work primarily in environments that foster collaboration and independence, such as Green and Teal organizations, while it is considered less significant in organizations with traditional structures and hierarchical management systems, including Amber and Red organizations.

Table 14.
Organizational Color Preferences and Declared Approach to Creativity

		Creativity				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	1	3	1	1
	Amber	1	**8**	6	8	0
	Orange	6	7	**15**	28	31
	Green	1	7	17	**17**	21
	Teal	0	3	2	15	**9**
	Total	9	26	43	69	62

Source: own elaboration.

Table 15.
Organizational Color Preferences and Declared Approach to Employee Engagement

		Employee Engagement				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**1**	0	3	2	1
	Amber	2	**2**	5	8	6
	Orange	0	5	**13**	31	38
	Green	1	2	9	**21**	30
	Teal	0	3	6	12	**8**
	Total	4	12	36	74	83

Source: own elaboration.

Table 16.
Organizational Color Preferences and Declared Approach to Procedural Adherence

		Procedural Adherence				
		Red	Amber	Orange	Green	Teal
Workplace preference	Red	**0**	3	1	1	2
	Amber	4	**9**	1	2	7
	Orange	11	25	**19**	11	21
	Green	6	20	13	**11**	13
	Teal	7	4	9	8	**1**
	Total	28	61	43	33	44

Source: own elaboration.

Table 15 presents the relationship between the declared approach to **employee engagement** and organizational color preferences. The highest number of indications corresponds to Teal (83) and Green (74) organizations, suggesting that respondents associate high levels of engagement with workplaces based on autonomy, self-management, and partnership-based relationships. Orange organizations (36 indications) are also perceived as environments that foster engagement; however, in this context, engagement has a task-oriented character and is primarily linked to efficiency and the achievement of goals. In Amber (12) and Red (4) models, engagement is rated the lowest, which can be associated with the dominance of hierarchy, formal procedures, and limited autonomy. The findings indicate that respondents attribute the greatest importance to engagement in organizations that enable independence, transparency of actions, and shared responsibility, whereas traditional hierarchical structures are perceived as less conducive to activity and initiative.

Table 16 presents the perceived level of procedural adherence across different types of organizations. The highest number of indications corresponds to Amber (61) and Red (28) organizations, reflecting their highly formalized nature based on hierarchy and clearly defined operating rules. In Orange organizations (43), procedures primarily serve as tools supporting the achievement of goals and work efficiency. In Green (33) and Teal (44) structures, formal rules are less prominent and play a supportive role, maintaining transparency and coordinating activities without limiting autonomy or collaboration. Respondents prefer environments in which procedures ensure order and predictability but do not create barriers to independence and initiative. Therefore, the most attractive organizations are those that combine clarity of rules with a flexible approach to their implementation.

6. Preferences and Fit with the Organization

The analysis of Generation Z respondents' preferences in the context of organizational characteristics reveals interesting relationships between the type of work environment in which young students would feel most comfortable and the nature of specific traits. The results presented on a 1 to 5 scale should be interpreted as a measure of preference for a particular type of organization. The highest value in the study was attributed to Mutual Respect (4.4), indicating that this trait aligns respondents most closely with Teal organizations, environments based on trust, partnership-based relationships, and a culture of respect. Other traits related to relationships and collaboration, such as Employee Engagement (4.1), Cooperativeness (4.0), Effectiveness (3.9), Creativity (3.7), and Autonomy (3.5), suggest affiliation with Green organizations, which promote autonomy, collaboration, and joint decision making. Traits more closely associated with procedures, structure, and task management, such as Innovativeness, Stress, Self Management, Procedural Adherence, Sense of Security, Control, Loyalty, and Clear Procedures, indicate that respondents would function best in Orange organizations, which combine a results-oriented approach with clearly defined operational frameworks and procedures. Stability of Work occupies a unique position, showing that in this area, respondents most frequently resemble Amber organizations, reflecting their need for predictability and an orderly structure in the workplace (Figure 6).

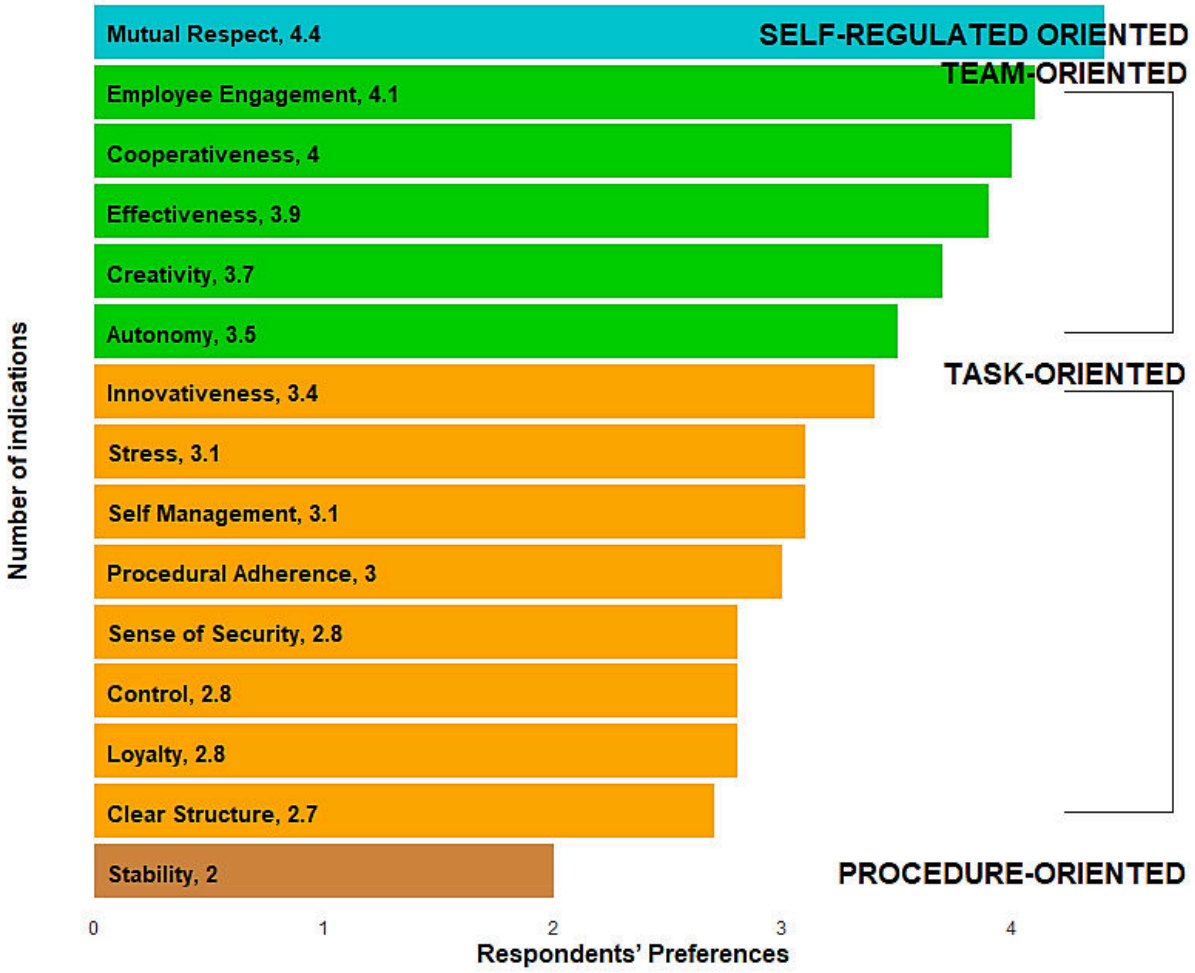


Figure 6. Four Preference Orientations of Respondents and Types of Organization.
Source: own elaboration.

The respondents focus on relationships and collaboration, valuing autonomy and creativity, while simultaneously needing environments that provide clear procedures and support in task management. The color assigned to each characteristic indicates the type of organization that best fits the students based on that trait - only Mutual Respect aligns them with Teal organizations, whereas most other responses suggest that they would function best in Orange companies, or possibly Green ones. Ideal alignment for this group involves balancing the structure and procedures typical of Orange organizations with environments that support collaboration and autonomy, characteristic of Green organizations. Teal organizations appear only in the context of relational values, such as Mutual Respect, and thus do not constitute the dominant environment for this generation. However, this outcome may be due to the respondents' limited professional experience and limited familiarity with models based on full self-management and trust. Generation Z is only beginning to enter the labor market, and despite their openness to collaboration, they still expect clear frameworks, rules, and predictability. Therefore, Teal organizations, as the most advanced but also most demanding form, remain outside their natural comfort zone for the time being.

Table 17.
Alignment of Organizational Type with Organizational Characteristic

Organizational Characteristic	Measure of Alignment	Organizational Type with the Highest Alignment	Two Most Preferred Types of Organization	
			First	Second
Cooperativeness	29.7%	Green	Teal	Green
Innovativeness	29.2%	Orange	Orange	Green
Self Management	28.2%	Orange	Orange	Green
Autonomy	27.8%	Orange	Orange	Green
Effectiveness	27.3%	Green	Teal	Green
Stress	25.4%	Orange	Orange	Green
Creativity	23.9%	Green	Green	Teal
Control	23.4%	Orange	Orange	Amber
Clear Structure	23.4%	Orange	Amber	Orange
Employee Engagement	21.5%	Green	Teal	Green
Mutual Respect	20.1%	Teal	Teal	Green
Procedural Adherence	19.1%	Orange	Amber	Teal
Loyalty	19.1%	Orange	Red	Orange
Sense of Security	18.2%	Orange	Amber	Orange
Stability	12.1%	Amber	Amber	Red

Source: own elaboration.

The analysis of the alignment between the preferred type of organization and the assessment of how individual characteristics are implemented (Table 17) shows that the overall level of consistency is generally low. The values of the conformity measure range from 12.1% (Stability) to 29.7% (Cooperativeness), indicating that the declared preferences regarding the type of organization do not always align with the respondents' perceptions of how the corresponding organizational values are realized in practice. In other words, the type of organization respondents consider most desirable does not necessarily correspond to how they perceive its actual functioning. The highest levels of consistency are observed for characteristics such as Cooperativeness (29.7%), Innovativeness (29.2%), Self-management (28.2%), Autonomy (27.8%), and Effectiveness (27.3%). This suggests that in areas related to teamwork, creativity, and independence, respondents consider the realization of these values - typical of Green and Orange organizations - to be satisfactory. They do not aspire to the most advanced, Teal model of collaboration, but rather to one that combines clear structure and efficiency (Orange type) with partnership and trust (Green type). This indicates a preference for a balanced level of autonomy and cooperation without the need for full self-organization typical of Teal environments. The lowest levels of consistency - Stability (12.1%), Sense of Security (18.2%), Procedural Adherence (19.1%), and Loyalty (19.1%) - show that respondents do not clearly associate these values with any specific type of organization. This does not reflect a lack of awareness or random choices; rather, Generation Z consciously distributes its preferences across various organizational models. In practice, this means that some characteristics are identified with Orange organizations, others with Green, while still others may be associated with Amber, Red, or even Teal structures.

These patterns of preferences can be summarized into four main orientations: Self-Regulated Oriented, valuing autonomy and creativity; Team-Oriented, prioritizing collaboration and partnership; Task-Oriented, focusing on efficiency and goal achievement; and Procedure-Oriented, emphasizing stability, predictability, and clear rules. These orientations provide a concise way to understand the dominant traits that may guide Generation Z respondents toward organizational environments in which they are most likely to thrive. At the same time, young respondents do not limit themselves to a single orientation - their preferences show an ability to combine different traits depending on needs and circumstances. They blend idealistic aspirations, for example, those related to Teal values such as trust and shared decision-making, with realistic work expectations, such as a sense of security, stability, and predictability. In practice, this translates into a flexible and pragmatic approach: they consciously balance between different types of organizations, selecting elements from each that best match their current needs, experiences, and expectations regarding the work environment.

7. Conclusion

The most significant characteristic identified among the surveyed students is Mutual Respect, which aligns them with teal organizations, defined by trust, partnership, and participative relationships. Other attributes related to collaboration, autonomy, and teamwork - such as Engagement, Cooperativeness, Effectiveness, Creativity, and Autonomy - indicate a preference for green organizational environments, which emphasize cooperation, empathy, and collective decision-making. In contrast, features associated with procedures, structure, and task management - including Innovativeness, Stress, Self-management, Procedural Adherence, Sense of Security, Control, Loyalty, and Clear Structure - are predominantly linked by respondents to orange organizations, which value efficiency, goal orientation, and individual initiative. Meanwhile, Job Stability is primarily associated with amber organizations, characterized by hierarchy and predictability. The overall level of alignment between the preferred organizational type and the perceived realization of specific characteristics is relatively low, ranging from 12.1% (Stability) to 29.7% (Cooperativeness). This suggests that although students demonstrate clear preferences regarding organizational models, their perceptions of how these values are implemented in practice do not always correspond to their declared ideals. The highest alignment levels are observed for Cooperativeness, Innovativeness, Self-management, Autonomy, and Effectiveness, indicating that respondents perceive the realization of values typical of green and orange organizations as satisfactory, without requiring the full implementation of the more advanced teal model of self-management and shared responsibility. The lowest levels of

alignment, found for Stability, Sense of Security, Procedural Adherence, and Loyalty, suggest that respondents do not associate these characteristics consistently with any particular organizational type. This pattern reflects a dispersion of preferences - some traits correspond to the orange model, others to the green, while certain values resonate with the amber or even red types of organizational structures. Overall, Generation Z appears to combine aspirational inclinations toward teal values - such as trust, co-decision, and partnership - with a realistic approach to the work environment that prioritizes structure, predictability, and a sense of security. In practice, this translates into a preference for the orange organizational model, seen as the most attainable compromise between autonomy and development on one hand, and stability and clarity of rules on the other. Green elements of collaboration and independence are appreciated, yet full teal-style self-organization remains more of an aspiration than a current standard in young employees' expectations.

The most significant characteristic identified among the surveyed students is mutual respect, which aligns them with teal organizations characterized by trust and partnership. Other traits related to relationships, autonomy, and collaboration, such as engagement, cooperativeness, efficiency, creativity, and autonomy, indicate a preference for green organizational environments that promote teamwork and participative decision-making. Conversely, characteristics associated with procedures, structure, and task management - such as innovativeness, stress, self-management, procedural adherence, sense of security, control, loyalty, and clear structure - are primarily attributed by the respondents to orange organizations, while job stability is predominantly associated with amber organizations. The level of congruence between the declared preferred type of organization and the assessment of the realization of specific traits is generally low, ranging from 12.1% (stability) to 29.7% (cooperativeness). This indicates that although students have defined preferences regarding organizational types, their perception of how these traits are realized in practice does not always correspond to their stated choices. The highest congruence was observed for traits such as cooperativeness, innovativeness, self-management, autonomy, and efficiency. In these areas, respondents consider the level of value implementation typical of green and orange organizations to be sufficient, without requiring the full adoption of the more advanced teal model. The lowest levels of congruence were observed for stability, sense of security, procedural adherence, and loyalty, indicating that respondents do not unequivocally associate these values with a specific type of organization. This distribution of preferences demonstrates that certain traits are selected in forms typical for orange organizations, others for green organizations, and some may correspond to amber or red structures. Generation Z combines aspirations for teal values, such as trust, participative decision-making, and partnership, with a realistic approach to the work environment. In practice, this means selecting the orange model as the most achievable compromise between autonomy and professional development and a clear structure, rules, and predictability. Green elements of collaboration and independence are appreciated, but full teal self-organization remains an aspiration rather than

a current standard in young employees' expectations. The analysis of Generation Z preferences confirms the proposed hypothesis. Despite the declared appreciation among Generation Z students for values characteristic of teal organizations - such as autonomy, collaboration, mutual respect, and partnership - in practice, they most frequently choose work environments that do not fully realize these values. By opting for the orange model, partially supplemented with green elements, respondents prioritize the need for clear structure, predictability, and stability, which allows them to pursue their professional aspirations in a more accessible and secure manner. Teal values remain aspirational, while actual career choices reflect a compromise between idealistic expectations and the realities of the labor market. Teal organizations continue to constitute a niche in the labor market, whereas most companies operate according to the orange model with elements of green, offering clear structures, measurable goals, and performance-based reward systems. For Generation Z, autonomy, opportunities for development, and influence over work outcomes are of key importance. The orange model facilitates the realization of these needs while providing stable organizational frameworks that support the development of professional competencies in an orderly environment. The teal approach, based on full self-organization and co-responsibility, may be perceived as demanding and less accessible to individuals entering the labor market. Consequently, Generation Z aspires to teal values but chooses the orange environment as the most realistic and secure option. Teal remains an aspirational direction - a symbol of meaningful work and partnership - while the orange model combines autonomy with a clear structure and predictability. As young employees gain professional experience and increasing influence over organizational culture, it can be expected that they will increasingly operate within models that combine efficiency with partnership and independence, characteristic of a green-teal approach.

8. Discussion

The results of the study indicate that Generation Z's workplace preferences are complex and multidimensional, combining aspirations for modern, partnership-oriented organizational models with the need for stability and clearly defined operational frameworks. While prior literature highlights that young employees value autonomy, collaboration, self-organization, and meaningful work - traits characteristic of teal organizations - our findings show that, in practice, Generation Z more frequently aligns with orange and green models. Respondents rated interpersonal traits such as mutual respect, cooperativeness, and engagement the highest, suggesting an identification with values close to a teal organizational culture. **Novelty of findings**. A key contribution of this study is demonstrating that although Generation Z declares a preference for teal-like values, their practical choices reflect a hybrid approach, combining aspirational and realistic considerations. Previous research has identified the importance of

autonomy and collaboration for young employees (Titko et al., 2020; Ragin-Skorecka et al., 2023), but the present study systematically shows how these preferences are distributed across organizational types and where discrepancies occur. This highlights a gap between idealistic aspirations and practical decision-making in early career stages. **Assessment of hypotheses**. The initial hypothesis - that Generation Z would prefer work environments fully embodying teal values - was only partially confirmed. While respondents identify with autonomy, collaboration, and mutual respect, their actual choices favor organizations offering structure, stability, and predictability. This confirms the pragmatic approach of young professionals: they aspire to teal values but prioritize security and clarity when entering the labor market. **Comparison with existing literaturę**. Our results align with prior findings indicating that teal organizations are perceived as effective and supportive of mutual respect (Blikle, 2016; Łyszkowska, 2023), yet few young employees choose them as their preferred workplaces. This study extends the literature by showing which specific traits - such as autonomy, innovation, and self-management - are valued across organizational types, and which - like stability, procedural clarity, and loyalty - are less aligned with aspirational values. Unlike some earlier research focusing primarily on declared preferences (Papież, 2016; Muster, 2020), our findings integrate both preferences and perceptions of trait realization, offering a more nuanced picture of Generation Z's workplace orientation. **Theoretical implications**. The study suggests that theories of organizational color models, particularly Laloux's Teal model, should account for the transitional nature of early-career employees' preferences. While idealized models promote self-management and shared responsibility, young professionals may require hybrid structures that provide guidance and predictability alongside autonomy. This highlights the importance of integrating developmental considerations into organizational design, especially when introducing self-organizing frameworks. **Practical implications**. For organizations seeking to attract and retain Generation Z talent, the findings underscore the need to balance **aspirational values** with **practical structural elements**: Combine autonomy, collaboration, and trust with clear procedures, role definitions, and predictable workflows. Use elements of orange structures - such as measurable outcomes, hierarchy, and clear responsibilities - to facilitate gradual skill development and self-management. Introduce opportunities for participation in decision-making and meaningful engagement, even in traditionally structured environments. Such an approach allows organizations to harness Generation Z's innovative potential while addressing their realistic needs for security and stability. **Future research directions**. Further studies could investigate how professional experience and exposure to different organizational models affect the evolution of Generation Z's preferences over time. Additionally, research on managerial practices that effectively support the adoption of teal values without increasing uncertainty would provide actionable guidance for organizations aiming to implement self-organizing or partnership-based structures. **Conclusion of discussion**. In sum, Generation Z exhibits a pragmatic blend of aspiration and realism: while they value autonomy, collaboration, and partnership,

their practical choices favor environments that offer security and structural clarity. This dual orientation highlights the importance of designing organizational models that integrate **flexibility, trust, and shared responsibility** with **efficient, predictable structures**, bridging the gap between idealistic expectations and practical workforce needs.

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ENERGY POLICY AND MINING INVESTMENTS IN ENERGY RESOURCES IN POLAND – HOUSEHOLDS' PERSPECTIVE – SELECTED ASPECTS

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Purpose: Assessment of the state's energy policy and the state of mining investments in Poland's energy resources. Determination of the dynamics of mining investments and their scope, as well as identification of household assessments of energy management issues.
Design/methodology/approach: Analysis of publicly available data in reports on the state of mineral deposits in Poland. Data collection through a survey and presentation of the results, along with the presentation of conclusions drawn from the results - construction of a model of energy policy preferences.
Findings: As a result of the analysis of data on Poland's energy resources and the findings resulting from the survey of Polish households regarding their attitudes towards energy policy, several fundamental conclusions were drawn. 1. Energy resources are a factor positively impacting the country's energy security. 2. Over the last decade, a decline in the share of non-renewable energy sources in the energy consumption structure has been observed. 3. During periods of economic or social crisis, increasing confidence in non-renewable energy sources can be observed. 4. The decarbonization process is likely not an absolute ambition, but it is sensitive to factors other than environmental factors, including national security. 5. Polish society is willing to invest in renewable energy sources and limit investments in non-renewable energy sources, but above all, out of a sense of energy security.
Originality/value: A synthesis of areas considered independent: central-level policy, preferences expressed at the household level, and issues at the intersection of geology, economics, and ecology. The research may be useful in supporting the assessment of public consultations regarding the country's energy transition and educational directions for improving energy security, rather than in addressing trends or dogmatism related to energy transition.
Keywords: energy transition, energy transformation, mining investments, household attitudes, energy resources.
Category of the paper: Research paper.

1. Introduction

A state's energy policy can be implemented under at least several conditions. First, it requires legitimacy. This can be understood in two ways: as the subject of a given state's government's activity, but also as the inclinations of society, which influenced the formation of the government. Second, resources (own or acquired) must be available for management in the course of policymaking.

These conditions constitute the research problem of this article. The first part will examine the existing resources of the main energy resources whose exploitable deposits are located in Poland: natural gas, crude oil, lignite, and hard coal. The resources of these resources will be analyzed, taking into account primarily the quantities that are technically extractable and those whose extraction would be profitable. Data will cover the last decade.

The second part will present the results of our own research, which was conducted in the form of a survey addressed to households from all over Poland and concerned preferences regarding the direction of energy policy, including the assessment of the current policy.

2. The state energy policy and the aspect of energy resources in Poland and their management

Considering the topic of mining investments in energy resources from a household perspective is a process that falls into categories that will ensure a comprehensive approach after taking into account the context of:

- energy security,
- raw material resources,
- energy policy,
- strategies and tools for implementing energy policy.

Energy security can be understood according to the definition provided by the Mining Law: it is the state of the economy that enables the current and future demand for fuels and energy to be met in a technically and economically justifiable manner, while maintaining environmental protection requirements (Mining Law). This understanding is appropriate from the perspective of the party ensuring this state of security, which is, in principle, the state. From the perspective of the end user, security can be considered equivalent to the state of availability. This availability, in turn, can be understood in two aspects: the level of energy prices and the guarantee of reliable supply (Mazurkiewicz, 2008). Analysis of the cited definitions allows us to conclude that the perception of energy security depends on the process of ensuring it,

but two identical and simultaneous statements about the existence of energy security do not necessarily have to be equivalent.

The procedure for determining the state of energy security requires the identification of the following parameters (Kostecka-Tomaszewska, 2024; Nowiński, 2021; Szczerbowski, 2013; Hebda, 2023; Golarz, 2016):

- level of dependence on energy imports,
- structure of the energy mix,
- degree of diversification of energy sources.

In principle, it seems that a country's appropriately diversified and diverse energy sources, with the lowest possible level of dependence on energy imports, should translate into sufficient energy availability. Availability is therefore a desirable condition, but from the perspective of households, it is not necessarily fully understood in the long term. Therefore, it can be concluded that such research is burdened with the risk of inconsistent conclusions from attempts to identify categories with a dual meaning (i.e., energy security). Households may define energy security, but without taking into account future resources and needs, and without necessarily identifying the economic, technical, and ecological conditions of available supplies.

The context of raw material resources allows us to specify that among all mineral deposits found in Poland, from the point of view of mining investments in the context of energy policy, only energy resource deposits are important, among which the following should be distinguished (PIG, 2025):

- nitrogenous natural gas,
- natural gas,
- helium,
- coalbed methane,
- crude oil,
- brown coal,
- hard coal.

Despite Poland's abundance of the aforementioned mineral deposits, the country's energy policy primarily considers deposits of hard coal, lignite, crude oil, and natural gas (MKIŚ, 2021). The author believes that the identification of these energy resources, along with their resource dynamics, can be inferred from data on the quantity of minerals in deposits, broken down into developed, undeveloped, and abandoned deposits, along with a measure of the degree of development of existing deposits and the degree of abandonment. These figures are presented in the graphs – figures 1 to 8.

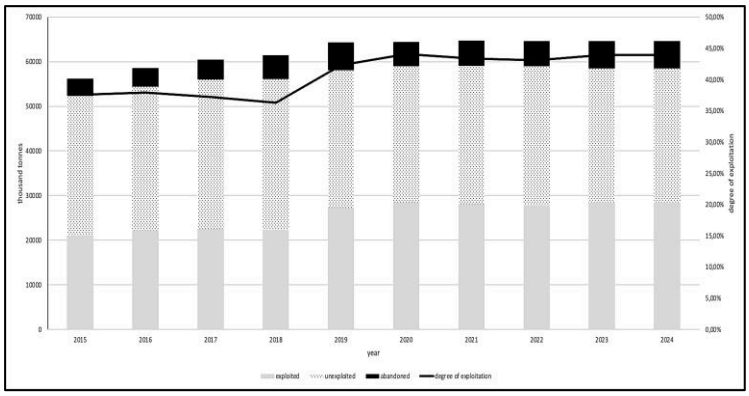


Figure 1. Technically recoverable hard coal resources.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

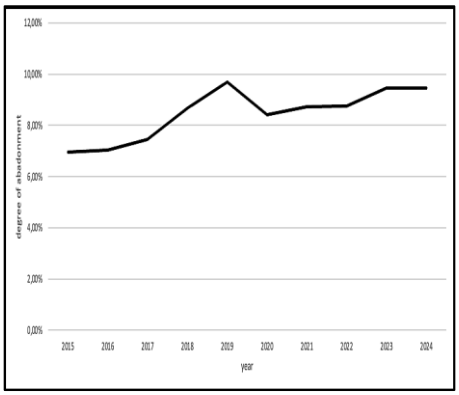


Figure 2. Degree of abandonment – hard coal.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

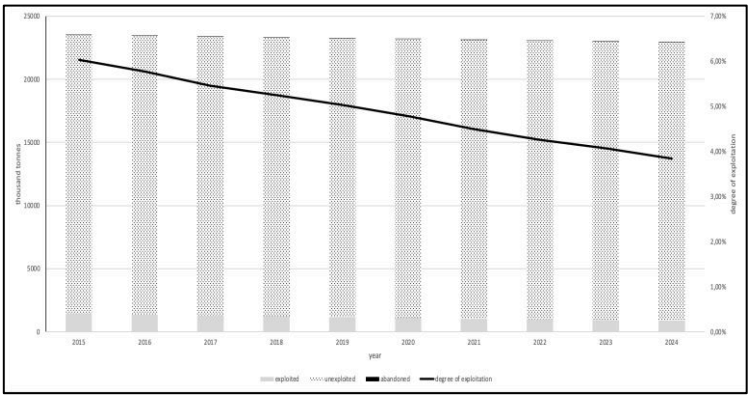


Figure 3. Technically recoverable lignite resources.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

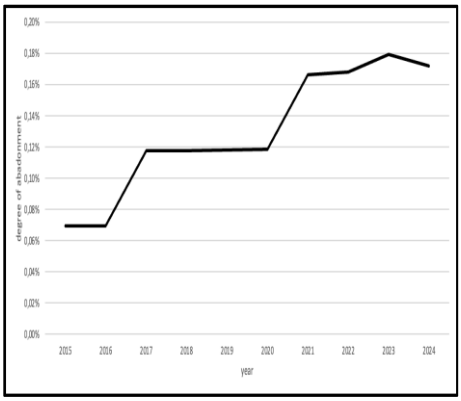


Figure 4. Degree of abandonment – lignite.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

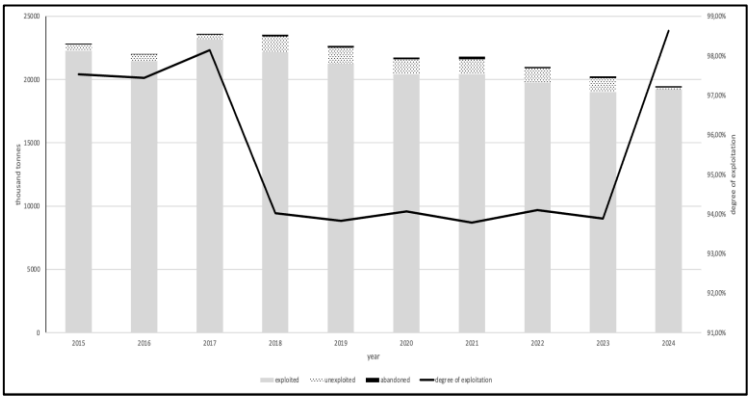


Figure 5. Technically recoverable crude oil resources.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

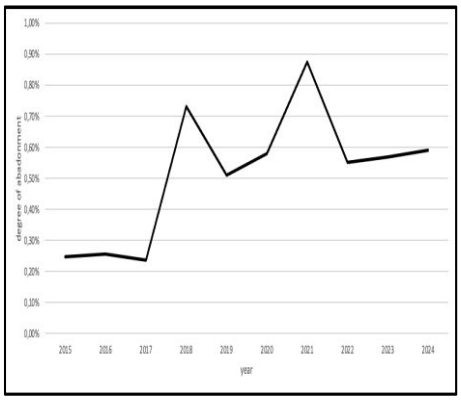


Figure 6. Degree of abandonment – crude oil.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

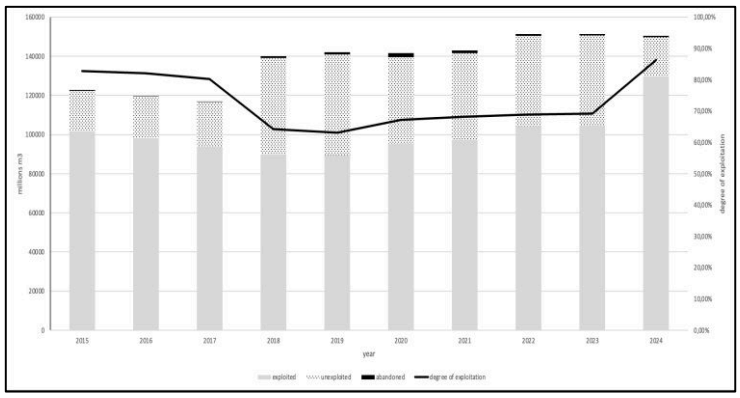


Figure 7. Technically recoverable natural gas resources. Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

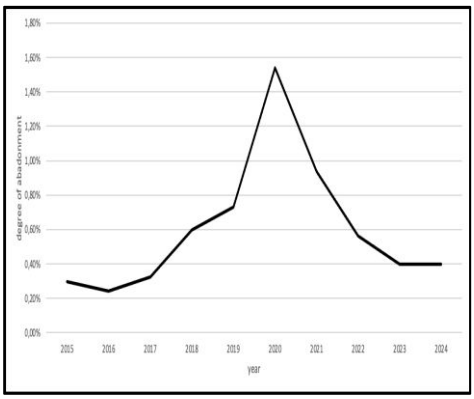


Figure 8. Degree of abandonment – natural gas.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

The data analysis, the results of which are reflected in Figures 1 to 8, is based on the assumption that raw material resources are understood as technically recoverable resources. This category means that we are talking about those resources of a deposit or part thereof whose natural characteristics, defined by recoverability criteria and conditions of occurrence, enable its exploitation (Saługa, 2011). This refers to the technical potential of the resources, for now without taking into account the transitional conditions of exploitation profitability. Furthermore, the data on hard coal were not divided into thermal and coking coal; this approach is based on three reasons. First, coking coal, as a result of coking—and thus indirectly—is used to generate energy. Secondly, from the point of view of mining investments, including the extraction of hard coking coal, the focus is on the overall usefulness of solid fuels, not necessarily solely as fuel in heating boilers – thus, we are talking here about their function as fuel, reducing agent, and carburizer for pig iron in blast furnace processes[1] (Blaschke, Ozga-Blaschke, 2015). Thirdly, if one wishes to compare data on resources with data on consumption, statistical data at the national level are presented on the aggregate consumption of thermal and coking coal (Grudziński, Stala-Szlugaj, 2014; GUS, 2024).

A comparative analysis of the four main energy resources found in Poland indicates that the relatively highest level of exploitation of technically recoverable resources can be observed in the case of crude oil (Figure 5). Existing technically recoverable resources have been depleted over the last decade, and the relative level of development of deposits increased in 2024 after stagnating for five years, when it declined in 2018 (the curve in Figure 5). In turn, the relative size of deposits abandoned in the last decade is on an upward trend.

[1] Coking coal as a reducing agent and carburizer is losing its usefulness due to the limitation of blast furnace processes in favor of Direct Reduced Iron (DRI) technology.

In contrast, the highest level of unused technically recoverable resources can be observed in the case of lignite, whose total resources were relatively stable during the period under review (Figure 3). Additionally, there is a steady downward trend in the degree of utilization of available resources (the curve in Figure 3) with a simultaneous upward trend in the degree of abandonment of exploitation of available resources (Figure 4). The reason for the stable level of technically recoverable resources may be the fact that not only there is no priority for its use or exploration, but also the small potential for new deposits, with its extraction being decreasing and small.

In the case of natural gas resources, their overall resources have been increasing over the last decade (Figure 7), and the degree of their development was at a relatively high level, which was stable until 2023; in 2024, there was a relatively large increase in the degree of field development (curve in Figure 7). In turn, in the years 2016-2020, the degree of abandonment of exploitation of technically recoverable resources increased significantly, reaching a maximum in 2020, from which it is decreasing at a comparable rate until 2024 (Figure 8).

The analysis of the structure of hard coal resources indicates two possible basic conclusions: (1) hard coal is treated as an important component of the energy mix, which is to ensure security in terms of availability - the technically recoverable resources have not fluctuated significantly in the last decade, and have increased slightly since 2018 (Chart 1), while the degree of deposit development has changed proportionally to the amount of resources (curve in Chart 1); (2) the decarbonization process is noticeable, the relative amount of resources whose exploitation has been abandoned is the highest among all the analyzed raw materials (from about 7% to about 10%) and a constant but weak upward trend is noticeable. The increasing share of abandoned exploitation results from a chain of causes, the links of which include both the legal regulations regarding the possibility of using coal and the resulting development of alternative energy sources replacing coal technologies.

A study conducted in a similar convention can be found in the work of Gawlik and Mokrzycki, however, one can find there a comprehensive analysis of all energy resources, but only in one year, i.e. 2016 (Gawlik, Mokrzcki, 2017).

Energy policy is a synthesis of means and goals, i.e., natural resources that can be useful in achieving energy security. Energy policy can be defined (as with security) from various perspectives. From the perspective of a household, which in principle has the freedom to allocate funds for goods and services, energy policy can be a calculation with a single-season time horizon, comparing heating needs with the possible fuels available for a given heating installation, their quantity, and price. From a formal perspective, conceptualized as the state's energy policy, the issue is addressed more broadly and with a long-term perspective.

The assumptions of Poland's energy policy are expressed in the document "Poland's Energy Policy until 2040" and the "Assumptions for the Update of Poland's Energy Policy until 2040". These documents articulate the framework for Poland's energy transformation, based on three pillars (in the version before the update): a just energy transition, a zero-emission energy

system, and good air quality. These pillars are linked to eight specific objectives, including (energy policy):

1. optimal use of domestic energy resources,
2. expansion of electricity generation and grid infrastructure,
3. diversification of supplies and expansion of the grid infrastructure for natural gas, crude oil, and liquid fuels,
4. development of energy markets,
5. implementation of nuclear energy,
6. development of renewable energy sources,
7. development of heating and cogeneration,
8. improvement of energy efficiency

and after the update – taking into account the fourth pillar: energy sovereignty. A key element of the fourth pillar is the rapid independence of the national economy from imported fossil fuels (Assumptions for the update). For the remaining eight goals, the primary area of modification would be the issue of sovereignty and reducing dependence, primarily on the Russian Federation. It is worth noting that one of the methods of implementation would be to increase the capacity to use domestic coal resources, which would slow the pace of decarbonization.

In this paper, the specific elements of national energy policy considered are Objectives 1 and 6. The final element of the planned analysis will therefore be data on the changing resources whose extraction is profitable and the degree of their extraction during the period under analysis – in terms of the tools used to implement the national energy policy. The results of this analysis are presented in graphs – figures 9 to 12.

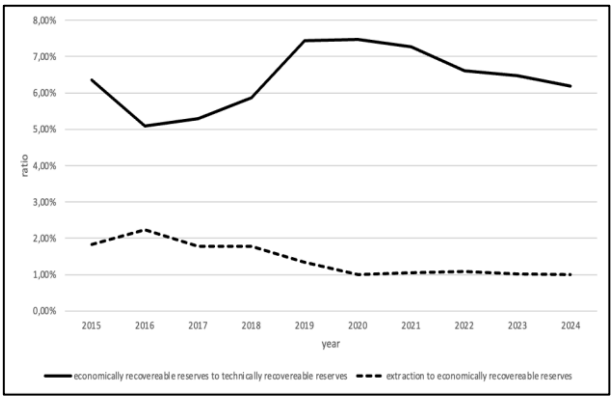


Figure 9. Economically recoverable reserves of hard coal and its extraction.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

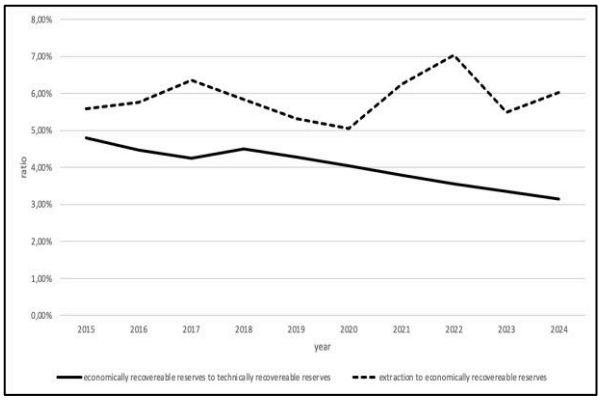


Figure 10. Economically recoverable reserves of lignite and its extraction.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

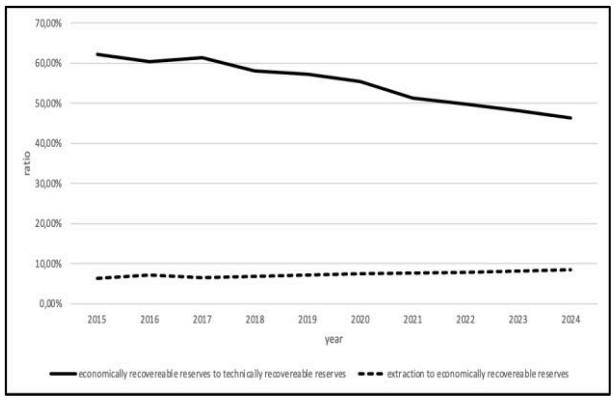


Figure 11. Economically recoverable reserves of crude oil and its extraction.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

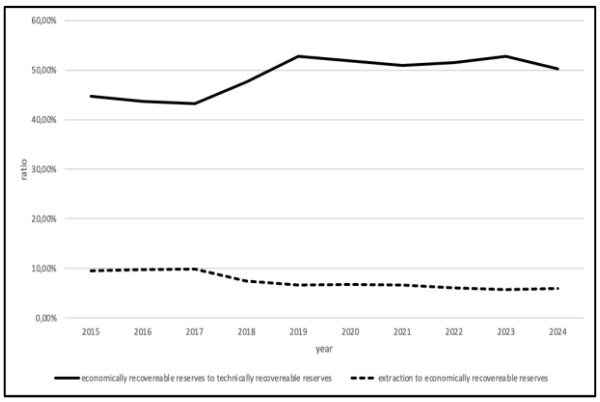


Figure 12. Economically recoverable reserves of natural gas and its extraction.

Source: own study – based on The Balance of Mineral Resources Deposits in Poland 2016-2025.

Two measures were used to analyze the implementation of energy policy between 2015 and 2024: the ratio of technically recoverable resources to economically viable resources, and the ratio of a given resource's production to economically viable resources in subsequent years.

It can be noted that over the last decade, economically recoverable resources have fluctuated relative to technically recoverable resources. A significant increase was observed between 2017 and 2019, which may be related to increased activity in the coal sector caused by the COVID-19 pandemic crisis (Montrone, Steckel, Nemet, 2023; Zhang, Lu, Chen, 2023). At the same time, this was associated with a decline in relative hard coal production, so the potential for available resources was not associated with a proportional increase in production (absolute production values – which are not presented in the graph – indicate a decrease in the number of tons mined).

For lignite, the amount of economically recoverable resources relative to technically recoverable resources is steadily declining. Considering the low variability of the absolute amounts of technically recoverable resources presented in Figure 3, it can be concluded that the attractiveness and, consequently, the profitability of lignite mining is decreasing. Despite the above, production relative to resources has fluctuated, and in the period 2020-2022, an increase in production can be observed.

In the case of crude oil, the ratio of economically recoverable resources to technically recoverable resources is also in a downward trend in the period under analysis, while its production, also in a downward trend, was not proportional to the general decline in the profitability of extraction. This observation can be seen as evidence of a policy aimed at reducing import dependence. The study did not analyze the intensity of exploration and discovery of new resources, but the data indicate that this activity was conducted effectively. The relatively high level of extraction may be related to the high importance of this resource, despite the stagnant profitability of extraction.

Both natural gas and crude oil are characterized by a high ratio of resources whose extraction is profitable to those whose extraction is feasible – while in the case of hard coal and lignite, this level ranged between approximately 3% and 7.5%, in the case of natural gas and crude oil, it is between approximately 43% and 62%. In the case of natural gas, this measure indicates stabilization since 2019, with the level being lower before 2019. Natural gas production is on a downward trend, even considering the increasing profitability of this resource.

3. Household preferences towards mining investments and the state's energy policy – survey results

The category of mining investments may address several issues. The link between energy policy, in the sense of investment projects in the form of raw materials, and household preferences does not appear to be close. However, in the author's opinion, it can be assumed that existing beliefs and judgments held by households may reflect the rationale for the state's energy policy. Proof of this and the results of research conducted in this area will be the subject of the second part of the article.

The category of mining investments can refer to several issues. Mining investments and household preferences for them can be considered indirect investments, such as shares of mining companies or commodity futures contracts. This approach can be seen in the work of Pera (Pera, 2020). Another understanding of investing is the strategy adopted by a company engaged in mining activities. This approach can be found in the work of Zochorek (Zochorek, 2021). In a similar context, but at a higher level of generalization—that is, conducting a business that could potentially involve mining—this problem is described in the work of Kulczycka and Nowaczek (Kulczycka, Nowaczek, 2016).

This article adopts yet another perspective. Based on the assumption that the mining problem is not solely a matter of Poland's geological characteristics, nor merely a form of capital investment or a business concept. Instead, it is strongly linked to tradition and the labor market, and simultaneously to capital held by the State Treasury, it can be assumed that household preferences may be clear and that Polish society has a sense of responsibility and influence on the development of energy policy – for example, in the assessment of mining activities in Poland. Social conflicts over the access to raw material deposits in Poland can be found in Badera's work (Badera, 2010). This context is also highlighted in the discussion of the development of the lignite industry in Kasztelewicz, Ptak, Sikora work (Kasztelewicz, Ptak, Sikora, 2016). Mining and its development in the social and economic context of the global economy are described, for example, by Ranosz (Ranosz, 2014). As mentioned, the mining industry in Poland is strongly linked to the employment context, and the decarbonization process is considered a significant factor in the increase in unemployment, as can be read in the

report Decarbonization and employment in hard coal mining in Poland (Sokołowski et al., 2021).

Own research, conducted in the form of a survey addressed to adult household members, allowed us to determine household preferences regarding mining investments in Poland and the state's energy policy. The survey included questions on the following areas: values, knowledge of the state's energy policy, assessment of energy policy, preferences regarding the direction of energy policy development, and personal habits regarding household heat and electricity management.

In this article, in addition to the analysis conducted in the first part of the article, there will be described the results obtained from one part of the survey, which concerned the preferred shape of the state's energy policy. The questions asked were as follows:

1. As a taxpayer who finances energy policy, I support spending on phasing out non-renewable fuel mines while supporting the development of renewable energy sources.
2. As a taxpayer who finances energy policy, I support spending on phasing out non-renewable fuel mines regardless of the possibilities of obtaining energy from renewable sources.
3. As a taxpayer who finances energy policy, I support spending on supporting the operation of non-renewable fuel mines and increasing their number while supporting the production of energy from renewable sources.
4. As a taxpayer who finances energy policy I suport spending on supporting the operation of non-renewable fuel mines and increasing their number regardless of the development of opportunities to obtain energy from renewable sources.

All questions included suggested responses on a five-point Likert scale ("strongly agree", "agree", "neither agree nor disagree", "disagree", "strongly disagree"). The results were presented in graphs – figures 13 to 16.

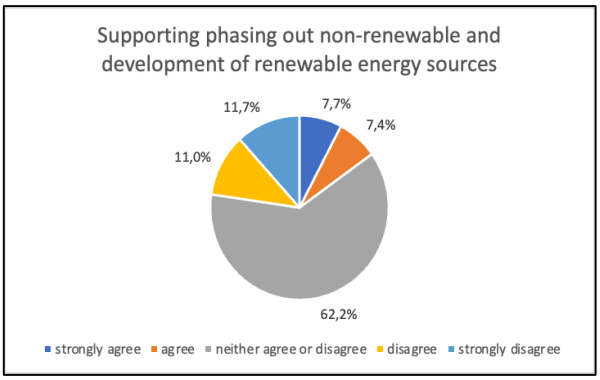


Figure 13. Supporting phasing out non-renewable and development of renewable energy sources.

Source: own study – based on survey results.

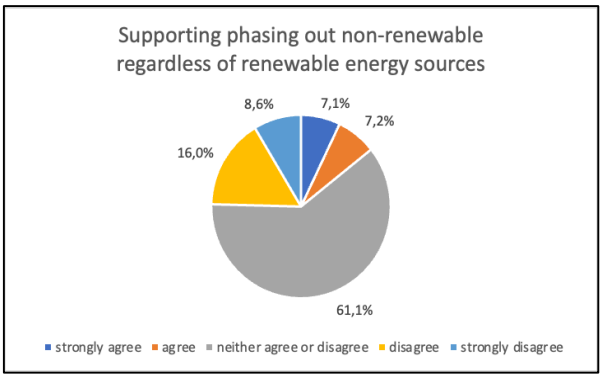


Figure 14. Supporting phasing out non-renewable regardless of renewable energy sources.

Source: own study – based on survey results.

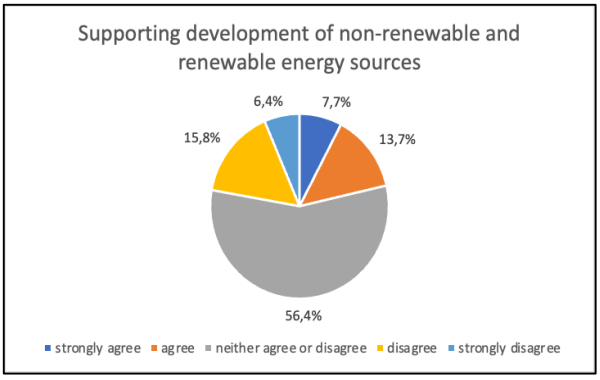


Figure 15. Supporting development of non-renewable and renewable energy sources.

Source: own study – based on survey results.

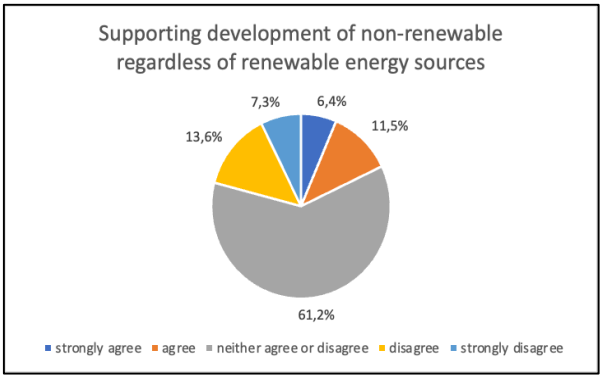


Figure 16. Supporting development of non-renewable regardless of renewable energy sources.

Source: own study – based on survey results.

The presented results allow for the construction of an intuitive model of preferences regarding the implementation and direction of national energy policy development. Analysis of the collected data can be translated into four household attitudes, which, along with the results, are presented in Table 1. It was assumed that the approval attitude would be determined by the sum of the "agree" and "strongly agree" responses, while the disapproval attitude would be determined by the sum of the "disagree" and "strongly disagree" responses.

Importantly, a potential drawback of the study and its conclusions may be the lack of a more precise definition of renewable energy sources in the survey. At the same time, the primary focus of the study was mining investments – their current status, development dynamics, and phase-out dynamics. The study's conclusions are therefore biased by an asymmetric examination of specific energy policy strategies based on the extraction and consumption of fossil fuels and ecological, renewable energy sources. Nevertheless, the author intends to conduct the missing research in the future and supplement the existing conclusions.

Table 1.

Types of energy policy and household preferences towards them

	non-renewable fuel mines renewable energy sources	non-renewable fuel mines renewable energy sources	non-renewable fuel mines renewable energy sources	non-renewable fuel mines renewable energy sources
agree and strongly agree	15,1%	14,3%	21,4%	17,9%
disagree and strongly disagree	22,7%	24,6%	22,2%	20,9%
neither agree nor disagree	62,2%	61,1%	56,4%	61,2%

KEY:	
	supporting development
	supporting reduction
	neutral

Source: own study – based on survey results.

The table presents the results of the responses, subordinated to four types of energy policy. In accordance with the structure of the questions and the actual possibilities of selecting energy sources in implementing energy policy, it was assumed that one of the cross-sections of this policy is a combination of non-renewable and renewable sources. Furthermore, it was determined (as indicated in the legend with markings) that three possible approaches can be distinguished: support for the development of the use of given energy sources, support for their abandonment, and a neutral stance. While the author is aware that defining only two stances would be easier in terms of scientific reasoning, after analyzing the literature and considering his own position on energy policy strategies, a neutral stance seems justified given the current trend towards the attractiveness of renewable energy sources. Therefore, in the final form of the study, it was possible to express approval or disapproval of non-renewable energy sources, and approval or indifference towards renewable energy sources.

Preliminary conclusions from the respondents' responses (N = 1000) indicate a high degree of indecision. Despite the large number of neutral responses, it can be seen that the most preferred energy policy for households would be simultaneous support for the development of energy production from both renewable and non-renewable sources. Furthermore, the least preferred solution would be to abandon non-renewable sources without developing energy production from renewable sources.

Such observations suggest that Polish society is sensitive to energy acquisition and its environmental impact. However, given the desired state of energy security (as defined from the perspective of final energy consumers at the beginning of this article), non-renewable sources are considered a factor stabilizing both energy availability and costs. Considering that the topic of decarbonization has been present in public discourse for a long time, and that Poland is simultaneously subject to European Union legislation, but also takes responsibility for Poland's abundance of energy resources (of course, there are also significant imports of energy resources), the preferred energy policy in Poland is balanced, and the cautious approach to energy transition reflects a strong concern for energy security.

4. Conclusions and discussion

This article presents two fundamental areas from the perspective of the research problem of energy policy. Firstly, the possibilities of conducting policy, i.e. the question of the resources at disposal, including objective possibilities (geological and technological conditions for fuel extraction and consumption) and subjective possibilities (economic conditions that will allow for the financially efficient exploitation of deposits and the subsequent use of resources for energy production). Second, in correspondence with the first part, which indicates the possibilities and changes analyzed over the last decade in the area of resources and extraction

of Poland's main energy resources, it identifies preferences regarding the selection of energy sources for the energy mix.

The first part of the study involved analyzing and drawing conclusions from data on the dynamics of the abundance and exploitation of energy resource deposits in Poland. Additionally, based on literature, the potential of Poland's energy resources was identified in light of the four pillars of the national energy policy. The structure of the energy resource balance, the dynamics of changes in the resources of deposits that were exploited and those that were abandoned, were considered. The issue of resources whose exploitation would be economically justified, along with the dynamics of change, was also examined, as well as the degree of extraction of deposits relative to potentially profitable deposits.

The second part presents the results of our own research, conducted using a questionnaire survey addressed to households across Poland. The survey results presented here outline household preferences for mining investments as a tool of the state's energy policy. The intensity of support for the development of renewable and non-renewable energy sources was determined.

Analyses of the state's energy policy, conducted in two contexts, led to the following conclusions:

1. Energy resources are a factor positively impacting the country's energy security.
2. Over the last decade, a decline in the share of non-renewable energy sources in the energy consumption structure has been observed.
3. During periods of economic or social crisis, increasing confidence in non-renewable energy sources can be observed.
4. The decarbonization process is likely not an absolute ambition, but it is sensitive to factors other than environmental factors, including national security.
5. Polish society is willing to invest in renewable energy sources and limit investments in non-renewable energy sources, but above all, out of a sense of energy security.

The study also identifies several areas requiring further development. The author believes it would be worthwhile to compare Poland's energy resources with those of other countries and analyze the volume of energy imports and exports, including energy resources. Secondly, the study should be supplemented with investments in technologies that reduce the negative environmental impacts of consuming fuels from non-renewable resources. Thirdly, in the area of household preferences, a separate analysis of preferences for specific forms of energy generation from renewable sources would be warranted. Fourthly, prospective resources and the trends in European Union energy policy should be considered to identify possible scenarios for the possibilities and legal conditions of energy policy in the future. Bearing in mind the weaknesses of the conducted research, the author plans to continue research on these issues.

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APPLICATION OF CONVOLUTIONAL NEURAL NETWORKS FOR WINDTHROW AND WINDBREAK TIMBER VOLUME ESTIMATION IN THE STARE JABLONKI FOREST DISTRICT

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Purpose: The study aims to estimate the volume of windfall timber using convolutional neural networks. The focus of the study centres on several key challenges in assessing the aftermath of wind damage to forests. This includes accurate quantification and volume measurement of densely downed trees, correct detection of log masks to determine their surface area and then volume, as well as revenue estimation based on wood composition variances and fluctuations in the prices of specific tree species. This capability enables forestry managers to conduct rapid financial impact assessments, crucial for insurance claims and operational budgeting. The goal is to determine whether detailed information on tree-level wind damage can be obtained using aerial imagery. The Methods section outlines the implementation of predefined objectives and assumptions. From a business perspective, the automation of this process significantly reduces the time and cost of traditional ground surveys, improving operational efficiency. The impact of hyperparameter selection on the performance and effectiveness of the resulting model was analysed. The stages of the model's training and refinement to its optimal form have been described. The detection model's effectiveness was evaluated using detection model performance indicators. A reliable, automated estimation system enhances supply chain planning for wood processing mills by providing early and accurate data on available raw material volume and quality. The article concludes with an analysis of volume and revenue estimates for a sample area in the Stare Jabłonki Forest District. Calculations of potential revenue from windthrows was performed. This directly supports strategic decision-making, allowing for optimized timber sales scheduling to capitalize on favorable market prices for specific species or grades. The estimation of potential revenue was carried out taking tree species and timber grades into account, using a detailed timber price list published by the forest districts. Ultimately, this technology transforms aerial data into a actionable business intelligence tool for revenue forecasting and resource management following disruptive natural events.

Design/methodology/approach: The study used aerial imagery acquired from two forest districts - Dobrocin and Stare Jabłonki - using a Riegl 1560i-DW II LiDAR scanner and a 150 MP RGB camera. A dataset of 538 images containing 2160 annotated logs was prepared. Detection was performed using a Mask R-CNN model based on the ResNet-101 backbone and Feature Pyramid Network (FPN) architecture. The model was trained and validated on data representing different stand densities and windthrow concentrations. Model performance was

evaluated using Precision, Recall, F1-score, and Intersection over Union (IoU) metrics. Estimated timber volumes were compared with reference data and used for potential revenue estimation according to detailed timber price lists published by the forest districts.
Findings: The model achieved high detection accuracy. The Pearson correlation coefficient between the predicted and reference values ranged from 0.96 to 0.97, and the average F1-score reached 0.766. The highest accuracy was achieved for low IoU thresholds (0.1-0.5). The difference between the estimated and actual timber volume amounted to 354 m³, and the mean estimation error for potential revenue was 7.13%.
Research limitations/implications: The main limitations of the study arise from manual data labeling and the limited sample size in areas with high tree density. The model occasionally splits long logs into several parts. Future research should expand the dataset to include more diverse examples and apply Explainable AI (XAI) methods to improve interpretability and transparency of results.
Practical implications: The use of convolutional neural networks for aerial image analysis enables fast and accurate estimation of windfall timber volume. This approach can significantly support forest management operations, improve post-storm planning efficiency, and provide rapid economic assessments before the wood loses its industrial value.
Social implications: Rapid and accurate assessment of windstorm damage supports effective forest management, reduces economic and environmental losses, and strengthens adaptive measures against climate change impacts.
Originality/value: This study presents a novel application of **Mask R-CNN convolutional neural networks** for precise estimation of windthrow timber volume based on aerial imagery. The results demonstrate the potential of artificial intelligence methods in forestry for automatic damage assessment, resource planning, and revenue forecasting.
Keywords: Disaster management, Deep learning, Instance segmentation, Timber volume.
Category of the paper: Research paper.

1. Introduction

The study aim entails an attempt to estimate the volume of windfall timber, using selected artificial intelligence methods. The implementation of a project involving estimation of timber volume has been motivated by the growing number of windstorm disasters in Poland. Wind disturbance is a worldwide issue. In the Amazon rainforest, wind damage, mainly caused by the growing incidence of convective winds, has become one of the greatest negative impacts. Strong wind is responsible for 50% of all tree mortality (Feng et al., 2023). Forest biomass plays a role in climate stability and numerous ecological processes (Pravalie et al., 2023). Throughout 2000-2021, the amount of harvested timber steadily increased. During this period, two phases were observed, characterized by an increase in the amount of harvested deadwood and windthrow. In 2021, Polish forests averaged 9.8 m^3/ha of coarse deadwood. A similar proportion was observed for dead and windfall trees, recorded at 4.9 m^3/ha. On average, every hectare of forest consists of 272 stumps in a standard distribution. Countrywide, the volume of dead coarse wood averages 9.8 m^3/ha. Half of this volume, i.e., 4.8 m^3/ha, is windfall trees

(Office of Forest Management and Geodesy)[1]. The study analyzes the case of wind damage in northern Poland, where forests have been ravaged by severe hurricanes in recent years. In 2017, the so-called 'hurricane of the century' hit the regions of the Kuyavian-Pomeranian and Pomeranian voivodeships. On August 11-12, a so-called bow echo hurricane struck, reaching speeds of up to 150km/h (Dmyterko, Bruchwald, 2020). The hurricane severely damaged a total of 39.2 thousand hectares of forest. The incidence of hurricanes in Poland shows regularity. Just a year later, in July 2018, a hurricane uprooted 10 000 trees in the Stare Jabłonki Forest District, which has been assigned the highest level of forest threat (estimated risk between 40-50%) (Dmyterko et al., 2015).

2. Natural disasters

In the face of widespread climate change awareness, a shift in approach to forest management has ensued. It has been forced by the increasing intensity and frequency of climate change-related disturbances. The consequences of these processes are difficult to predict in the long term. Authors (Filotas et al., 2014) indicate that we have been facing an unprecedented rate of abiotic changes. The new approach recognizes the uncertainty associated with environmental and social change. It promotes the view of forest management as a complex, functional network, subject to continuous and dynamic monitoring (Messier et al., 2019). These systems, used in forest planning and management, are aimed at strengthening the resilience of forests against climate change (Walker et al., 2004; Filotas et al. 2014). The sensitivity of forests to the effects of climate change can be reduced through appropriate 'forest operations' (Lindner et al., 2010). In the context of natural disasters, these measures improve the resilience of forests, counteracting the destructive effects of climate change (Seidl et al., 2014). Of importance in this context is the implementation of adaptive forestry strategies that are responsive to the ongoing climate change. Authors emphasize that the management of a forest as a complex adaptive system calls for constant monitoring of ecosystems and implementation of strategies increasing resilience to disturbances (Walker et al., 2004). The key aspect is to prevent these disturbances from affecting the ecosystem's ability to perform it basic functions. Of equal importance is the continued education of management personnel on the changing environmental conditions (Tampekis et al., 2024). Abiotic disturbances are characterized by a rapid and dynamic progression (Gieralowiec, 2020). Tree species with robust root systems are prone to breakage. Those typified by weaker root systems are more susceptible to uprooting (Krisans et al., 2020). Hurricane damage changes the landscape and reduces timber production, negatively affecting the management of forests, hydrological balance,

[1] Office of Forest Management and Forest Geodesy (2020) Guidelines for conducting a large-scale forest status survey.

and biodiversity. European forests suffer most severely due to insect infestations and plant diseases, as well as wind and wild fauna (Gardiner et al., 2013). Hurricane activity has been observed to reduce the potential for harvesting higher-grade timber (Gieralowiec, 2020). The prevalent atmospheric factors and the damage to wood limit the industrial usability of timber, which is why salvage logging operations are of such vital importance. Prompt assessment of the extent of damage allows for estimation of the workforce needed for salvage logging (Kühmaier et al., 2022). The potential for harvesting high-grade windfall and windsnap timber is also dependent on the technology and equipment utilized to harvest the timber in a given area (Gieralowiec, 2020). Windthrow stands are more susceptible to disease, given that these areas become, over time, a breeding ground for insects and fungi (Dhubháin, Farrelly, 2018). In the past, undetected clusters of uprooted trees served as breeding grounds for the bark beetle (Einzmann et al., 2017). The risk of wind damage increases proportionally to tree stand height (Zachara, 2006). A stand's susceptibility to damage is also conditional on its species composition (Zachara, 2006), soil composition, and geomorphology (Gardiner, Quine, 2020). Another factor increasing the risk of tree damage is snow cover (Heinonen et al., 2009). Recent research suggests that coniferous trees are more susceptible to wind damage than deciduous trees (Valinger, Fridman, 2021). Despite the availability of preventive measures aimed at reducing forest vulnerability to wind damage, forest managers' accountability remains limited (Zachara, 2006). The preventive measures have been conceptualized as development of logging areas narrower than 30 meters, as well as reduction of stand density by eliminating resistance points through thinning cuts. The permeability of forests reduces the risk of wind damage (Zachara, 2006). The strength and frequency of gusts are considered significant factors in terms of damage (Dhubháin, Farrelly, 2018). Stephen J. Mitchell mentions in his work the interaction of three major factors contributing to wind damage susceptibility, namely topographic exposure, soil properties and stand characteristics - the windthrow triangle (Mitchell, 1995).

3. Utilization of AI for Object Recognition

Artificial intelligence methods are employed in the modelling of phenomena when detection of patterns in data via classical statistical models proves impossible. Neural network models are increasingly utilized to solve forestry-related problems (Diez et al., 2021). Vasileios Linardos explains in his publication that the use of ML/DL algorithms allows for detection of areas affected by all types of natural disturbances (Linardos et al., 2022). Deep Learning models show great potential in estimating the risk of wind damage and assessing the extent of windthrow and windsnap damage. Artificial intelligence methods are far superior to humans in terms of data analysis speed (Sun et al., 2020). Artificial neural networks outperform such

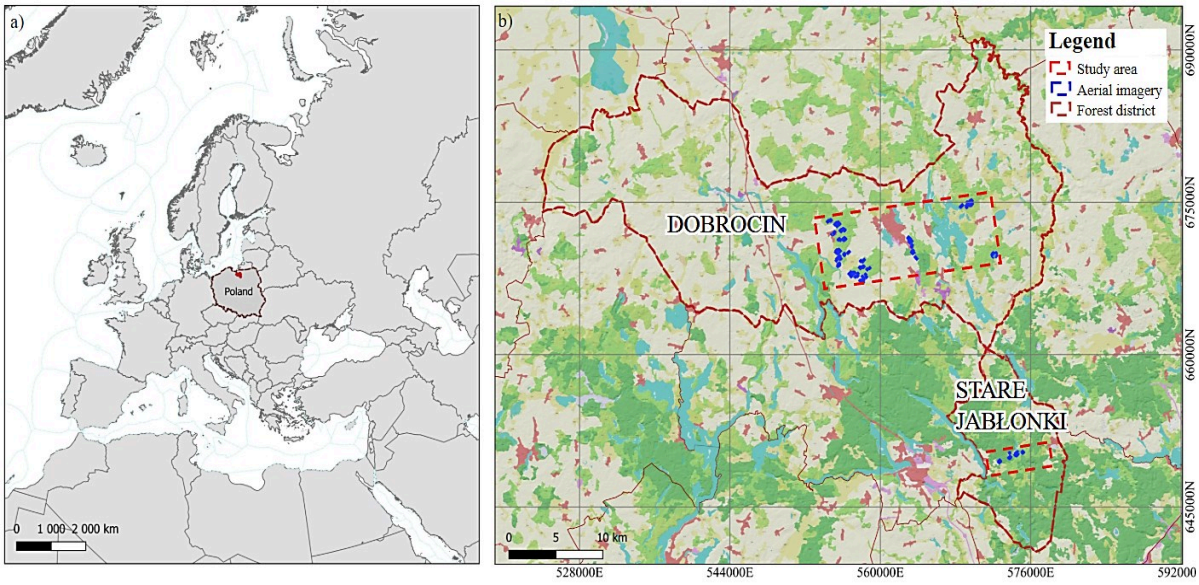
classical statistical models as the Naive Bayes classifiers, logistic regression, support vector machines or SAMME.R in identifying areas affected by windstorm damage (Kislov, Korznikov, 2020). The advantage of such an approach lies in the automatic identification of patterns in data, without the need for feature engineering (Kislov et al., 2021). The disadvantage of using a Deep Learning model stems from its black-box nature, precluding interpretation of its performance (Cheng et al., 2022). The study involved the use of convolutional neural networks. Convolutional neural networks are a type of model tailored to structured data, e.g., images (Goodfellow et al., 2018). They are widely employed in image analysis, for such tasks as classification, detection, object recognition and semantic segmentation (Zhang et al., 2016). The neurons in convolutional neural networks are arranged three-dimensionally – by width, height, and depth, with each layer only connecting to their corresponding neurons in previous layers (O'Shea, Nash, 2015). Artificial intelligence models require vast amounts of training data, typically annotated manually by humans. Human intervention in data can input errors, potentially limiting the peak accuracy of the models (Kislov et al., 2021). Validation and correction of any manually created data by means of field measurements is recommended (Kislov et al., 2021). The advancement of artificial intelligence methods offers unprecedented opportunities in the modelling of high complex phenomena. Adaptation of these models towards solving the problems generated by natural disasters can prove beneficial to forest managers and owners (Cheng et al., 2022). Features such as precision and short lead times can play a valuable role in the planning of windstorm mitigation tasks (Sun et al., 2020). From a business perspective, the automation of this process significantly reduces the time and cost of traditional surveys, improving operational efficiency. A reliable, automated estimation system enhances supply chain planning for wood processing mills by providing early and accurate data on available raw material volume and quality.

4. Research methodology

Study area

The study utilized data on two Forest Districts - Dobrocin and Stare Jabłonki, located in Poland (Figure 1a). An analysis of the volume of windthrow and windsnap waste wood harvested in July 2018 in the Stare Jabłonki Forest District was performed. Both forest districts are geographically situated in the Warmian-Masurian Voivodeship. The Dobrocin Forest District borders the Orneta, Kudypy, Stare Jabłonki, Miłomłyn, Susz, Kwidzyn, Elbląg, and Młynary Forest Districts (Żokowski, 2023). The area of the unit extends over 842.78 km^2. The Forest District borders the Stare Jabłonki Forest District to the southeast (Figure 1b).

The area of the Stare Jabłonki Forest District totals 175.6 km^2. The dominant species in these forests are pine (79.4%), beech (7.4%), birch (6.2%), and oak (3.5%) (Przesław, 2023).



a) b)

Figure 1. Study area. Stare Jablonki, Dobrocin Forestry Districts. Information on recorded wind disturbance damage derived from the Stare Jablonki Forest District's data.

Source: own eleboration. Map generated using Land Use/Land Cover (LULC): Karra et. al., 2021.

Data collection

The Dobrocin Forest District data was collected during a leaf-off period (April), whereas the Stare Jabłonki District data – during a leaf-on period (August). Simultaneous use of data with different characteristics is assumed to affect models' ability to generalize during the processes of learning. The feature characterising the images recorded during leaf-off is the visibility of the lower strata of the stand, unobscured by tree canopy; hence, given this data, the model is expected to be more effective in detecting windthrows and debris in dense forest sections. The Stare Jabłonki District data was collected during a period of leaf cover. Despite the limited visibility of the undergrowth, downed tree boles stand out clearly against the background of dense, lush vegetation. Both data sets were acquired using a Riegl 1560i-DW II scanner in an aerial survey. The measuring device utilizes a medium-format RGB camera of 150MP resolution with a 64mm CMOS sensor. The camera is equipped with a 50 mm focal length lens. The spatial resolution was identical for both data sets. Log masks were mapped manually using QGIS 3.12 software (https://qgis.org/). Each was outlined as a polygon, rasterized and segmented into a raster mask. Using a customized Python script, the geodata was converted to the standard COCO format (Lin et al., 2014). A total of 538 images (509 x 1688 m) with 2160 downed trees marked were used in the study. Out of the entire set of images, 407 served as training data, 102 as validation data, and 32 as test data. In total, of 579 downed trees were identified and marked in the test data.

Neural Network model architecture

The Mask R-CNN model (Figure 2) consists of several stages implemented sequentially, and utilizes 63 621 918 trainable and 111 488 non-trainable parameters. The first Model block involved the use of a Feature Pyramid Network (FPN). FPNs serve to identify the input image features that allow localization of expected objects. In this stage of the model, ResNet-101 architecture, renowned for its effectiveness, was utilised (He et al., 2015).

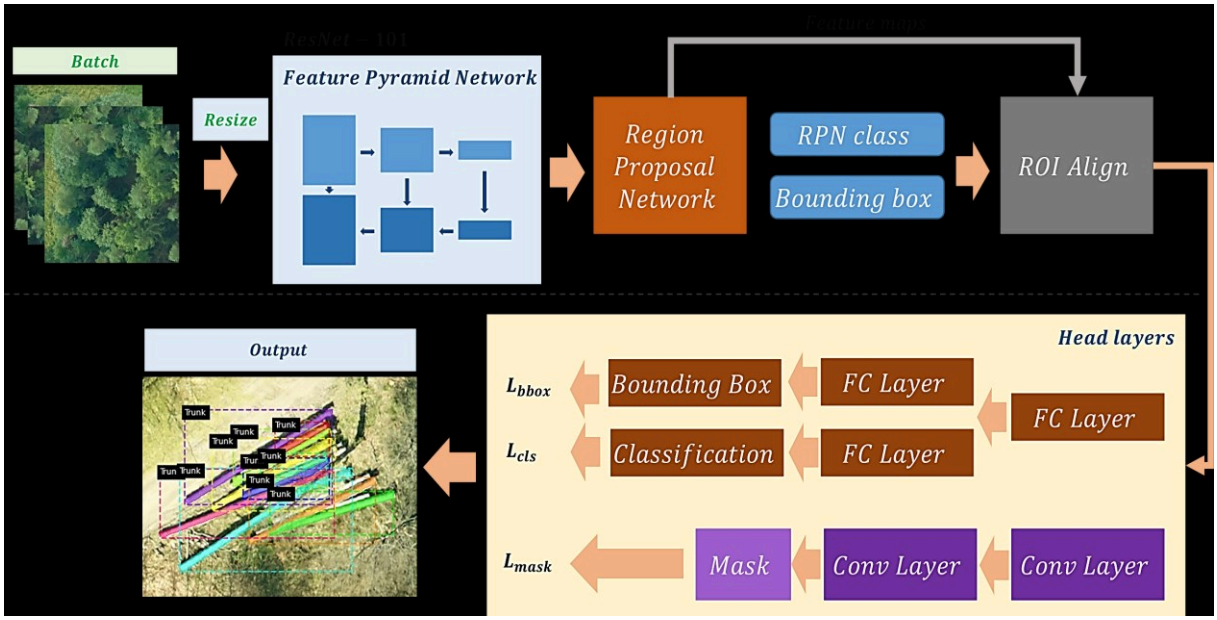


Figure 2. Diagram of MaskR-CNN model. The model consists of several sequential segments, dedicated to separate components in the task of instance detection and segmentation.

Source: a report based on: Karra et. al., 2021.

The feature pyramid outputs are fed into the next stages - Region Proposal Network (RPN) and Mask Recurrent Neural Network (MRCNN). The Region Proposal Network part conveys the layers showing proposed object locations. RPN then generates a set of predefined anchor box rectangles serving as proposed ranges within which the objects can be located. Using the anchor boxes, the model performs a regression task, indicating the area of bounding box occurrence. Correct localization of objects is achieved by the matching thereof to the areas of interest (anchor boxes). The location of potential anchor boxes is determined by the model based on the features extracted from the FPN block. Position and size errors are determined by the overlaps between the bounding boxes and the anchor boxes (based on the value of the Intersection over Union metric). Simultaneous use of anchor boxes enables identification of spatially overlapping objects. At the end of the detection process, ‘non-maximum suppression’ filtering is used in the RPN block. This process eliminates the redundant number of ranges assigned to the same object, based on the model's confidence. NMS likewise eliminates false positive indications, improving detection accuracy. The NMS function is used in RPN and MRCNN blocks to eliminate excessive bounding boxes. The process of ROI Alignment is used to extract the features characterizing the regions of interest, to predict the masks. The size of

the masks is consistent, despite the fact that bounding boxes differ in size. This is accounted for by the process of range matching performed in the ROI Align block (He et al., 2017). The function bilinearly interpolates the pixel coordinates and enables precise image masking, regardless of the size of the masked object. Each instance (bounding box) is subject to a binary mask classification by the model. The classification of masks, also known as segmentation, serves to extract a subset or uniform region from an image, based on specific properties (Stąpor, 2011). Mask R-CNN utilizes three different loss functions for each task; to classify the masks, the model calculates the average cross-entropy (Hastie et al., 2001):

$$\boldsymbol{\mathcal{L}(\Theta) = -\sum_{k=1}^{K}\sum_{i=1}^{N} y_{ik}\,\log[f_k(x_i)]} \tag{1}$$

To determine the location error limiting bounding box detection, the model calculates the smooth L_1 loss function:

$$\boldsymbol{\mathcal{L}(\Theta) = \sum_{k=1}^{K}\sum_{i=1}^{N} L_1(|y_{ik} - f_k(x_i)|)} \tag{2}$$

$$where: L_1 = \begin{cases} 0.5x^2 \; if \; |x| < 1 \\ |x| - 0.5 \; if \; |x| \geq 1 \end{cases}$$

The loss function in Eq. 2 is highly resistant to extreme outliers. Ultimately, the loss function is formulated by summing the losses from three different tasks (He et al., 2017):

$$\mathcal{L} = \mathcal{L}_{cls} + \mathcal{L}_{bbox} + \mathcal{L}_{mask} \tag{3}$$

In the above formula, $\boldsymbol{\mathcal{L}_{cls}}$ denotes the loss of classification in an instance, $\boldsymbol{\mathcal{L}_{bbox}}$ represents the bounding box position, and $\boldsymbol{\mathcal{L}_{mask}}$ signifies the loss of overlap between the predicted and reference mask. The form of the total loss function $\boldsymbol{\mathcal{L}}$ shown in Eq. (3) allows for multi-task optimization.

Training

Due to its stochastic nature, the model necessitates an iterative search for the optimal set of hyperparameters. Two phases of the model training process were planned. The first - preliminary training - was aimed at arriving at the best possible form of the weights identifying relevant image features in the Feature Pyramid Network block. The second entailed the training of remaining blocks, excluding the FPN block. This phase began with 'knowledge transfer,' i.e., the import of the weights obtained through MS COCO (Microsoft Common Objects in Context) dataset-based learning (Lin et al., 2014). The use of weights from an already trained model, capable of recognizing specific patterns in an image, was assumed to accelerate the learning process, in contrast to the learning from scratch scenario (Pi et al., 2020). All weights, except those forming part of the FPN (Feature Pyramid Network), proved trainable in the first phase of the training. Empirical observation revealed that the learning coefficient, initially set at of 0.01, caused instability during the process of model training, resulting in numerical complications. This drawback was mitigated by decrementing the learning coefficient to a value of 0.002 and employing a learning rate decay strategy, particularly the Reduce LR On Plateau technique. The weight decay (regularization) coefficient was set at 0.0005 and was not modified

throughout the entire process of the model's learning. With such an approach, loss function reductions undetected over five consecutive epochs automatically result in a downward correction of the learning coefficient's value. The correction process draws on the potential of smaller learning coefficients to aid the model's convergence through incremental adjustments, thus preventing possible instability and numerical problems potentially induced by larger steps. Systematic implementation of learning rate decay strategies, therefore, effectively optimizes the process of iterative training, ensuring a more consistent and reliable progression towards model convergence. The use of a lower coefficient value is intended to limit the impact of individual instances on the model's final decision-making capacity, thereby promoting more balanced and generalized learning. Substantial improvement in the model was observed after extending the training epochs from the initial count of 150 to 400. This extended phase of training lasted 13 hours. The training process was run using hardware equipped with two *NVIDIA GeForce GTX 1080 Ti GPUs* graphics cards of 2x11 GB memory capacity. During the initial iterations, the model showed significant susceptibility to overfitting, necessitating an expansion of the image augmentation technique repertoire. The methodological assortment was supplemented with expansion strategies, including removal of image fragments (via zero-filling) and addition of white noise. A decision was made to increase the number of validation iterations to 70, to obtain a more statistically reliable assessment of the model's actual performance. The first phase of the model training ended with an underestimation of the volume of timber, quantified at 1457 cubic meters. The model showed suboptimal performance in mask classification. In this stage of the training, the model proved highly sensitive in detection, misidentifying tree bole-like objects as downed trees. After testing, the model identified an average of 83% more uprooted trees than indicated in the ground annotations. In the second phase of the learning process, the weights in all layers were unfrozen. The process of arriving at the correct combination of parameters entailed a greater number of iterations to adjust the hyperparameters. Simultaneously, the size of the training data was gradually increased. Since the detection model employed necessitates a large amount of training data, data on both forest districts (Dobrocin and Stare Jabłonki Forest Districts) were used. The most relevant parameter modified in the second phase was the size of the generated anchor boxes. An increase in the size of the anchor boxes generated, from 256 to 512, was observed to have improved the detection of larger-sized downed trees. Subsequently, experiments were performed to assign weights to each task (mask classification and detection). Increasing in the weights of one loss function, however, compromised the learning performance in other tasks. The size of the training data in subsequent iterations was expanded by adding the instances which had posed the greatest difficulty for the model. The continuous increase in the size of the training data was instrumental in improving the model's quality. Satisfactory second-phase results were obtained after 70 epochs (over a 5-hour training process). Noteworthy is the observation that the data should be expanded to include instances of tree boles partially extending beyond the image area or partly obscured by the boles of other trees.

5. Data augmentations

To further prevent the risk of model overfitting and multiply the available data, augmentation, i.e., a series of image transformations, was used. These techniques can be categorized into two groups - radiometric transformation-related and image object geometry-related. Application of the transformation is predetermined at a certain probability, which ensures random input of data without alteration of all the data. Augmentation allows the model to expand the context contained in the data. Radiometric transformation applies to aerial images only; reference masks are not subject to such changes. To apply data augmentation, the Albumentations library (https://albumentations.ai/) was used.

Table 1.
Image transformation types. The training data generator each time modifies the data transferred to the model. Individual transformations are applied with a probability of p

Augmentation type	Transformation type	Values	p
Radiometric	*brightness modification*	$b \in [0.8, 1.0]$	0.5
	linear contrast change	$\gamma \in [0.9, 1.1]$	0.5
	Gaussian filter blurring	$\sigma \in (0, 0.1]$	0.5
Geometric	*mirror reflection*	-	0.5
	affine grid transformation	$r \in \{0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}\}$	0.5
	zoom in&out	$(x, y) \in [0.8, 1.2]$	0.25
	sharpening	$\alpha_s \in (0, 0.1]$	0.25
	snowflakes	$f_z \in [0.2, 0.4]$	0.25
	coarse dropout	$s \in [0.02, 0.25]$	0.25

Source: author's own elaboration based on: https://albumentations.ai/

Training loops split the training data into batches. Batch size affects the progress of learning - a too small size can update the weights in an undesired direction, destabilizing the training process, whereas a too large size can prolong the training and prevent the model's sensitivity to rare events in data.

Analysis of the loss function curves (Figure 3), both collectively and by task, shows that the model did not lose its ability to correctly identify downed and broken trees, based on independent validation data, throughout the entire training process. The loss function values determined using the validation data are higher compared to those determined using the training data, yet the discrepancy between the two in subsequent epochs remains constant, which possibly signals an overfitting of the model.

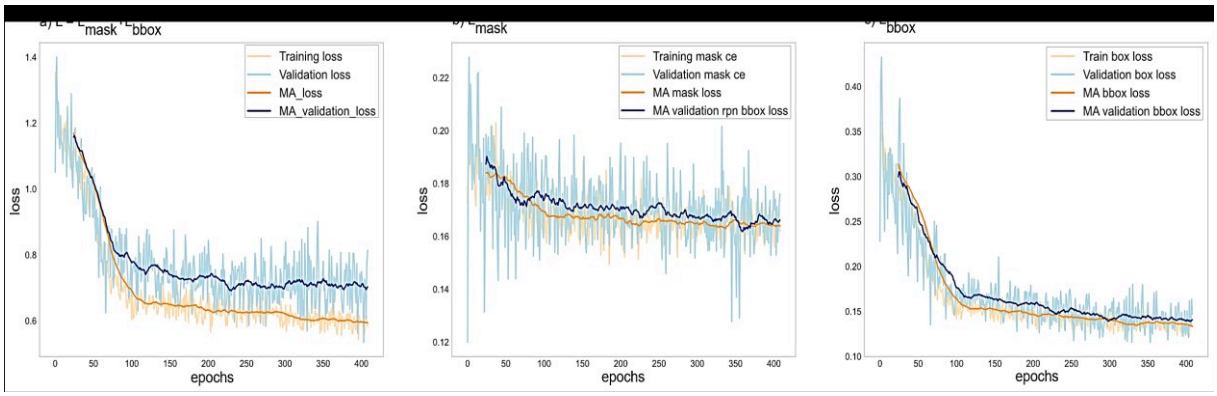


Figure 3. Different loss functions for each task. The cumulative value of the cost function consists of the sum of the loss function values determined for each discrete task. The figure shows the first stage phase of the training process.

Source: own eleboration.

Evaluation metrics

The model's effectiveness was verified using the classic indicators employed in the evaluation of classification and detection results. The model's performance was evaluated using such metrics as *Precision*, *Recall*, *F1-score*, *Average Precision (AP)* and *Intersection over Union (IoU)*. *Precision* determines the accuracy of detection:

$$Precision = \frac{TP}{TP+FP} = \frac{correctly\ predicted}{all\ predicted\ as\ positive\ instance} \tag{4}$$

$$Recall = \frac{TP}{TP+FN} = \frac{correctly\ predicted}{all\ positive\ instances} \tag{5}$$

where TP, TN, FP, and FN respectively represent true positive, true negative, false positive, and false negative indications. The overall effectiveness of the model was assessed using the *F1-score* metric, calculated as the harmonic mean of sensitivity and precision, with P_r and R_c denoting Precision and Recall, respectively (Pi et al., 2020).

$$F1 - score = \frac{1}{Pr^{-1}+Rc^{-1}} \tag{6}$$

The instances of correct object identification by the model were evaluated using *the Intersection over Union* metric. Only the cases involving *IoU* values greater than 0.1 were factored in. *Intersection over Union* (*IoU*) measures the ratio of the overlap area between the reference and predicted sets to the area of their union (Pi et al., 2020):

$$IoU = \frac{TP}{FN+FP+TP} = \frac{bbox_{predicted} \cap bbox_{reference}}{bbox_{predicted} \cup bbox_{reference}} \tag{7}$$

Average Precision (AP) is a metric widely used in detection tasks. It is calculated as the area under the precision-recall curve across all *IoU* threshold variants (ranging from 0 to 1). In the *AP* metric, r and p respectively denote recall and precision, with p_k and r_k accordingly representing the precision and recall in specific *IoU* subranges (Zhu, 2004):

$$AP = \int_0^1 p(r)dr \approx \sum_{k=1}^{n} p_k * (r_k - r_{k-1}) \tag{8}$$

Average Precision was calculated for several threshold variants k, within a defined range of $0.1 \leq k \leq 0.5$. The rationale behind such a range definition is discussed further in the article.

6. Results

Statistical evaluation

Subsequently, a prediction was performed on a pre-prepared test area, the results of which were compared against the labels of the reference data. After refining the model to a satisfactory form through training, a simulation was carried on a separate set compiled for testing purposes. A section of 10.24 ha, designated for testing, was delineated within the area of interest and divided into a grid of squares for analysis purposes. The size of a single grid cell (80 x 80 m) was dictated by the requirement to maintain the original spatial resolution – 4 cm. The analysis covered both the area directly affected by severe wind damage as well as the forest section that had withstood the force of the storm. The estimation of harvested timber volume based on annotated post-damage data provides an approximation of the actual extent of wind disturbance damage. One additional factor contributing to the uncertainty of the estimates arises from the fact that the reference data was prepared manually. Predictions were performed on the test area; for each image (i), the number of indicated uprooted trees ($\widehat{N}$) was calculated, and the volume of logs (j) from the uprooted trees ($\widehat{V}$) was estimated.

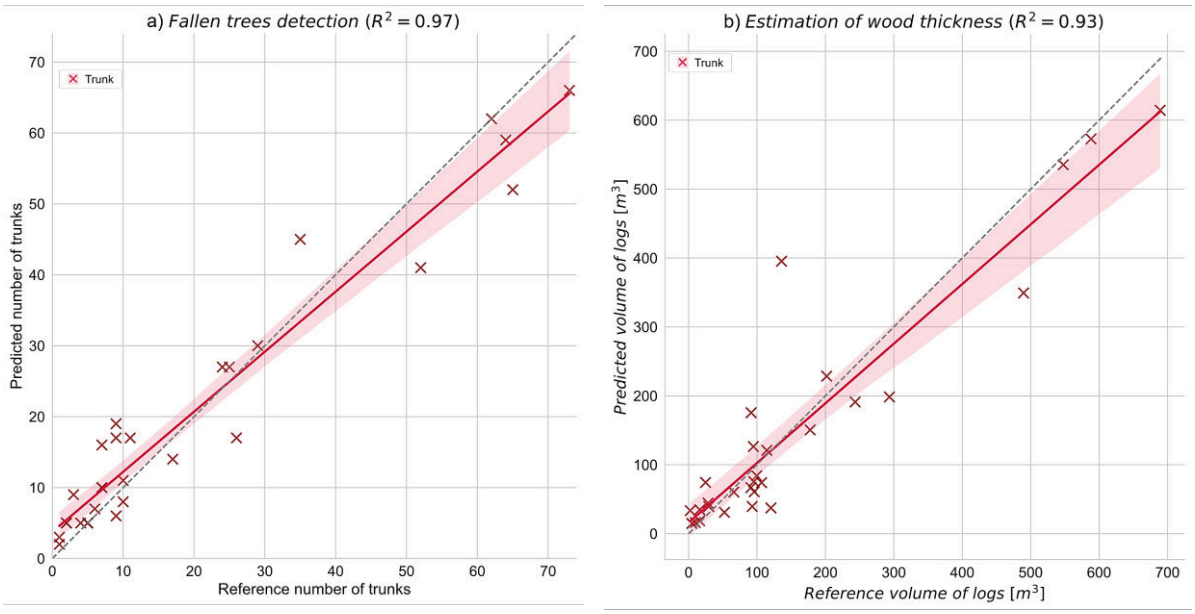
$$\widehat{N} = \sum_{i\neq 0}^{N} \sum_{j}^{M} 1_{i,IOU(j)>0.1} \tag{9}$$

To estimate the log volume, cross-sectional area A and tree length h were applied. To calculate the log length, a parallel thinning algorithm was used (Zhang, Suen, 1984).

$$\widehat{V}(m^3) = \frac{1}{d\times 10^6} \sum_{i=1}^{N} \sum_{j=0}^{M} A_{i,j} * h_{i,j} \Leftrightarrow$$
$$\frac{1}{d\times 10^6} \sum_{i=1}^{N} \sum_{j=0}^{M} [\pi * r^2]_{i,j} * h_{i,j} \tag{10}$$

On each image, the number of identifiable uprooted trees varies as M. The volume is adjusted by spatial resolution at d ≈ 4 cm. As shown in Eq. (10), the function can be rewritten as the volume of a cylinder, using the number π and the radius r.

When applied to areas of lower windthrow density, the model shows high precision. For areas of high windrow density (d > 50 trunks/100 m²), however, the model's error of underestimation gradually increases with the rising number of windrows. A strong correlation (Pearson's correlation: 0.96) between the reference and estimated counts of identified tree boles was observed. An equally strong relationship (Fig. 4) was noted between the reference and the estimated volume of logs (Pearson's correlation: 0.97). Average Precision AP, Recall, and F1 scores were calculated for all test images. The tabular summary (Table 2) shows the mean values with standard deviation, calculated for the test dataset. Logs that minimally overlap with the reference (IoU < 0.1) are not considered as identified. The results were calculated for a confidence score above 0.6.



a) b)

Figure 4. a) Estimated log volume and b) Predicted number of logs. Each point on the scatter plot represents the number/volume of tree boles, calculated for each aerial image of the test area.

Source: own eleboration.

Table 2.
Mask R-CNN detection results. The model's effectiveness was calculated for variants with IoU (Intersection over Union) values of IoU = [0.1, 0.2, 0.3, 0.5], for the range of 0.1:0.5. Additionally, Precision, Recall, and F1-score values were computed at IoU ≥ 0.1.

AP_{10}	AP_{20}	AP_{30}	AP_{50}	AP_{10-50}	$Precision_{10}$	$Recall_{10}$	$F1-score_{10}$	N
0.522	0.427	0.312	0.118	0.418	0.795 ± 0.06	0.733 ± 0.08	$0.766 + 0.02$	32

Source: own eleboration.

The average value of the Precision metric is higher than the Recall (Table 2), indicating that, despite the model's strong performance in identifying wind-downed tree boles, it also tends to miss certain cases, rarely yielding false-positive errors. In developing the model, the key concern was to avoid missing any downed trees and prevent misidentification of leaning boles as standing trees. The Recall metric deviated by more than 2% from the average. The detection model's overall performance is expressed by the F1-score (reaching 0.766), as the harmonic mean of Precision and Recall. The model was evaluated using 32 test images. The average IoU value for the entire test dataset was 0.41±0.26. The standard deviation at 0.26 indicates a high degree of variability in the detection of downed tree logs. The maximum average value of IoU for a single image was 0.78. Out of the total instances, 75% fall below 0.61, and 50% below 0.41. The low AP for higher IoU thresholds indicates the model's low detection capabilities at low overlap criteria. High values of IoU overlap proved difficult to achieve, given the log small area, the numerous overlapping objects, and the narrow and irregular surface shape of uprooted or windsnapped trees. In small object detection, even slight differences between

the prediction and the reference can result in low Intersection over Union values. Given the above conditions, the results were analyzed in ranges lower than the typically analyzed range of 0.5-1.0. As the IoU_(10-50) threshold increases, the AP value decreases (-0.404). The model achieves its highest accuracy at low IoU overlap criteria. For overlap values between 0.1 and 0.5, the AP was 0.418. The highest AP (0.522) value within the IoU range analyzed reached an IoU threshold of 0.1.

Visual assessment

The nature of the tasks performed by the Mask R-CNN model also necessitates an evaluation of the decisions it makes, through a visually analysis of the nature of the errors it produces. This allows additional conclusions to be drawn regarding the errors.

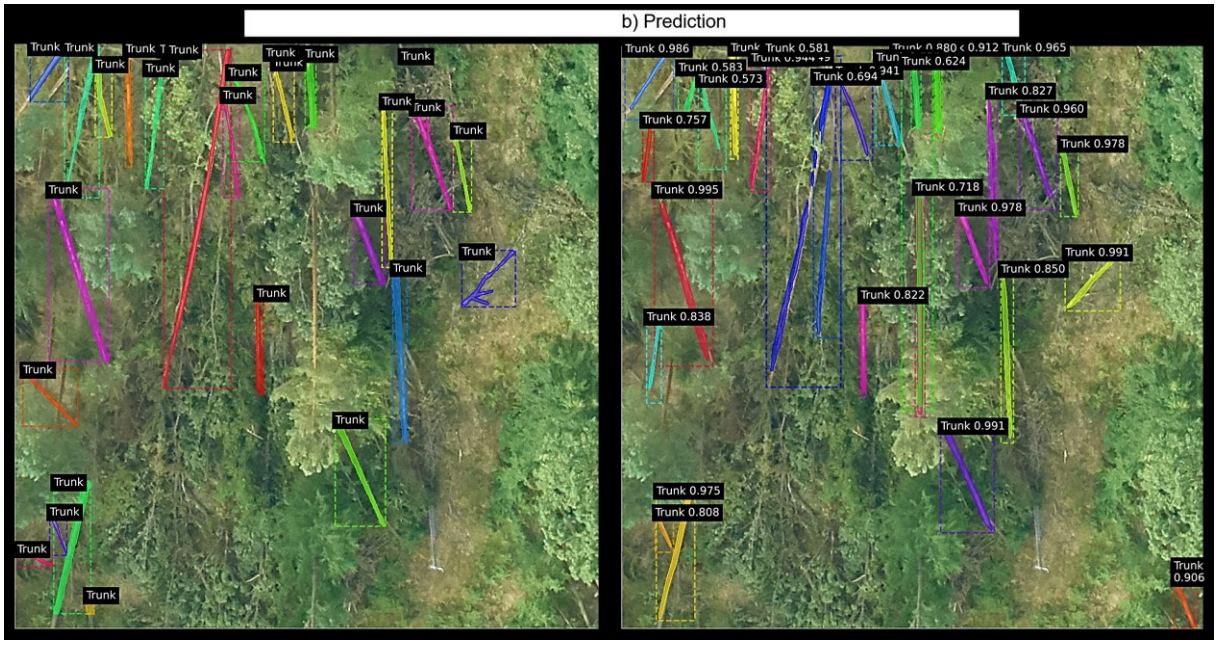


Figure 5. Prediction results. Apart from the mask and bounding box annotations, the illustration shows confidence scores for each indicated instance.

Source: own eleboration.

The model shows high sensitivity in identifying such objects as uprooted trees. Indication errors arise in the case of the tree boles partially obscured by neighboring tree branches. The continuity of tree log masking can be interrupted by obscurations from other objects (Figure 5).

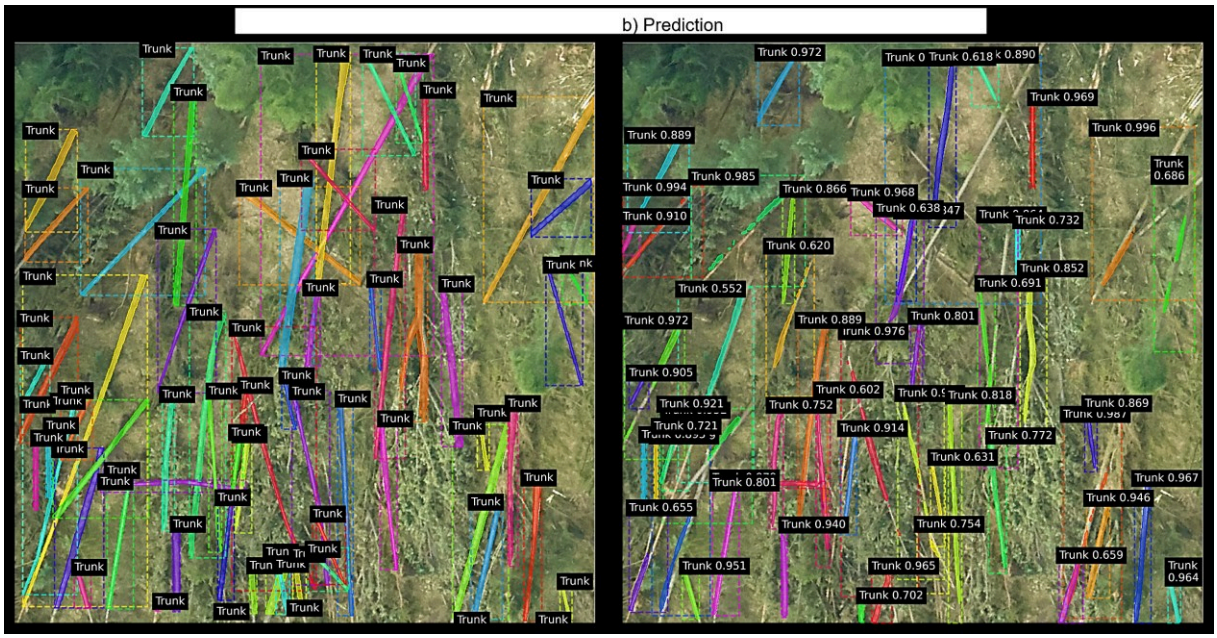


Figure. 6. Prediction results. The model is observed to encounter difficulties in accurate masking of very long tree boles extending beyond the image area.

Source: own eleboration.

The model remains capable to identifying individual boles, even under conditions of high density of downed trees. Strongly leaning, but not dead, trees are at high risk of misidentification as uprooted. The effectiveness of determining the extent and location of a dead tree is higher than that of an exact mask defining the extent of the bole (Figure 6).

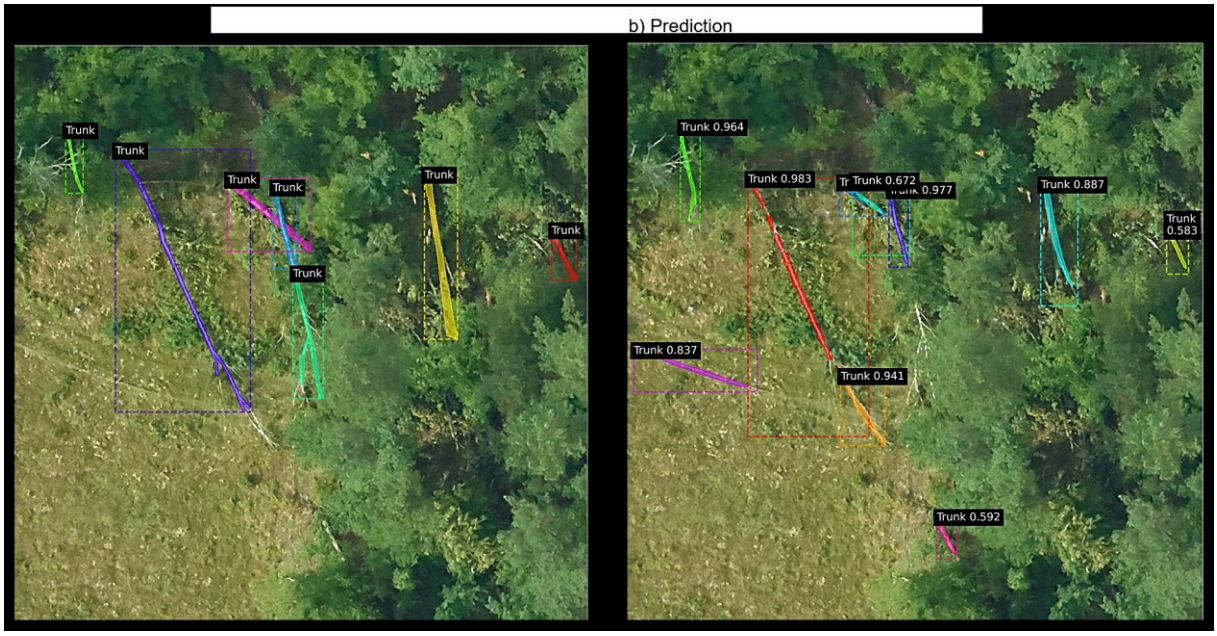


Figure 7. Prediction results. Whenever overlong logs are detected, the model splits the object into smaller parts, without omitting any segments of the identified log.

Source: own eleboration.

Despite the adjustment of the anchor scale parameter, to identify larger objects, the model was observed to continue to split longer logs into several parts (Figure 7). Perhaps the dataset representation needs to be extened to include examples of larger bole dimensions, especially in areas of higher uprooted tree density.

Estimation of potential revenue from timber sales

The log volumes calculated from the reference data and the predictions were summed and compared for the test area, the, taking several conditions into account (Table 3). Possible occurrence of two assortments and several common species was factored in. Based on the timber retail price list published by the Stare Jabłonki Forest District, potential timber sales revenue was estimated at the prices of the most economically viable species, such as pine, larch, spruce, beech, oak, and birch. The highest potential yield was calculated for a stand predominatly consisting of beech (533 PLN/m^3 net) or birch (482 PLN/m^3 net). The lowest prices were determined for larch (292 PLN/m^3 net) and spruce (305 PLN/m^3 net) (Przesław, 2023). The difference between the cumulative estimated and reference timber volumes totals 354 m^3 (Table 3).

Table 3.
Revenue estimation using timber volume predictions and unit prices for assortments S2A and S4.

Specie	Assortyment	Volume [m^3]	Net unit price [PLN]	Net price [PLN]	Value Added Tax [8%]	Gross price [PLN]
Pine	S2A	4961	316	1 567 676	125 414,08	1 693 090,08
		4607	316	1 455 812	116 464,96	1 572 276,96
Larch	S2A	4961	292	1 448 612	115 888,96	1 564 500,96
		4607	292	1 345 244	107 619,52	1 452 863,52
Spruce	S2A	4961	305	1 513 105	121 048,40	1 634 153,40
		4607	305	1 405 135	112 410,80	1 517 545,80
Beech	S2A	4961	533	2 644 213	211 537,04	2 855 750,04
		4607	533	2 455 531	196 442,48	2 651 973,48
Oak	S2A	4961	352	1 746 272	139 701,76	1 885 973,76
		4607	352	1 621 664	129 733,12	1 751 397,12
Birch	S2A	4961	482	2 391 202	191 296,16	2 582 498,16
		4607	482	2 220 574	177 645,92	2 398 219,92
Pine	S4	4961	125	620 125	49 610,00	669 735,00
		4607	125	575 875	46 070,00	621 945,00
Larch	S4	4961	115	570 515	45 641,20	616 156,20
		4607	115	529 805	42 384,40	572 189,40
Spruce	S4	4961	105	520 905	41 672,40	562 577,40
		4607	105	483 735	38 698,80	522 433,80
Beech	S4	4961	153	759 033	60 722,64	819 755,64
		4607	153	704 871	56 389,68	761 260,68
Oak	S4	4961	140	694 540	55 563,20	750 103,20
		4607	140	644 980	51 598,40	696 578,40
Birch	S4	4961	147	729 267	58 341,36	787 608,36
		4607	147	677 229	54 178,32	731 407,32

Source: own eleboration.

The usability of timber is determined through assortative classification. Grade S2A timber, used in the pulp and paper industry, can contain hard rot and insect galleries, but foreign bodies and charring are not acceptable. Grade S4 timber is intended for firewood use, thus foreign matter, charring and curvature are in this case acceptable. Firewood is subject to less stringent criteria requirements than industrial wood (Lewandowska-Gross & Stępień, 2013). The average difference between the estimated and the reference S2A assortment density is 145.281 PLN gross, and 50.02 PLN gross for the S4 assortment. The estimated revenue error totals 7.13%. Noteworthy are the large differences in the S2A and S4 assortment retail prices. The assortment-specific difference between the reference and the estimated gross revenue from pine is 950 331.96 PLN. Such significant differences lead to the conclusion that the key factor is the speed of logging operations in a given area, before the downed timber loses its industrial usability.

7. Discussion

Related works

The challenging issue of assessing forest damage caused by high-speed winds has been studied by various researchers. Artificial intelligence methods find application in post-disturbance crisis management (Xu et al., 2021). The methodologies employed entails certain limitations, however, which this study seeks to address and potentially remedy. The study involved the use of the Mask R-CNN convolutional neural network model to estimate the amount downed timber. Estimation of the extent of windstorm damage has already been attempted. Vasileios Linardos et al. expound in their work that the extent of post- disturbance damage is of crucial relevance to rapid rescue operations (Linardos et al., 2022). Using Landsat satellite imagery, windstorm-affected areas can be identified with up to 86% accuracy (Haidu et al., 2019). The level of detail in the satellite imagery analysis results is limited by the low spatial resolution of the images. Landsat data can be used to identify damage exceeding 0.5 hectares (Haidu et al., 2019). Smaller clusters of downed trees should not be ignored, as they potentially harbor unwanted species of insects and fungi (Einzmann et al., 2017). Similar results were obtained using the images recorded by the Sentinel-2 and Planet Scope satellite constellations (Dalponte et al., 2020). Images recorded by cameras attached to Unmanned Aerial Vehicles (UAV) are also used in post-disturbance area identification (Mokroš et al., 2017). The use of aerial imagery offers a clear advantage over satellite imagery, as it provides much more detailed information. The results obtained using Landsat satellite images were observed to be underestimated, compared to those obtained using aerial UAV images and ALS ground laser scanning. The estimate based on both types of data overestimated the actual

amount of timber by 4.93% (Mokroš et al., 2017). The design of our model began with exclusive use of aerial images, which can be integrated with other types of data in the future. Multi-temporal elevation data, such as Digital Surface Models (DSM), enable identification of damaged areas by calculating the differences in tree stand height. The extent of damage is determined based on these differences (Ivanova, Shashkov, 2022). Remote sensing methods, applied to monitor forest changes, employ three main approaches. The first is based on individual tree detection (ITD). The second - Object Based Image Analysis (OBIA) - involves analysis of grouped raster cells (objects). The third approach derives predictors from pixel-based analysis (PBA) of image values (Einzmann et al., 2017). As emphasized by Yanlei Feng et al., however, the drawback in monitoring methods based on optical images alone lies in the need to use images of the Earth's surface unobscured by cloud cover (Feng et al., 2023). Considering the above factors, the method offers the advantage of its applicability regardless of cloud cover. The solution described utilizes the post-disturbance data collected. Some solutions, however, utilize multi-temporal data, involving a comparison of data collected prior and after the onset of a windstorm. Using the ITD method and the terrestrial laser scanning data collected both prior to and after the windstorm event, the volume of timber can be estimated with an MPE error of: -10.6% (Onoszko et al., 2019). Based on the difference in vegetation intensity, damaged forest areas can be identified using the Normalized Difference Vegetation Index (NDVI). The use of high-resolution data allowed precise volume estimations in the selected area (Onoszko et al., 2019). The approach employed in a study by Kathrin Einzmann et al. necessitates the collection of data over two relevant periods - prior to and after the windstorm. The advantage satellite images offer lies in the use of additional infrared spectral channels and the generation of useful vegetation indices. Vegetation indices have been proven to enable the identification of windthrow areas (Einzmann et al., 2017). Satellite image resources allow such information to be collected over a broad window of time. One limitation lies in the frequency of image recordings of the same location. In crisis management, quick collection to data is of crucial significance. Dmitry E. Kislov et al. also proved that the extent of windstorm damage can be determined by convolutional neural network models utilizing high-resolution satellite images (Kislov, Korznikov, 2020). They classified windstorm-affected areas using the PBA approach, based on satellite images of 0.3-0.5 meter resolution. The overall accuracy of the naive Bayes classifier amounted to an F1 score of 0.79. Using two variations of the U-Net convolutional neural network, however, they obtained an F1 score ranging between 0.90 and 0.92 (Kislov et al., 2021). The authors emphasize that a model tailored to data of a specific resolution can yield underestimations when data of lower spatial resolution is used (Kislov et al., 2021). Fuzhou Duan has developed a pixel classification model for UAV aerial images. Using the Random Forests model, downed logs were identified with the accuracy of 94.48%. Highlighted pixels, corresponding to the windthrow logs, were analysed using the Hough Transform (Duan et al., 2017). The author stresses that the method is suitable for identifying slender-boled trees (Duan et al., 2017). Stefan Reder et al. employed a semantic

segmentation approach to identify downed logs. Using the U-Net convolutional neural network model, they obtained an F1-score of 75.6% (Reder et al., 2021). Although the benefits of using pre-trained models have been recognized, the approach can lead to longer inference times. The original images were split using the sliding window technique, with consecutive sections of the aerial image fed into the model, each section sized 256 x 256 pixels. Due to the longer inference time, however, the initial spatial resolution of 6.3 cm was reduced to 7 cm. The authors used image tiles sized 20 m x 20 m, corresponding to the 256 x 256 pixel grid at a GSD of 6.3 cm, and thus eliminated the need for the sliding window approach (Reder et al., 2021). In our study, we adhered to the conventional method of segmenting larger aerial images into smaller sections. The author emphasizes, nevertheless, that by preserving a high spatial resolution, the precision of calculations is maintained, at a simultaneous multiplication of the time needed for inference (Reder et al., 2021). The U-Net model was used in a study on the segmentation of individual tree boles. The model outputs a confidence map for raster pixel classification. Its output is transformed using the SAC function, which extracts individual logs from the mask. The study yielded high quality results. The Intersection over Union similarity between the prediction and the reference masks reached a range of 0.55-0.59, while the detection accuracy, in terms of completeness, ranged from 0.78 to 0.82 (Polewski et al., 2021). In a study by Nishant Jasiwal et al., volume estimates were derived from data collected during summer months. Worth mentioning is that wind disturbances are not exclusive to summer and can likewise occur in winter. Jasiwal's team formulated a model categorizing regions into five different types, one of which identifies windthrows. The model also detects regions of previous logging operations, although this particular study did not cover such cases. The aerial images used not only contained the RGB channels, but the near-infrared (NIR) channel as well. Jasiwal has emphasized that the DeepLabV3 model produced better results, as evidenced by the Intersection over Union score of 0.91. The study's applicability, however, lies primarily in the identification of potential damage zones (Jaiswal et al., 2022). Gherardo Chirici et al. employed the classic method of felled log area identification via Line Intersect Sampling in their study. The number of downed trees was estimated by multiplying the area affected by damage and the number of trees per hectare in that area. The volume was estimated based on pre-disaster tree bole height and diameter. The method also factors in species diversity, using existing Forest Inventory databases. The author has proposed a method for estimating the extent of losses, utilizing post-event ALS (Airborne Laser Scanning) data only (Chirici et al., 2018).

8. Conclusion

The present article describes a method characterized by low complexity. Its simplicity is evident in, for example, the type of data utilized. This low complexity also results in reduced aerial image processing time. The advantage of the proposed solution lies in the flexibility of data acquisition. The approach is based on the deployment of unmanned aerial vehicles (UAVs). The utilization of UAVs enables cost-effective aerial campaigns below cloud cover. As technology advances, the availability of these devices to forest managers continues to increase (Ecke et al., 2022). UAVs facilitate the acquisition of high-resolution data, which is particularly important when capturing imagery of terrain with variable topography or cloud cover, where alternative remote sensing methods encounter limitations (Zhang, Zhu, 2023). From a management perspective, the UAV-based approach demonstrates exceptional cost-effectiveness, achieving approximately 70% reduction in aerial survey expenses compared to conventional manned aircraft operations, while simultaneously providing on-demand deployment capabilities that align with dynamic business requirements. We anticipate that interest in artificial intelligence applications utilizing aerial photography will continue to expand. Previous investigations addressing wind damage extent assessment have also employed airborne laser scanning (ALS) data. However, the processing of LiDAR data necessitates substantially greater pre-processing effort. The proposed method enables damage localization at the individual tree level. A comprehensive dataset can be obtained through a single aerial survey. This single-survey requirement translates into significant operational efficiency gains, enabling forest managers to minimize operational downtime and expedite decision-making processes, thereby mitigating potential revenue losses associated with delayed timber salvage operations. Accuracy is maintained through, inter alia, the acquisition of imagery with a consistent spatial resolution of 4 cm. The standardized 4 cm resolution ensures consistent, auditable data quality that satisfies regulatory compliance requirements and facilitates transparent stakeholder communication, both of which are essential for maintaining business credibility and securing favorable insurance terms. Considering these aspects, the proposed method demonstrates clear advantages over previously described methodologies. The scalability of this method enables organizations to expand monitoring operations across multiple forest districts without proportional increases in technical personnel, thereby creating strategic advantages through centralized data processing and integrated management dashboards. For several reasons, further refinement of this solution is warranted to ensure its broadest possible application. The study reveals considerable potential for development; the approach can be enhanced through modifications to both the utilized data and the employed estimation methodologies. Implementation of this technology positions organizations as industry innovators, attracting premium clients and strategic partners while creating opportunities for novel service offerings and revenue streams within the rapidly expanding

forest management technology sector. Future improvements to detection capabilities are planned, including expansion of the training dataset size and incorporation of cases from additional forest districts. Dataset enrichment may include the integration of imagery captured during seasons other than summer. Currently, the model's effectiveness achieved during training can only be sustained when applied to data exhibiting characteristics similar to those of the training dataset. Enhancement of input data quality is planned through implementation of a two-stage verification protocol for the prepared reference data. This modification is expected to substantially improve the reliability of the obtained results. The method requires further validation based on field measurement temporal data. To minimize error, dataset enrichment through integration with satellite radar data represents a viable approach. More sophisticated volume calculation methods, based on the Smalian, Huber, or Newton formulae, warrant exploration in subsequent research phases (Mushar et al., 2020).

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

9. Author contributions

All authors have contributed to the study conception and design. Material preparation, data collection and analysis were performed by Dominik Mielczarek, Krzysztof Najman. The first draft of the manuscript was written by Dominik Mielczarek and all authors commented on previous versions of the manuscript. All authors have read and approved the final manuscript.

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COMPARATIVE ANALYSIS OF SUSTAINABLE DEVELOPMENT OF HIGHER EDUCATION INSTITUTIONS IN PERCEPTION OF STUDENTS OF SELECTED POLISH AND INTERNATIONAL UNIVERSITIES

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Purpose: The aim of this study was to assess the awareness of sustainability among higher education students of seven public, non-public and foreign universities, as well as their perceptions of sustainable development in higher education institutions and their expectations in this regard.

Design/methodology/approach: The study was quantitative and survey-based, utilizing a questionnaire method, and consisted of two stages. In the first stage, a literature review was conducted to provide a foundation for selecting the issues to be included in the questionnaire. Proper definition of the research topics was essential to ensure the reliability of the study.

The next stage involved administering a survey to the aforementioned research group using a computer-assisted web interview (CAWI) format. This method was chosen primarily due to facilitating anonymity, which may contribute to the reliability of responses and improve response rates. The advantages of this method also include its reach, the time required to conduct the study, and cost minimization.

Findings: The study clearly revealed a high level of awareness among students on this topic, with a level of 87.50% demonstrating awareness. Apart from the students of one university, the level of unawareness was insignificant.

The surveyed students identified features they believe should characterize a sustainable university. Of the 26 proposed features, students from both Polish universities highlighted all of them with varied number of votes. The least score obtained a feature "Offers a study program in Sustainable Development". These findings suggest a noticeable lack of program solely dedicated to sustainable development neither as major or minor in none of the surveyed universities.

Moreover, the surveyed students, perceive their higher education institution completely different in terms of sustainable development. Students of TUoW, firstly see the university as any other institution (apart from educational mission) that cares about ecology and their internal and external stakeholders. While the students of ATA primarily perceive their university as sustainable developed institution through the prism of the program of studies (curricular and non-curricular courses and classes provided by the university) as well as the once for social responsibility for internal stakeholders; Students of Lusofone on the other hand provided a social approach to sustainable university.

The most surprising finding was very low level of participation in extracurricular activities and initiatives among all universities' students, except of Sapienza. These activities, which include social, charitable, organizational, and scientific endeavors, are essential for developing sustainable development skills find little interest among surveyed students.
The study suggests that, the surveyed universities still incorporate considerably fewer sustainable development topics in their curricula and organize limited extracurricular activities to support these competencies. Nevertheless, overall students' awareness of the concept of sustainable development is considerably high and highly satisfactory.
Research limitations/implications: Due to the sample selection and non-representative sample size, the study's results cannot be generalized to all students at higher education institutions neither in Poland, nor abroad. Nevertheless, the study provides new insights and can serve as an initial attempt at empirically verifying the awareness of students from all higher education institutions regarding sustainable development, their perceptions of the phenomenon of a sustainable higher education institution, and their expectations in this area. This is especially relevant given that the research questionnaire, due to its comprehensiveness, universality, and reliability, offers the potential for replication.
Practical implications: This article presents original research on the sustainable development of Polish and foreign higher education institutions in perception of their students' expectations, which has several implications for both researchers and university authorities and may serve as a starting point for developing analytical frameworks to assess the level of sustainable development implementation and measurement models for sustainable development in both Polish and foreign universities.
Social implications: Universities can contribute to the solutions of major challenges of the 21st century such as increasing environmental and socio-economic crises, inequalities of income and wealth and political instabilities by integrating the concept of sustainable development (SD) in research, organization, and by educating future decision makers. For instance, by integrating sustainability into the organization, universities can lead by example. Furthermore, through the curriculum, future decision makers can learn the competences needed to solve ecological, social, and economic problems in societies.
Originality/value: This paper has implications for both researchers and university authorities and may serve as a starting point for developing analytical frameworks to assess the level of sustainable development implementation and measurement models for sustainable development in both Polish and foreign universities.
Keywords: sustainable development, higher education.
Category of the paper: Research paper.

1. Introduction

The concept of sustainable development was first described in the 18th century (Meadows, 1972) and has evolved over the centuries to gain a central place in development discourse in the latter half of the 20th century (Du Pisani, 2007). Increased discussion about sustainable development has emerged in recent years due to growing ecological and social awareness, following years of focus primarily on economic growth. The approaching ecological crisis, along with global wealth inequality, has led to a renewed focus on sustainable development in global terms and across three dimensions (ecological, social, and economic). This has resulted

in the adoption of the Paris Agreement in 2015, which includes measures to limit global warming, adapt to and mitigate the effects of climate change, implement low-emission development in a way that does not restrict food production, and ensure that financial sector activities align with climate goals (Adoption of the Paris Agreement, December 2015). However, this concept will be difficult to implement without the involvement of traditional sources of social legitimacy in science and education, which are related to knowledge creation (Sulejewicz, 2008).

This article presents original research on the sustainable development of higher education institutions in perception of their students' expectations, which has several implications for both researchers and university authorities and may serve as a starting point for developing analytical frameworks to assess the level of sustainable development implementation and measurement models for sustainable development in both Polish and foreign universities.

2. Theoretical approach

Although there have been proven and successful developments in Higher Education for Sustainable Development (HESD) over the past 15 years, numerous challenges remain. One of the most significant challenges is the need for Higher Education Institutions (HEIs) to better integrate sustainability into curricula and research, and, most importantly, to embed it holistically within their institutional systems (Leal Filho et al., 2017).

Universities have the potential to contribute substantially to addressing major challenges of the 21st century, including escalating environmental and socio-economic crises, growing income and wealth inequalities, and political instability. They can do so by integrating the concept of sustainable development (SD) into research, institutional governance, and education. By incorporating sustainability into their organizational structures and operations, universities can lead by example. Furthermore, through sustainability-oriented curricula, future decision-makers can acquire the competencies needed to address ecological, social, and economic challenges. Despite this potential, however, many universities lag behind internationally in the implementation of comprehensive sustainability strategies (von Hauff, Nguyen, 2014).

Universities are key actors in supporting sustainable development through the development of SD strategies, the advancement of research, the education of future generations, and the implementation of sustainability within their own organizations. At the international level, the United Nations proclaimed 2005-2014 as the “Decade of Education for Sustainable Development”, emphasizing the integration of Education for Sustainable Development (ESD) across all levels of education. At the national level in Germany, the Hochschulrektorenkonferenz (HRK) and the German Commission for UNESCO issued a joint statement in 2010 entitled *Universities for Sustainable Development,* calling on

universities to act in accordance with SD principles and to establish ESD as a core element across all areas of institutional activity (HRK & DUK, 2010).

With their three core functions—research, teaching, and service—universities are called upon to accept responsibility and actively contribute to sustainable development (Moore, 2005). The importance of SD in higher education is reinforced by international networks such as the International Sustainable Campus Network (ISCN). In addition, major research institutions, such as the Fraunhofer-Gesellschaft, have anchored sustainability in their mission statements and launched initiatives such as the internal "Sustainability Strategy" project in 2011 to support the development of a sustainable society, economy, and environment (Fraunhofer-Gesellschaft, 2011). As central actors in knowledge generation and dissemination, universities contribute to sustainable solutions through both basic and applied research, while equipping future leaders in government, business, and civil society with the skills and knowledge required to address complex sustainability challenges (Barth et al., 2007).

Due to their mission and scope of activities, universities have a particular responsibility to contribute to societal transformation and to the advancement of a more sustainable humanity (Barth, Rieckmann, 2012). HEIs can integrate sustainability across multiple domains, including education and curricula, research, campus operations, community engagement, organizational change and governance structures, as well as assessment and reporting (UNESCO, 2012; Lozano et al., 2015). This integration can occur through isolated initiatives within specific domains or, more effectively, through a whole-institution approach that embeds sustainability across all institutional functions (UNESCO, 2012).

Indeed, universities worldwide are making diverse efforts to incorporate sustainable development into their institutional frameworks. These efforts include innovative teaching and pedagogical approaches, curriculum reform, collaboration with other HEIs, the promotion of sustainable campus life experiences, and "educating-the-educators" programs (Lozano et al., 2013; Ramos et al., 2015). Particularly in Europe, some universities have emerged as leaders by implementing best practices in sustainability. Nevertheless, many initiatives remain limited to one or two sustainability domains, resulting in fragmented and compartmentalized approaches rather than holistic, systems-oriented strategies that integrate knowledge and perspectives across disciplines (Ramos et al., 2015). An exploratory literature review by Lozano et al. (2015) found that sustainability efforts in HEIs predominantly focus on education—such as curricula, pedagogies, competencies, and educator training—followed by campus operations, institutional frameworks, outreach, and assessment and reporting. Research was identified as the least developed domain. Curriculum-related initiatives range from the inclusion of environmental topics in existing courses to the development of dedicated modules or new undergraduate and postgraduate programs.

3. Materials and Methods

3.1. Research Objective

The literature presents numerous studies on sustainable development concept with a special concern of higher education institutions and their role in building awareness in the field of sustainable development.

The aim of this study was to perform comparative analysis of sustainable development of higher education institutions in perception of students of selected polish and international universities.

The main research questions were:

1. Are students aware of what sustainable development is?
2. What characteristics should define a sustainable higher education institution, and which of these characteristics are present at the institution where the students are studying?
3. Does the university provide students with opportunities to engage in extracurricular activities outside the curriculum, including social, charitable, organizational, and scientific initiatives that build competencies in the field of sustainable development? Do students participate in these activities, and why did they decide to take part in them?
4. Which form of activity offered by the university best develops competencies in sustainable development, and how do students plan to further develop their competencies in this area?

3.2. Sample and Data Collection

The study was conducted in years 2020-2025 using a non-random sample. The 480 respondents to the research questionnaire were students of:

Public universities in Warsaw:

- Maria Grzegorzewska University (Grzegorzewska) (89).
- Warsaw University of Technology (WUoT) (61).

Non-public universities in Warsaw:

- Management Academy of Applied Sciences in Warsaw (MANS) (25).
- WSB Merito University Warsaw (WSB) (55).
- University of Technology and Art in Applied Sciences in Warsaw (UTA) (139).

Foreign universities:

- Sapienza University of Rome (Sapienza) (48).
- Lusophone University of Porto (Lusophone) (63).

Among the respondents, the majority were women—274, representing 57.08% of the sample. The study included 206 men (42.92%).

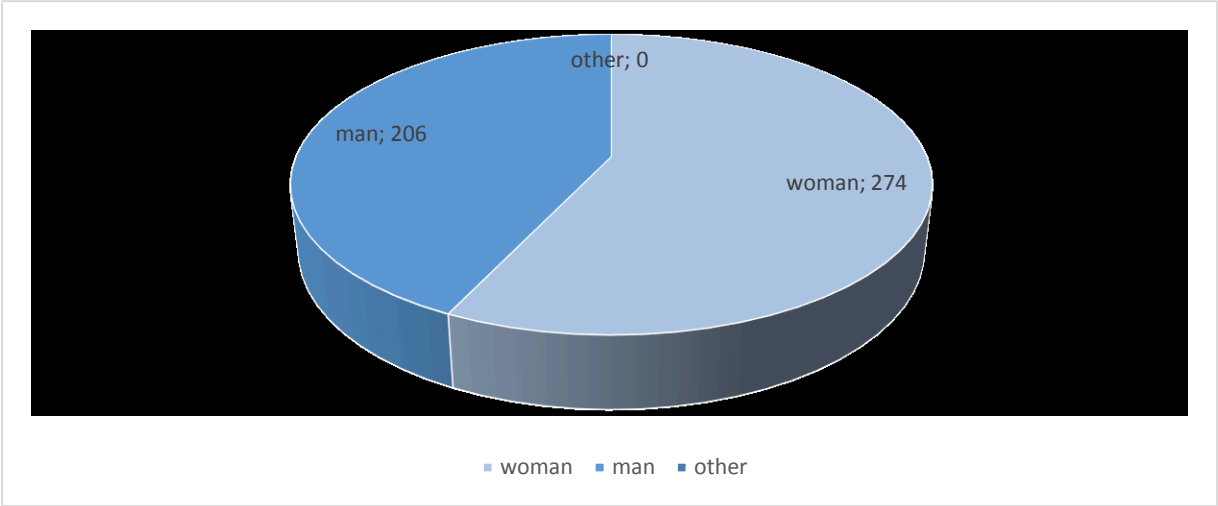


Figure 1. Gender representation in the surveyed sample.

Source: own research.

Regarding the level of studies, the largest group consisted of 1st cycle students—320 (66.67%), while the second-largest group were students of 2nd cycle studies—160 (33.33%). None of the respondents was enrolled in postgraduate studies. Moreover, the students of MANS were entirely students of 1st cycle program.

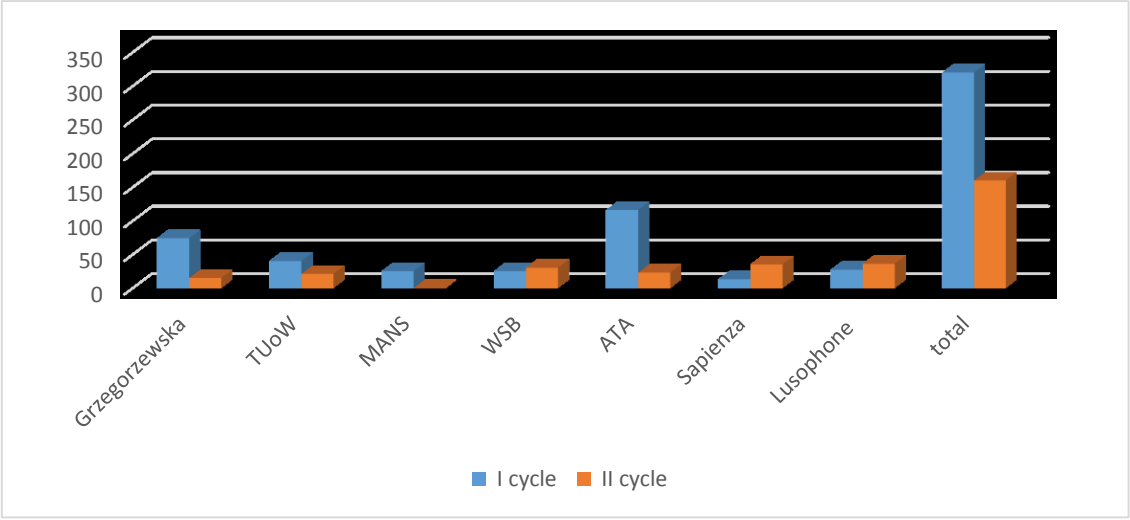


Figure 2. Level of studies by respondents.

Source: own research.

The predominant group by year of study was first- (55 students) and second-year (46) students, numbering 101 (68.24%). The third- and fourth-year students, totaling 47, were represented by 24 and 23 students respectively. None of the respondent wad fifth-year student. Moreover, none of TUW students were at their third- and fourth-year of studies.

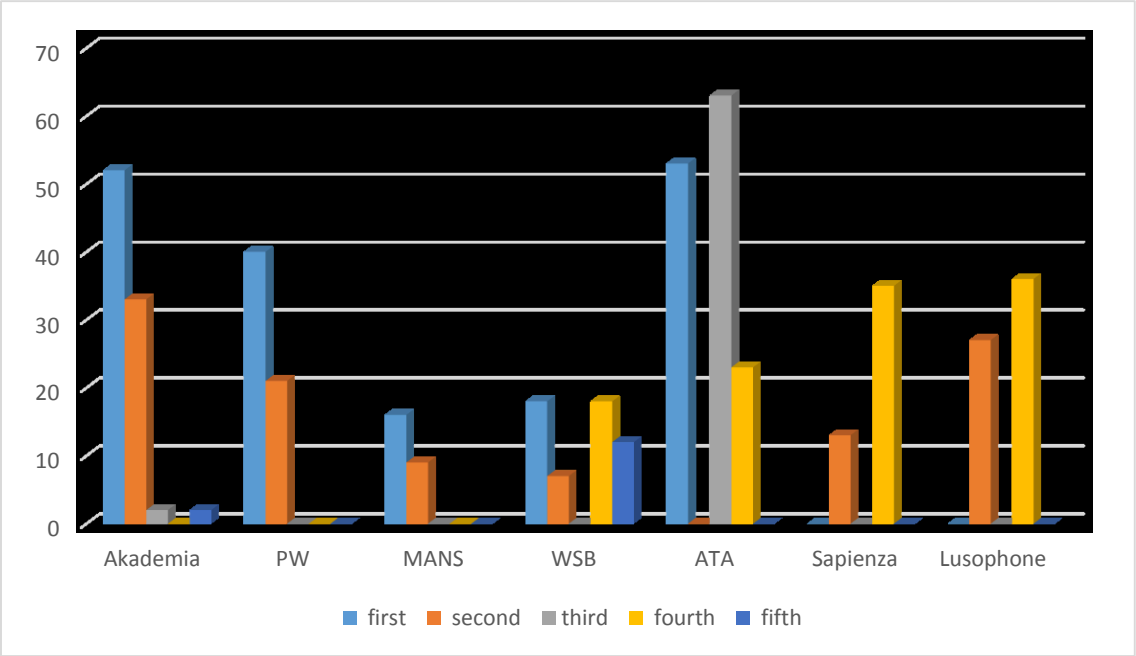


Figure 3. Year of studies by respondents.

Source: own research

Respondents were categorized into four work experience groups:

- 0-3 years,
- 4-6 years,
- 7-9 years,
- Over 9 years.

The vast majority of respondents fell into the 0-3 years work experience category—243 students (50.62%). The smallest group, consisting of 22 students were with over 9 years of experience represented 4.58% of the sample. The second-largest group, representing students not employed yet equaled 13.75% of respondents; Students with 4-6 years of experience—62 individuals represented 12.92% of the sample. Twenty-two respondents (4.58%) reported over 9 years of work experience.

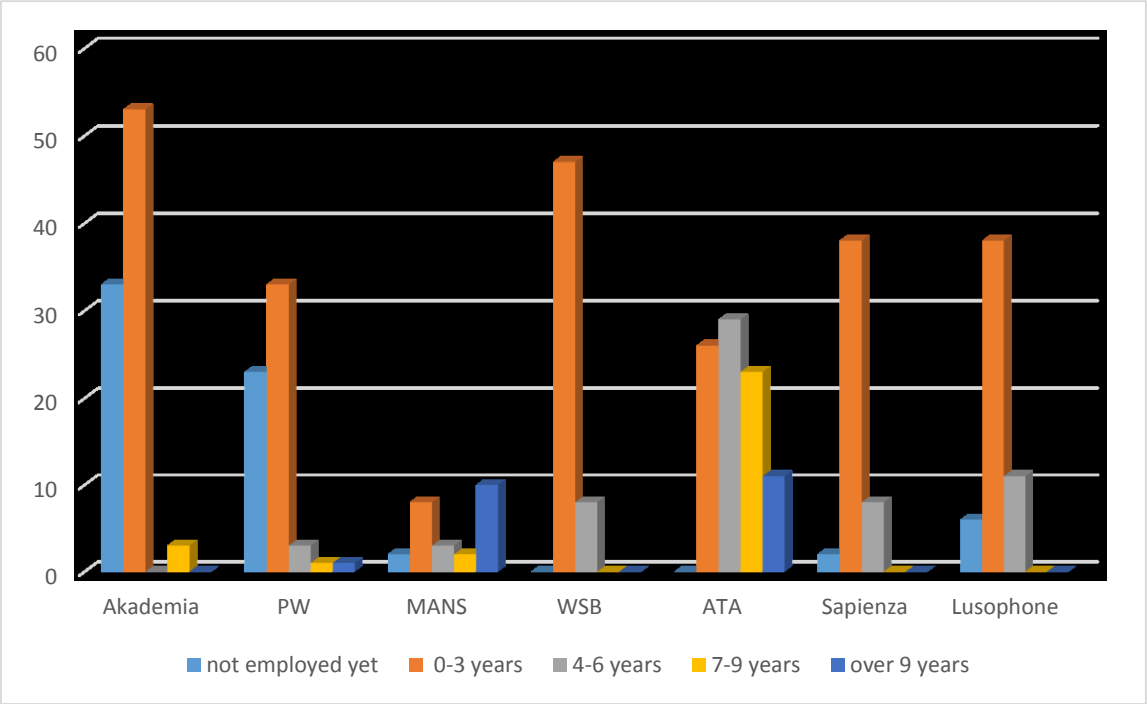


Figure 4. Length of a professional career by respondents.

Source: own research.

3.3. Research Methods

The study was quantitative and survey-based, utilizing a questionnaire method, and consisted of two stages. In the first stage, a literature review was conducted to provide a foundation for selecting the issues to be included in the questionnaire. Proper definition of the research topics was essential to ensure the reliability of the study.

The next stage involved administering a survey to the aforementioned research group using a computer-assisted web interview (CAWI) format. This method was chosen primarily due to facilitating anonymity, which may contribute to the reliability of responses and improve response rates. The advantages of this method also include its reach, the time required to conduct the study, and cost minimization.

The study employed methodological triangulation, primarily data triangulation—i.e., comparing research conducted across different populations and locations—such as two public universities in Warsaw: Maria Grzegorzewska University and Warsaw University of Technology; three non-public universities in Warsaw: Management Academy of Applied Sciences in Warsaw, WSB Merito University Warsaw and University of Technology and Art in Applied Sciences in Warsaw and two international universities: Sapienza University of Rome and Lusophone University of Porto.

Additionally, comparisons were made with theoretical studies. To a lesser extent, researcher triangulation was used, as the study was conducted by two researchers.

Due to the sample selection and non-representative sample size, the study's results cannot be generalized to all students at higher education institutions in Poland. Nevertheless, the study provides new insights and can serve as an initial attempt at empirically verifying the awareness of students from all higher education institutions regarding sustainable development, their perceptions of the phenomenon of a sustainable higher education institution, and their expectations in this area. This is especially relevant given that the research questionnaire, due to its comprehensiveness, universality, and reliability, offers the potential for replication.

4. Research

The first question of the survey concerned students' awareness of what sustainable development is. A total of 146 students, representing 87.50% of the study sample, responded that they are aware of the concept of sustainable development. The remaining 12.50% of respondents answered this question negatively. The responses are presented in Figure 5.

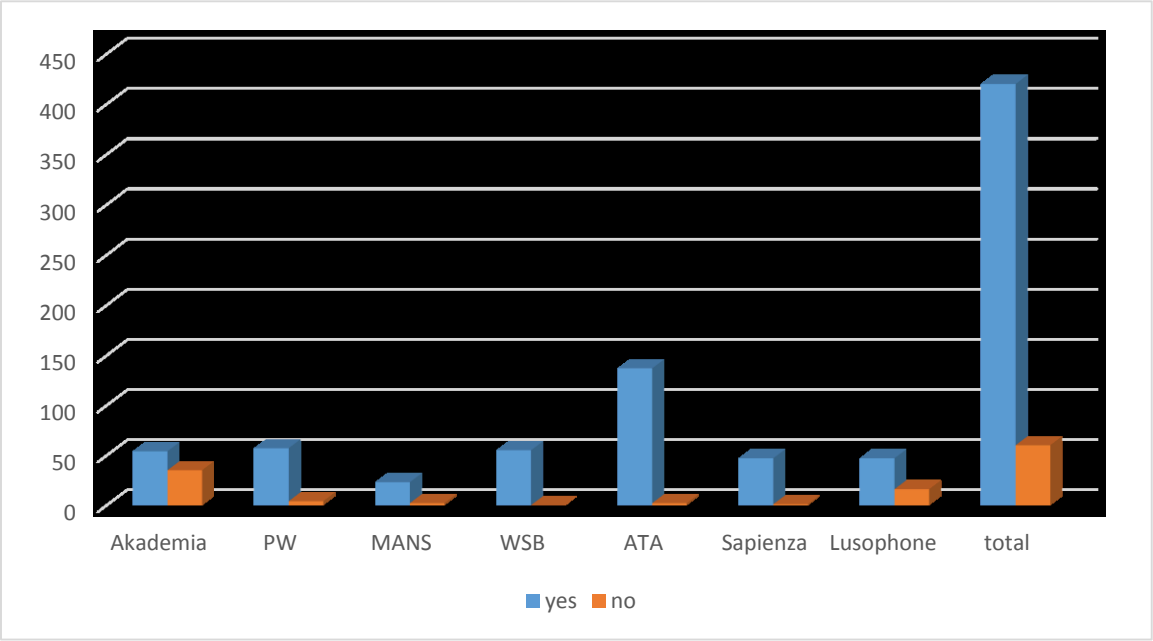


Figure 5. Students' awareness of sustainable development concept.

Source: own research.

Next, students were asked to indicate the characteristics they believe define a sustainable university. They could select any number of features from the list of responses:

- provides knowledge on sustainable development in courses not directly related to sustainable development,
- offers courses specifically on sustainable development,
- provides extracurricular activities that promote sustainable behaviors,

- offers a study program in "Sustainable Development",
- uses renewable energy sources,
- implements solutions aimed at saving water, heat and electricity,
- promotes sustainable waste management (sorting, recycling, reuse),
- promotes green mobility for students,
- promotes green mobility for employees,
- reduces the consumption of natural resources, including paper,
- encourages students to reduce their consumption of natural resources,
- encourages employees to reduce their consumption of natural resources,
- eliminates exclusion of people with disabilities among employees,
- eliminates exclusion of minorities among employees,
- eliminates exclusion of disadvantaged groups among employees,
- eliminates exclusion of people with disabilities among students,
- eliminates exclusion of minorities among students,
- eliminates exclusion of disadvantaged groups among students,
- eliminates exclusion of people with disabilities among prospective students,
- eliminates exclusion of minorities among prospective students,
- eliminates exclusion of disadvantaged groups among prospective students,
- promotes gender equality, minority rights and inclusion of disadvantaged groups within the organization,
- promotes high standards of environmental and social behavior through projects and initiatives,
- encourages charitable work and volunteer projects,
- implements projects aimed at social inclusion,
- provides scholarship programs for economically disadvantaged students.

Students provided answers which were grouped in Table 1.

Table 1.
Students' indication of characteristics of sustainable university

What do you think are the characteristics of a sustainable university?	**Grzegorzewska**	**TUW**	**MANS**	**WSB**	**ATA**	**Sapienza**	**Luzofone**
Provides knowledge about sustainable development in classes not directly related to sustainability	23	25	10	34	84	9	8
Offers courses specifically on sustainable development	28	23	15	23	76	23	5
Provides extracurricular activities that promote sustainable behaviors	26	24	10	14	78	19	12
Offers a study program in "Sustainable Development"	3	6	17	1	35	6	0
Uses renewable energy sources	34	29	14	0	74	5	1
Implements solutions aimed at saving water, heating, and electricity	39	39	14	0	58	17	15

Cont. table 1.

Promotes sustainable waste management (sorting, recycling, reuse)	40	45	17	46	65	12	14
Promotes green mobility for students	31	26	12	0	62	17	16
Promotes green mobility for staff	27	25	12	0	61	21	0
Reduces the consumption of natural resources, including paper	35	33	14	35	76	14	25
Encourages students to reduce their consumption of natural resources	32	29	6	12	54	13	14
Encourages employees to reduce their consumption of natural resources	24	25	8	15	52	16	8
Eliminates exclusion of people with disabilities among employees	33	30	7	0	38	10	2
Eliminates exclusion of minorities among employees	30	27	8	2	38	8	5
Eliminates exclusion of disadvantaged groups among employees	24	25	6	0	36	9	12
Eliminates exclusion of people with disabilities among students	29	28	2	4	50	7	25
Eliminates exclusion of minorities among students	29	23	6	2	46	8	37
Eliminates exclusion of disadvantaged groups among students	25	21	8	2	38	11	36
Eliminates exclusion of people with disabilities among prospective students	28	25	6	2	38	14	38
Eliminates exclusion of minorities among prospective students	29	22	5	4	48	8	34
Eliminates exclusion of disadvantaged groups among prospective students	26	18	4	0	46	16	26
Promotes gender equality, minority rights and inclusion of disadvantaged groups within the organization	30	27	5	3	64	14	32
Promotes high standards of environmental and social behavior through projects and initiatives	39	32	4	12	70	16	15
Encourages charitable work and volunteer projects	33	29	3	3	68	17	15
Implements projects aimed at social inclusion	20	18	2	5	68	28	19
Conducts scholarship programs for economically disadvantaged students	24	30	15	34	94	35	46

Source: own research.

The results were also visualized on the following Figure. Firstly, students identified the following as the most important characteristics of a sustainable university: Conducts scholarship programs for economically disadvantaged students; Promotes sustainable waste management (sorting, recycling, reuse); Reduces the consumption of natural resources, including paper; Provides knowledge about sustainable development in classes not directly related to sustainability; Offers courses specifically on sustainable development. The least significant feature according to students is: "Offers a study program in "Sustainable Development".

The full set of students' responses is presented both in Table 1 (above) as well as in Figure 6.

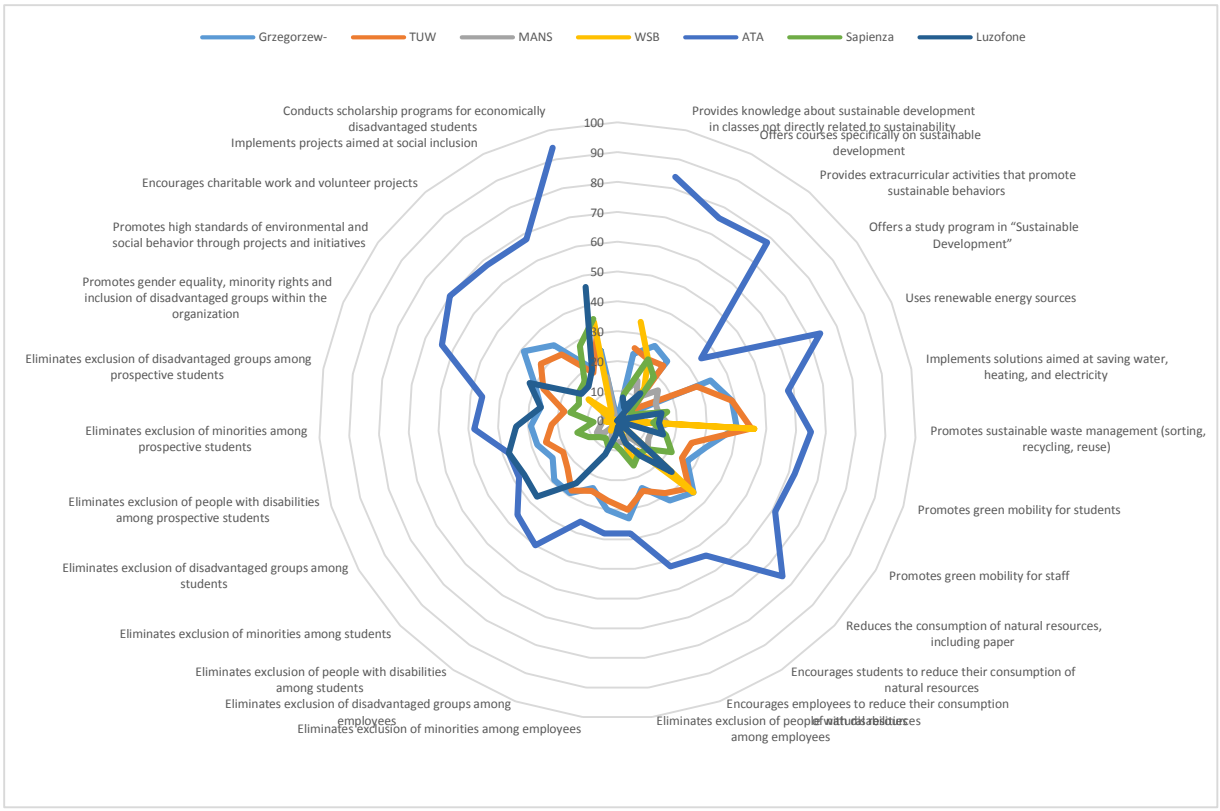


Figure 6. Students' indication of characteristics of sustainable university.

Source: own research

Students of the researched universities indicated different characteristics they believe define a sustainable university. While Students of ATA provided more indicators of sustainable development of the university from the point of view curricular and non-curricular courses and classes provided by the university as well as the once for social responsibility for internal stakeholders, students of TUW had more institutional approach to sustainable development of the university; Students of Lusofone on the other hand provided a social approach to sustainable university. For better visualization of the difference in responses between students of seven universities, the radar Figure 6 was introduced.

The next question asked to respondents to identify characteristics of sustainable development that are present at their own university. Once again, they could select any number of responses they deemed appropriate. The response options were the same as in the previous question.

Students of all researched universities most frequently appointed: "Conducts scholarship programs for economically disadvantaged students". That indication of sustainable development was selected 242 times. Second most appointed SD feature of the university was: "Provides knowledge on sustainable development in courses not directly related to sustainable development". That feature was selected 172 times. Third place was reserved for "Promotion sustainable waste management (sorting, recycling, reuse)" which was a SD characteristic of university for 126 students. "Encourages charitable work and volunteer projects" was the last feature of sustainable university that exceeded a threshold of 100 appointments.

Other characteristics received scattered selections, ranging from 90 to 34 mentions. Notably, not even one characteristic provided in a survey in students' vision of a sustainable university was selected below 34. “Offers a study program in “Sustainable Development”” was the least frequently chosen characteristics of sustainable university. Moreover, majority of characteristics of sustainable development university were aligned in the opinion of students of selected 7 universities. A detailed breakdown of these characteristics is shown in Table 2.

Table 2.
Students' sustainability indications of their university

What do you think are the characteristics of a sustainable university?	**Grzegorzewska**	**TUW**	**MANS**	**WSB**	**ATA**	**Sapienza**	**Luzofone**
Provides knowledge about sustainable development in classes not directly related to sustainability	14	21	7	32	84	10	4
Offers courses specifically on sustainable development	3	12	10	13	26	17	3
Provides extracurricular activities that promote sustainable behaviors	5	8	10	12	12	10	8
Offers a study program in “Sustainable Development”	1	1	18	1	8	5	0
Uses renewable energy sources	4	11	10	0	14	5	1
Implements solutions aimed at saving water, heating, and electricity	8	14	9	0	14	5	12
Promotes sustainable waste management (sorting, recycling, reuse)	28	25	10	26	11	16	10
Promotes green mobility for students	9	10	9	0	12	11	14
Promotes green mobility for staff	7	6	10	0	12	10	0
Reduces the consumption of natural resources, including paper	8	15	11	25	15	4	15
Encourages students to reduce their consumption of natural resources	8	9	5	10	6	5	8
Encourages employees to reduce their consumption of natural resources	5	8	8	8	8	5	8
Eliminates exclusion of people with disabilities among employees	29	12	1	0	6	6	2
Eliminates exclusion of minorities among employees	22	15	4	2	10	6	3
Eliminates exclusion of disadvantaged groups among employees	18	16	2	0	5	5	13
Eliminates exclusion of people with disabilities among students	29	15	3	4	3	5	12
Eliminates exclusion of minorities among students	25	13	4	2	4	9	18
Eliminates exclusion of disadvantaged groups among students	21	12	2	2	2	6	16
Eliminates exclusion of people with disabilities among prospective students	26	14	6	2	11	9	18
Eliminates exclusion of minorities among prospective students	25	17	4	4	15	4	14
Eliminates exclusion of disadvantaged groups among prospective students	21	15	2	0	12	16	16
Promotes gender equality, minority rights and inclusion of disadvantaged groups within the organization	24	12	3	3	6	15	12
Promotes high standards of environmental and social behavior through projects and initiatives	7	13	4	10	28	12	4
Encourages charitable work and volunteer projects	30	18	3	3	27	14	6
Implements projects aimed at social inclusion	15	16	2	5	25	16	14
Conducts scholarship programs for economically disadvantaged students	30	29	13	28	86	28	28

Source: own research.

The graphical representation of students' sustainability indications of their university was gathered in Figure 7.

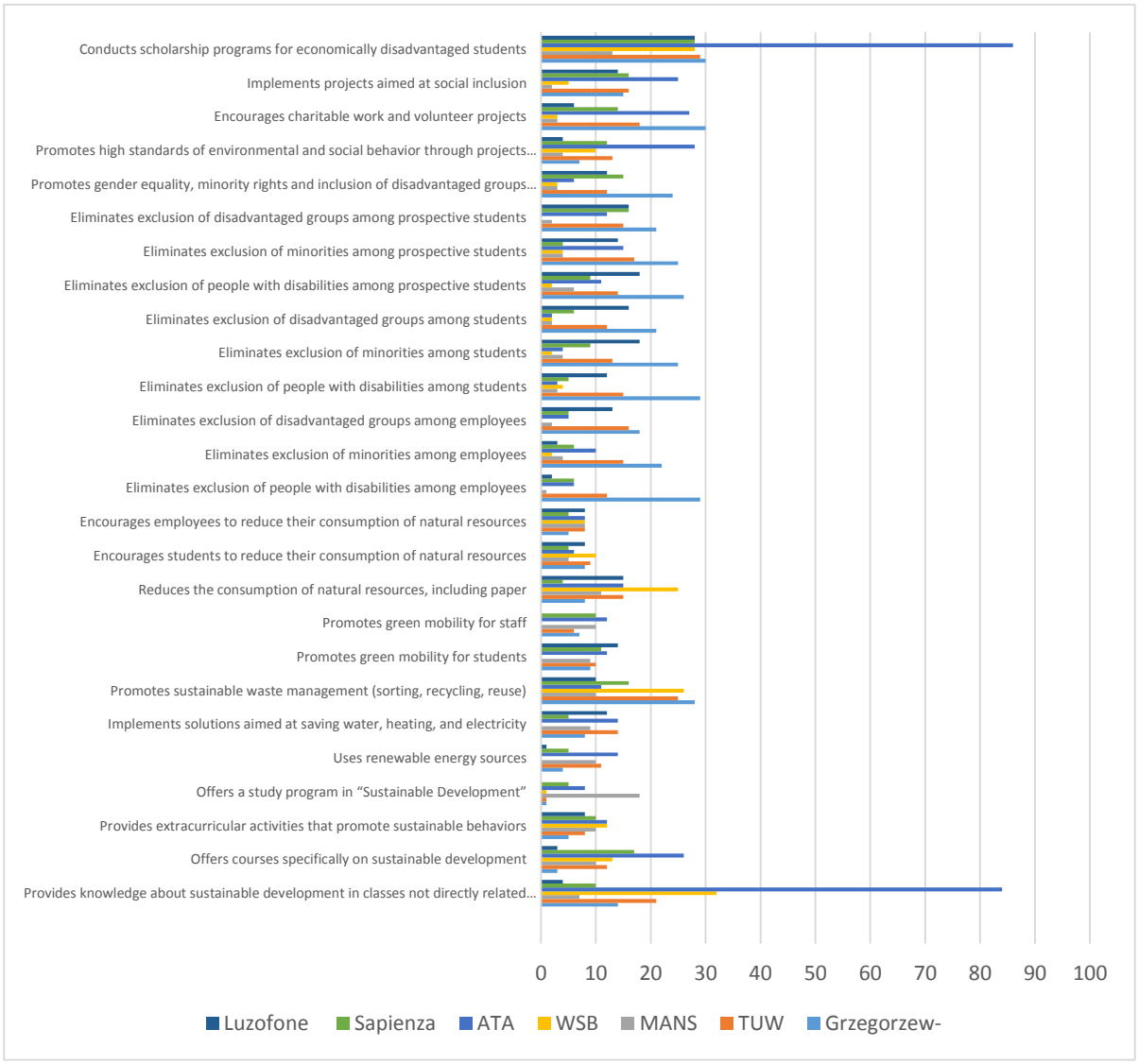


Figure 7. Students' sustainability indications of their university.

Source: own research.

The next question aimed to determine whether the universities surveyed provide their students with opportunities to engage in extracurricular activities, beyond the curriculum—such as social, charitable, organizational, and scientific activities—that help build sustainable development competencies.

The detailed answers of students of all the researched universities were collected in Table 3.

Table 3.
Students' awareness of opportunities to engage in extracurricular activities outside of the curriculum, including social, charitable, organizational, and scientific activities that build competencies in sustainable development organized by their universities

Does your university provide students with opportunities to engage in extracurricular activities outside of the curriculum, including social, charitable, organizational, and scientific activities that build competencies in sustainable development?	**Grzegorzewska**	**TUoW**	**MANS**	**WSB**	**ATA**	**Sapienza**	**Luzofone**
No	1	2	12	15	45	0	12
There are limited opportunities	7	8	3	23	24	15	25
Such opportunities exist	30	31	0	10	26	6	13
I don't know	20	18	8	7	44	6	15
total	58	59	23	55	139	27	65

Source: own research.

118 out of 426 answers, which represent 28% of responses declared that surveyed students are not aware of opportunities to engage in extracurricular activities outside of the curriculum, including social, charitable, organizational, and scientific activities that build competencies in sustainable development organized by their universities. 27% of investigated students indicated that such opportunities exist. ¼ of students in the research sample declared that there are limited opportunities to engage in those activities at their universities. Only 20% out of 426 answers declared no opportunity to engage in extracurricular activities outside of the curriculum, including social, charitable, organizational, and scientific activities that build competencies in sustainable development. Therefore, in the research sample 52% of the respondents are aware of these types of activities (see Figure 8).

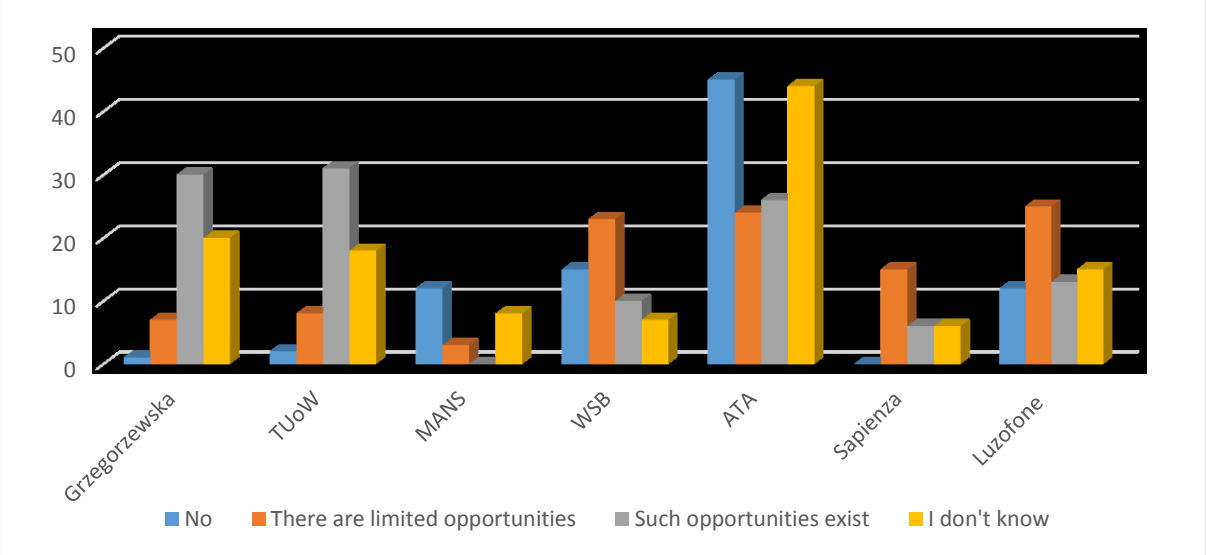


Figure 8. Students' awareness of opportunities to engage in extracurricular activities outside of the curriculum, including social, charitable, organizational, and scientific activities that build competencies in sustainable development organized by their universities.

Source: own research.

In response to the question of whether they participate in extracurricular activities, beyond the curriculum—such as social, charitable, organizational, or scientific activities organized by their university that build sustainable development competencies— 86.94% of all the respondents answered negatively. Only 13.06% of students declared that they participate in extracurricular activities building sustainable development competencies of students. Remarkably, they majority of them are students of Sapienza University of Rome (see Figure 9).

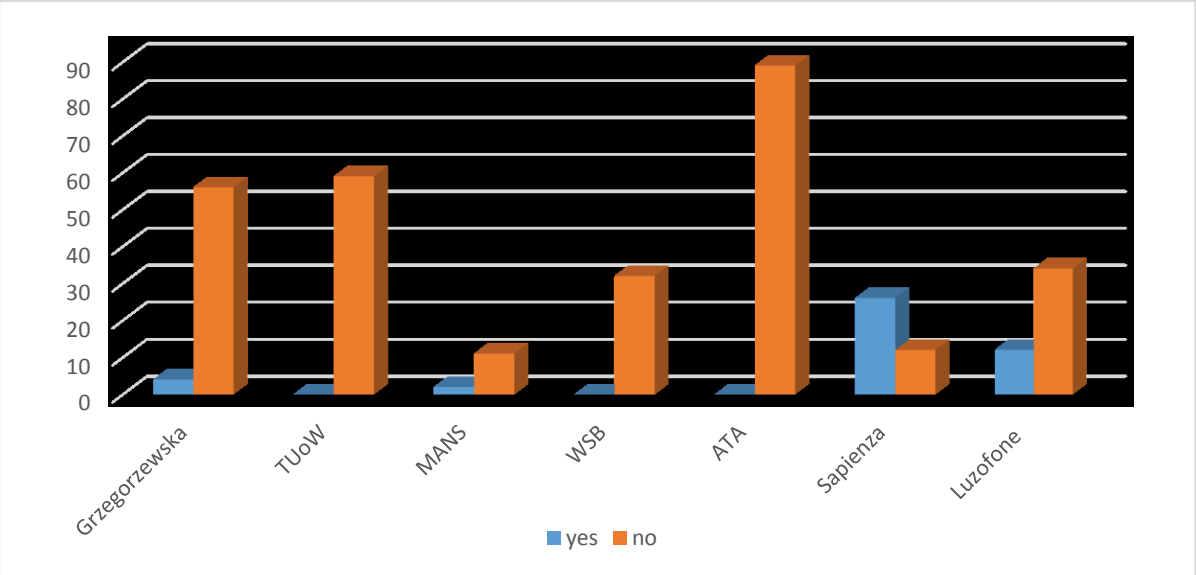


Figure 9. Participation in extracurricular activities building sustainable development competencies of students.

Source: own research.

Students of all researched universities were asked to appoint their motives of participation in activities organized by their university that build sustainable development competencies. Remarkably, students of only three universities (Maria Grzegorzewska University, Sapienza University of Rome and Lusophone University of Porto) answered in that field. Motives of participation in activities organized by their university that build sustainable development competencies received scattered selections: 16.84% appointed "Opportunities to make new connections", 15.79% of responses regarded "Self-development" and "Developing already acquired competencies" equally and 14,74% appoints belonged to "Gaining experience". The remaining answers ("Enriching CV", "Doing good" and "Earning extra points during studies") oscillated around 10% of indications. Moreover, majority of motives of participation in activities organized by their university that build sustainable development competencies were aligned in the opinion of students of 3 universities. A detailed breakdown of these characteristics is shown in Figure 10.

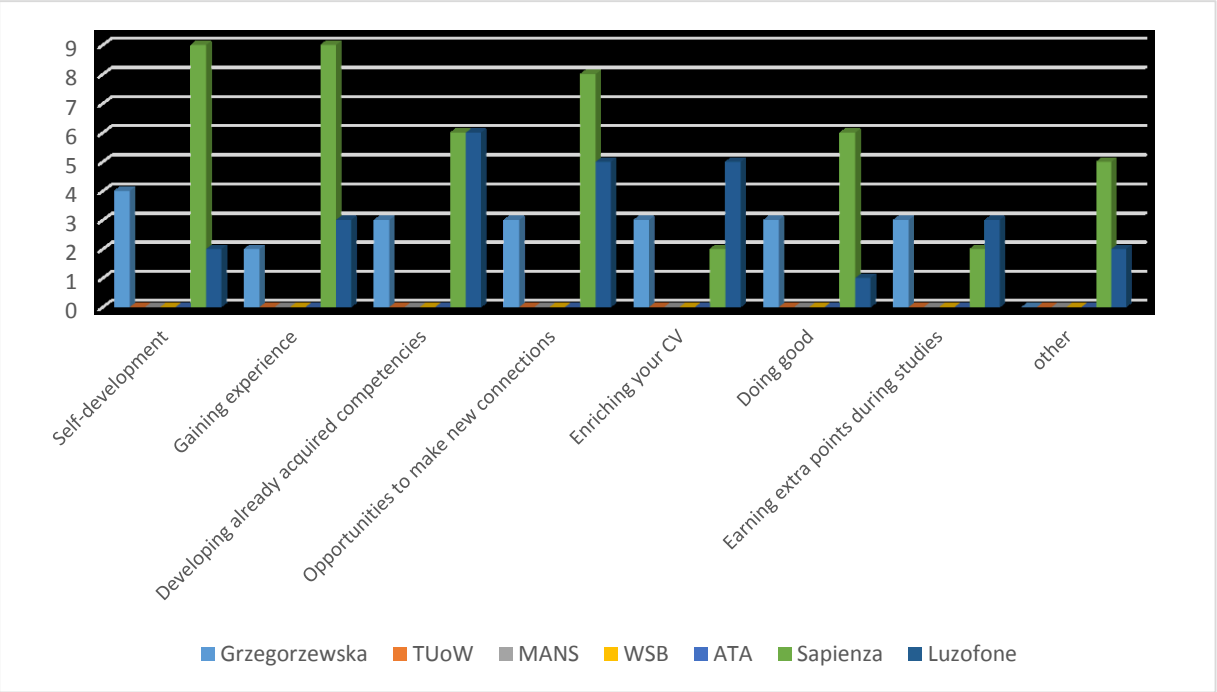


Figure 10. Motives of participation in activities organized by their university that build sustainable development competencies.

Source: own research.

The next question asked which types of activities offered by their university students felt most effectively developing sustainable development competencies. According to students that participated in the survey, projects were the top choice, with 27.78% of choices and workshops with 22.75%. The remaining forms of activities offered by universities students felt most effectively developing sustainable development competencies were less significant to the respondents and the detailed responses are presented in Figure 11.

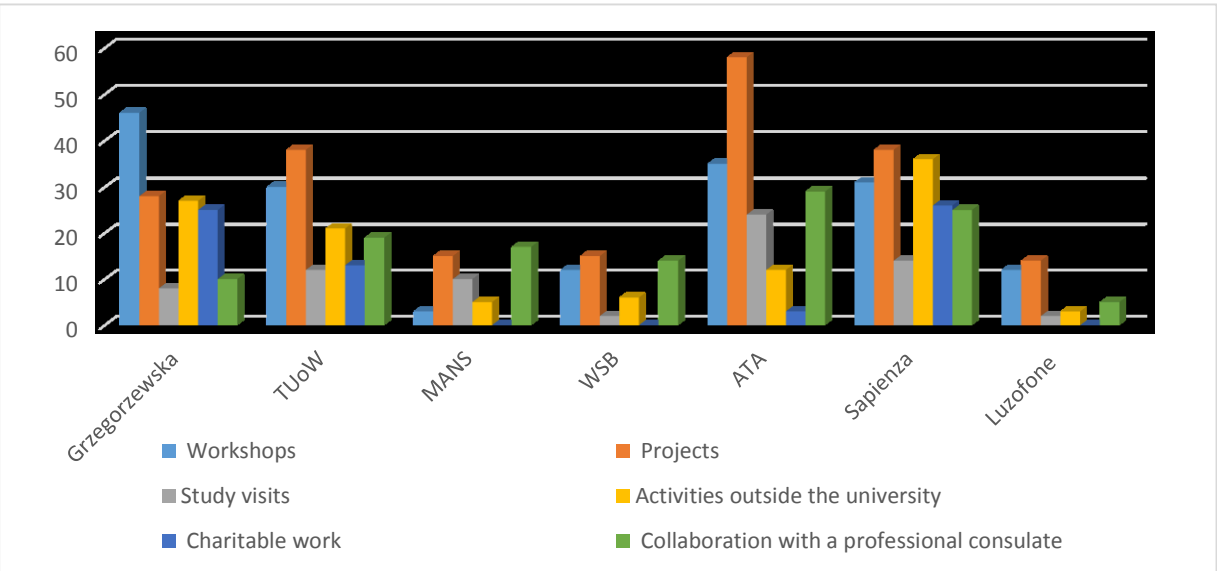


Figure 11. Types of activities offered by universities students felt most effectively developing sustainable development competencies.

Source: own research.

The final question asked how students plan to develop their competencies in sustainable development. Remarkably, students from all researched universities declared that they plan to develop their competencies in sustainable development. They prioritized participating in courses, training sessions, or workshops, with 55.92% of indications. Nevertheless, 28.65% of students do not plan to develop their competencies in sustainable development. For detailed answers, see Figure 12.

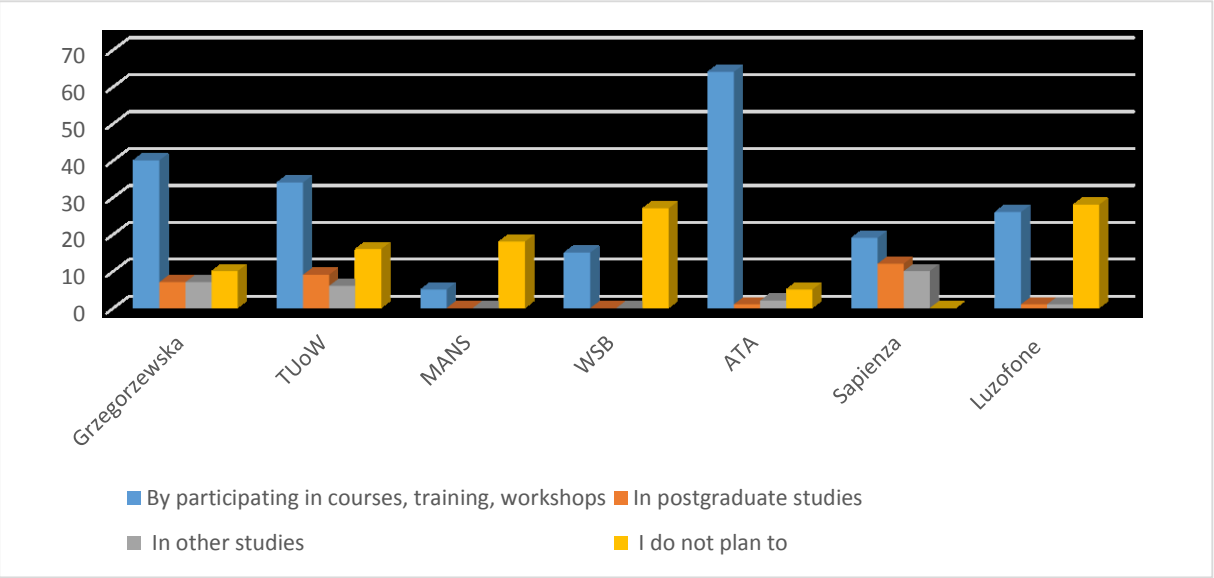


Figure 12. Students' plans to develop their competencies in sustainable development.
Source: own research.

5. Results and conclusions

The purpose of this study was to assess the awareness and expectations of university students from public universities in Warsaw: Maria Grzegorzewska University, Warsaw University of Technology; non-public universities in Warsaw: Management Academy of Applied Sciences in Warsaw, WSB Merito University Warsaw, University of Technology and Art in Applied Sciences in Warsaw; foreign universities: Sapienza University of Rome, Lusophone University of Porto regarding sustainable development at higher education institutions. The analysis focused on the students' perspectives. The study clearly revealed a high level of awareness among students on this topic, with a level of 87.50% demonstrating awareness. Apart from the students of one university, the level of unawareness was insignificant.

The surveyed students identified features they believe should characterize a sustainable university. Of the 26 proposed features, students from all the surveyed universities highlighted all of them with varied number of votes. The least score obtained a feature "Offers a study

program in Sustainable Development". These findings suggest a noticeable lack of program solely dedicated to sustainable development neither as major or minor in none of the surveyed universities.

Moreover, the surveyed students, perceive their higher education institution completely different in terms of sustainable development. Students of TUoW, firstly see the university as any other institution (apart from educational mission) that cares about ecology and their internal and external stakeholders. While the students of ATA primarily perceive their university as sustainable developed institution through the prism of the program of studies (curricular and non-curricular courses and classes provided by the university) as well as the once for social responsibility for internal stakeholders; Students of Lusofone on the other hand provided a social approach to sustainable university.

The most surprising finding was very low level of participation in extracurricular activities and initiatives among all universities' students, except of Sapienza. These activities, which include social, charitable, organizational, and scientific endeavors, are essential for developing sustainable development skills find little interest among surveyed students.

The study thus suggests that, the surveyed universities still incorporate considerably fewer sustainable development topics in their curricula and organize limited extracurricular activities to support these competencies. Nevertheless, overall students' awareness of the concept of sustainable development is considerably high and highly satisfactory (apart from the students of one Polish university). It is worth noticing, that the answers of students though from different scopes of universities are comparable to a large extent which proves the topic of sustainable development is equally seriously concerned in all surveyed universities. Considering the current labor market and the growing demand for sustainability specialists, universities could benefit from implementing a model based on a holistic approach to sustainability education, integrating these topics widely across educational programs and fostering the development of practical skills in this critical area. That approach could be reached by including the business environment entities as well as by introducing micro-credentials to the program of studies.

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CORPORATE GOVERNANCE FROM A DIGITAL TRANSFORMATION PERSPECTIVE

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Purpose: The objectives of this study are: (1) to identify digital technologies applicable to corporate governance; (2) to map ESG requirements related to corporate governance onto the principles outlined in the Best Practices of WSE-listed companies, considering their digitalization; and (3) to characterize the role of digitalization in implementing corporate governance principles and ESG requirements under ESRS 2 and ESRS G1 within the analyzed case study.
Design/methodology/approach: To achieve these objectives, the following research questions were formulated: how can digital technologies be used in corporate governance within companies? How are ESG requirements for corporate governance (ESRS) implemented in relation to the corporate governance principles contained in the Best Practices for WSE-Listed Companies? How is digitalization used to implement the corporate governance principles contained in the Best Practices for WSE-Listed Companies and the corporate governance requirements under ESRS 2 and ESRS G1 in the analyzed case study? The research employed a critical literature review using the Science Direct, Emerald, Springer (2021-2025), and Research Gate databases, as well as inductive reasoning. The study utilized the case study of TAURON Polska Energia S.A. The analysis was based on information from 2024.
Findings: An analysis of the digital transformation of enterprises was presented, pointing to the use of digitalization within the framework of corporate governance principles contained in the Good Practices of WSE-listed companies and corporate governance requirements within the ESRS as part of a case study.
Research limitations/implications A single case study was analyzed based on a fiscal year. Comparisons with international practices outside the Polish capital market and an analysis of the economic effectiveness of digitizing corporate governance were not included.
Practical implications: The need to develop a corporate governance digitalization strategy that takes into account industry specifics, along with the need to invest in digital competences of management board and supervisory board members, and to develop a regulatory framework that takes into account the possibilities of digital technologies.
Originality/value: Characteristics of the application of digital corporate governance.
Keywords: Digital transformation, Digital governance, Digital corporate governance, Warsaw Stock Exchange S.A., Tauron Polska Energia S.A.
Category of the paper: Viewpoint, Case Study.

1. Introdution

Modern businesses operate in a dynamic environment, interwoven with changing environmental conditions, uncertainty, complexity, and ambiguity in the VUCA paradigm, as well as organizational fragility, emotional anxiety, nonlinearity, and incomprehensibility that characterize the BANI environment (Cascio, 2020; Bennett, Lemoine, 2014).

In this business environment, digital transformation is no longer an optional development strategy, but rather an imperative for competitiveness and survival in the global market. Global spending on information technology amounted to approximately $5.11 trillion in 2024. In 2025, it is estimated to reach $5.6 trillion (a 9.8% year-on-year increase) (Gartner, 2025). Investments in AI development alone in 2024 amounted to $124.3 billion, while cloud solutions and distributed computing models (cloud and edge computing) accounted for $80.8 billion, digital trust and cybersecurity accounted for $77.8 billion, and advanced connectivity accounted for $44.2 billion (McKinsey, 2025).

Therefore, companies are adopting various forms of digital transformation to drive growth and improve customer experience (Deloitte, 2025). Various dimensions of digital transformation are highlighted in the value chain of enterprises, for example, digital platforms (Kawalec, 2021).

This fundamental shift in the business paradigm is impacting traditional corporate governance models. Traditional management models are unable to effectively cope with disruptions and changing stakeholder demands. Therefore, the need has arisen to adapt corporate governance structures to the new digital realities (Aguilera, Castillo, 2025). Digital transformation can significantly improve management effectiveness, for example, for minority shareholders by increasing their participation in shareholder meetings and strengthening oversight mechanisms (Hou, Wei, Yang, K., Luo, 2024). This is causing management boards and supervisory boards (boards of directors) to redefine their roles, responsibilities, and oversight mechanisms. Corporate governance, understood as a system of rules, practices, and processes by which enterprises are directed and controlled, must evolve to meet the challenges of the digital era. This also influences the construction of digital governance in organizations (Hanisch, Goldsby, Fabian, Oehmichen, 2023).

Ultimately, it aims to build digital corporate governance, which integrates digital technologies with traditional structures and principles of good corporate governance, enabling effective oversight of an organization's digital transformation. Its success will depend on the synergy between technological innovation and corporate responsibility. It will also require a proactive approach from all stakeholders, with particular attention paid to cybersecurity practices by both management and supervisory bodies.

2. Methodology

In relation to the digital transformation of enterprises, the research issues concern the use of digitalization in corporate governance.

The subject of the research is the use of digitalization within the framework of corporate governance principles included in the Good Practices of companies listed on the WSE (Warsaw Stock Exchange) and corporate governance requirements within the framework of the ESRS (Sustainability Reporting Standards - European Sustainability Reporting Standards).

The goals that have been set are:

1. Identification of digital technologies for use in corporate governance in companies.
2. Mapping ESG (Environmental, Social, Governance) requirements related to corporate governance (ESRS) to the corporate governance principles contained in the Best Practices for WSE-Listed Companies, taking into account their digitalization.
3. Characterization of the use of digitalization in implementing the corporate governance principles contained in the Best Practices for WSE-Listed Companies in the analyzed case study.
4. Characterization of the use of digitalization in implementing the corporate governance requirements under ESRS 2 and ESRS G1 in the analyzed case study.

In order to achieve the objectives, the following research questions were formulated:

1. How can digital technologies be used in corporate governance in companies?
2. How are ESG requirements for corporate governance (ESRS) implemented in relation to the corporate governance principles contained in the Best Practices for WSE-Listed Companies?
3. How is digitalization used to implement the corporate governance principles contained in the Best Practices for WSE-Listed Companies in the analyzed case study?
4. How is digitalization used to implement the corporate governance requirements under ESRS 2 and ESRS G1 in the analyzed case study?

The research utilized critical literature analysis using the Science Direct, Emerald, Springer (2021-2025) and Research Gate databases, as well as inductive reasoning that situates itself within the narrative of management and quality sciences. The study utilized a case study of Tauron Polska Energia S.A., a company listed on the Warsaw Stock Exchange (WSE) within the WIG 30 index. The analysis was based on information for the 2024 fiscal year.

3. Digital transformation

Digital transformation, through the strategic use of digital technologies, is associated with creating new value for customers, employees, and shareholders (Prayoga et al., 2025). This is a fundamental change that goes beyond the digitization of processes but also encompasses the reorganization of business models, organizational cultures, and ways of creating value within enterprises (Han et al., 2024). In research, digital transformation is defined as the use of digital technologies to create new or modify existing business processes, organizational culture, and customer experiences in response to changing business and market requirements (Sebastian et al., 2017; Vial, 2019).

The digital transformation of enterprises is characterized by three key dimensions: digitization, i.e., the conversion of analog to digital, digitalization related to the use of ICT to optimize processes, and the actual digital transformation, which involves a fundamental change in the business model (Stamoulis, Kopanaki, 2024). Digital transformation is a long-term process that requires a holistic approach.

Among the key factors for the success of digital transformation at the organizational level are organizational readiness, top management support, a culture of innovation, and adequate financial resources (Stamoulis, Kopanaki, 2024). From an individual perspective, the perceived usefulness of technology, ease of use, and personal innovation of employees are important (Khanfar et al., 2024). Digital technologies have a varied impact on the efficiency of processes in enterprises. The strongest positive effect is demonstrated by smart factories, big data analytics, and the Internet of Things (Bindeeba et al., 2025). Success is also associated with the development of new capabilities for co-creation with external partners and the establishment of a space for inter-organizational collaboration (Eikebrokk et al., 2024). Research conducted by Deloitte in 2024 on a sample of 391 technology leaders identified strong data foundations, an agile approach and teams, a culture ready for change, modern technological infrastructure, and a flexible approach to financing as critical factors for the success of digital transformation (Deloitte, 2024).

There are many barriers to implementing digital transformation in enterprises. Key obstacles include resistance to change, a lack of appropriate digital skills, and insufficient financial resources (Khanfar et al., 2024). Research highlights significant technical challenges in enterprises, such as the complexity of integrating new systems with existing infrastructure and insufficient security infrastructure (Zbořil, Svatá, 2022). A key problem is the lack of coordinated digital transformation implementation strategies. For example, in the public sector, barriers are even more complex, encompassing stringent legal regulations, rigid organizational structures, and conflicting stakeholder interests (Lamprousis, Jonathan, 2025). Data management, including issues with data availability, quality, and standardization, pose significant challenges (Zuiderwijk et al., 2021). Barriers include a lack of a transformation

strategy, reliance on legacy systems (considered as a dependence on outdated systems and technical debt), cybersecurity concerns, insufficient funding, and misaligned incentives among key stakeholders (Deloitte, 2024). These barriers and the resulting challenges contribute to digital transformation failure rates, which are estimated at over 80%. Four main categories of problems are identified: technological, innovation, management, and information systems (Oludapo et al., 2024).

The level of digital transformation maturity in organizations demonstrates significant differences between sectors and regions. Enterprises go through various stages of maturity, ranging from basic digitization through the expansion of digital capabilities to full transformation of business models (Paul et al., 2023). The private sector is characterized by dynamic development, particularly in the areas of artificial intelligence and digital platforms (Urˇsiˇc, Cˇater, 2025). The public sector, on the other hand, is characterized by a lower level of digital maturity, primarily due to regulatory and structural constraints (Lamprousis, Jonathan, 2025). However, as the experience of the European railway sector shows, regulatory compliance can serve as a catalyst for digital transformation (Stamoulis, Kopanaki, 2024). For example, the financial industry has a relatively high level of digital maturity, particularly in the use of AI for risk analysis and improving the information environment of capital markets (Lia, Zhang, 2025). At the same time, attention is drawn to the development of Industry 5.0, characterized by a shift from shareholder value to value for a wider group of stakeholders, particularly taking into account Cognitive cyber-physical (Hofer et al., 2025).

Research indicates that lower middle-income countries show a stronger digital transformation effect compared to high-income countries (Bindeeba et al., 2025). In this context, digital transformation may have greater potential in developing economies. Research in industrial sectors indicates that a higher level of digital maturity translates into increased EBIT and sales revenues (Deloitte, 2023). On the other hand, it is determined that despite the growing importance of digital transformation, only about 25% of enterprises achieve the desired results in their digitalization efforts. The main challenge is the lack of appropriate tools to assess the current level of digital maturity of enterprises, which makes it difficult to plan an effective transformation strategy. There is a tendency to create sectoral models, particularly oriented towards production (Kalendera, Žilkaa, 2024).

Implementing digital transformation in enterprises poses risks and has drawbacks. One of the main threats is the phenomenon of "digital washing", or selective disclosure and exaggeration in determining progress in digital transformation. This can, for example, lead to reduced accounting conservatism and a deterioration in the quality of financial reporting (Wei et al., 2025). New digital systems pose threats that include increased vulnerability to cyberattacks and vendor dependence, where vendor lock-in can limit flexibility and increase long-term costs (Bharadwaj et al., 2013). Digital transformation can lead to new forms of inequality, particularly in the context of employee access to technology and their digital competencies. Critical thinking and employee competencies can also be undermined by the

automation of epistemic processes (Shin, 2025). Human resources management can be an area of conflict between operational efficiency and ethical standards, particularly in digital recruitment and employee assessment. Ethical issues related to artificial intelligence also pose a significant threat, including the risk of algorithm bias, privacy violations and the lack of transparency in decision-making processes (Madanchian, Taherdoost, 2025).

One way to address digital transformation in enterprises is to create a Chief Digital Officer (CDO) position, which is key to shaping digital strategies. However, this organizational solution is subject to criticism. (Kessel, Graf-Vlachy, 2022).

A consequence of digital transformation in enterprises is the creation of digital governance. Digital transformation also influences corporate governance (Yang, Tai, Liu, 2024). Organizing digitalization-related activities in enterprises is related to digital governance. Digital governance can be both a consequence of digital transformation and a catalyst for it. Digital governance can be defined as a set of shared values, norms, and mechanisms guiding enterprise activities with respect to digital technology and data (Lobschat et al., 2021). It goes beyond traditional approaches to IT governance. It encompasses an organizational framework enabling management in digital networks. Three main modes of digital governance can be identified: analog (centralized) governance, enhanced (distributed) governance, and automated (decentralized) governance. Centralized governance is based on hierarchy and bilateral agreements, enhanced governance is associated with distributed digital tools and the multilateral use of digital channels, while automated governance is decentralized through autonomous algorithms and omnilateral coordination (Hanisch et al., 2023). Digital governance considers the benefits and risks of using ICT (Lin, Yaakop, 2024). It is the responsible use of ICT and the use of consumer data (Merbecks, 2024). In the context of so-called extended enterprises, it can be understood as the decentralized management of distributed ledger infrastructure (DLT) (Anthony, 2023). Elements of digital governance include management of data and the data lifecycle, data ownership and provenance, metadata, compliance and risk, data architecture, stakeholders, identity and access, and trust (Acev et al., 2025). In the context of digital governance, digital corporate responsibility is important, understood as a set of shared values and norms guiding an organization's activities. It can be related to four main processes related to digital technology and data. These processes include technology creation and data collection, operation and decision-making, inspection and impact assessment, and technology and data improvement (Lobschat et al., 2021). With regard to data, there are risks related to conflict with the GDPR, involving problems with data minimization and the right to be forgotten, as well as the problem of identifying data controllers in decentralized systems (Karisma, Tehrani, 2023).

Digital governance in enterprises is undergoing a phase of rapid development, characterized by a shift from simple analog mechanisms to complex automated systems. As digital maturity increases, companies are developing more advanced governance mechanisms to address the new challenges posed by Big Data, AI, IoT, and digital platforms. The remaining key challenge

is to find a balance between the effectiveness of digital solutions and maintaining control over business processes and compliance with regulatory requirements. Successful digital governance implementation requires a holistic approach that considers technological, organizational, and cultural factors, with particular attention to industry and regional specifics.

4. Digital corporate governance

Digital corporate governance is an evolutionary development of traditional corporate governance mechanisms, which involves integrating digital technologies into supervision, control, and decision-making processes (Steiner et al., 2025). It is a consequence of digital governance, which also contributes to its maturity. Digital corporate governance, through the use of digital technologies, enables better alignment of corporate governance with stakeholder requirements and increases the competitiveness of enterprises (Ziniuk et al., 2022). Effective implementation of digital corporate governance requires a structured process encompassing: defining the vision, engaging leaders, building organizational culture, ensuring resources and experience, and selecting appropriate technology (Ziniuk et al., 2022). The positive impact of digitalization on corporate management includes the technological capabilities of companies, intense industry competition, developed digital infrastructure of the region and higher environmental awareness of society (Cheng, Li, 2025). The digitalization of corporate governance also creates secure and improved remote collaboration, better information flow, increased participation in decision-making, greater transparency of processes and more effective management of conflicts of interest (Ziniuk et al., 2022).

In practice, digital corporate governance is intended to improve the functioning of management bodies through the use of artificial intelligence, big data, blockchain technology, IoT systems, and cloud platforms (Sun, Guo, 2024). One area of application of digitization within corporate governance is modeling the digital recruitment and selection process for future board members of public enterprises. This is intended to decentralize the process and make it more transparent, using DM Software (decision-making software) or the RACI matrix method (offering diversity elements and strategic requirements for board members) (Moșneanu, 2020).

Among the digital technologies used in digital corporate governance, artificial intelligence can be mentioned. Artificial intelligence can be used in various areas of corporate governance, such as board diversity analysis, real-time monitoring, decision-making support, ensuring regulatory compliance, streamlining audit processes, and strengthening shareholder engagement (Bhatia, 2025). Implementing artificial intelligence can reduce agency costs, leading to lower management costs (Xue, 2025).

Another example is the use of big data technology, which is characterized by large amounts of data, high processing efficiency, and a variety of information sources. Research indicates that big data has a positive impact on board oversight, social responsibility, and fraud detection (Sun, Guo, 2024).

Blockchain is also revolutionizing the transparency and security of corporate processes through data immutability, decentralization, and automated verification (Singh et al., 2020). For example, in the banking sector, blockchain has demonstrated a positive impact on both the quality of financial reporting and the effectiveness of corporate governance (Al-Shahamani et al., 2025). In the case of ESG reporting, blockchain solves three key challenges in ESG disclosure. Information is collected by creating a private ESG chain within the company; data integration uses cross-chain technology to interact with external systems; and verification leverages the blockchain's integrity and traceability (Zhu, Liu, 2024).

Growing regulatory requirements for sustainability reporting (CSRD and ESRS) therefore motivate the implementation of digital technologies that would facilitate reporting. They indicate that ESG influences the digital transformation of enterprises (Cheng, Li, 2025). Some studies present the use of digital technologies in the industrial, service, and trade sectors, including ERP systems, Big Data and Analytics, Cloud Computing, AI and ML, Blockchain, and IoT (Dudek, Kulej-Dudek, 2024).

For example, among software platforms for digital corporate governance, we can point to ProofHub - project and collaboration management; StudioCloud - cloud solutions; Timely - time and resource management; Scoro - comprehensive business management; iBE.net - corporate solutions; NetSuite - integrated business systems; Bitrix24 - collaboration platform; e-BDS - business decision support systems (Ziniuk et al., 2022). Companies must decide whether to purchase a digital solution or create their own, dedicated to their needs.

The main challenges of implementing digital corporate governance in the context of ESG include high costs for companies (65-75%), technological complexity (59-64%), lack of specialist knowledge (42-59%), internal resistance to change (51-62%) and difficulties in integration with existing systems (55-58%) (Dudek, Kulej-Dudek, 2024).

Another barrier highlighted is the insufficient knowledge of supervisory boards about AI technologies. Only 20-28% of boards possess the appropriate technological expertise (Russell Reynolds Associates, 2025). This problem is compounded by the fact that only 10% of companies plan to add AI/GenAI experts to their boards, while as many as 35% plan to add financial experts (PWCs, 2024).

The main threats to corporate governance digitalization include cybercrime, the rapidly changing world of digital technologies, regulatory challenges, as well as corporate blackmail and market manipulation (Ziniuk et al., 2022). A particular challenge is the opacity of AI decision-making processes, or the blind acceptance or rejection of AI suggestions. Digitalization can lead to a loss of human judgment in decision-making, excessive reliance on technology, and privacy and information security issues (Agnese et al., 2025). One of the threats

to corporate governance bodies, both management boards and supervisory boards, is regulatory uncertainty in implementing digital solutions within corporate governance. Furthermore, concerns arise about legal liability for decisions made using AI and the difficulty of maintaining compliance with various jurisdictions using global digital platforms. Research in Poland indicates that 81% of companies (the sample consisted of 68 large enterprises) are not technologically ready for the new ESG reporting requirements, and 47% of the largest companies still use only Excel spreadsheets (Dudek, Kulej-Dudek, 2024).

The future of digital corporate governance will likely be characterized by higher standards for boards and directors, a differentiated approach to ESG and risk management, and a greater emphasis on executive succession planning (Russell Reynolds Associates, 2025). Corporate governance will evolve from models focused solely on shareholders to an approach that takes into account a broader range of stakeholders (Aguilera, Castillo, 2025). Integrating digital solutions with ESG practices will become increasingly important, with technologies such as AI, IoT systems, and digital twins being key to achieving sustainable development goals (Celary, Piwowarczyk, 2025).

5. Digitalization within the framework of corporate governance principles and requirements

Digital corporate governance can take many forms. The study analyzed the forms of digitalization used based on the corporate governance principles contained in the Best Practices for WSE-Listed Companies (Resolution No. 13/1834, 2021). The degree to which listed companies implement individual principles is monitored on an ongoing basis (GPW, 2025).

The corporate governance principles have been thematically assigned to the individual requirements of ESRS 2 – "General Information" and ESRS G1 – "Business Conduct" (ESRS 2 GOV – 1 and G1-1 to G1-6), also related to corporate governance within the ESG framework. These requirements, together with information on environmental and social matters, are part of the framework for preparing the "Sustainability Statement", previously called the "Non-financial Sustainability Report" (EU Directive, 2022; EU Commission, 2023). Ensuring their appropriate reporting is part of the obligations for companies that report ESG. The very fact of reporting them is evidence of the functioning of corporate governance in this area.

Table 1.
The use of digitalization within the framework of the Corporate Governance Principles included in the Best Practices of WSE Listed Companies and the corporate governance requirements within the ESRS

Principles of Corporate Governance – Good Practices		**ESRS 2**	**ESRS G1**
Chapters, Rules	**Principles – a directly indicated way of digitization**		
1. Information policy and communication with investors	1.1. The company maintains efficient communication with capital market participants, providing reliable information on matters affecting it. To this end, it utilizes a variety of communication tools and forms, including, above all, its corporate website, where it publishes all information relevant to investors.		
	1.4. In order to ensure proper communication with stakeholders regarding the adopted business strategy, the company publishes on its website information on the assumptions of its strategy, measurable goals, including in particular long-term goals, planned activities and progress in its implementation, determined by means of financial and non-financial metrics.		
2. Management Board and Supervisory Board		**GOV – 1 – The role of administrative, management and supervisory bodies**	**G1-1 – Business Conduct Policies and Corporate Culture**
		GOV-2 – Information provided to the administrative, management and supervisory bodies of the entity and the issues they undertake related to sustainable development	**G1-5 – Political Influence and Lobbying Activities**
		GOV - 4 – Due Diligence Statement	

Cont. table 1.

3. Internal systems and functions		**GOV-5 – Risk management and internal controls over sustainability reporting**	**G1-2 – Supplier Relationship Management**
			G1-3 – Prevention and Detection of Corruption and Bribery (Appendix A – p. 248 Disclosure Requirement G1-3 – Prevention and Detection of Corruption and Bribery). To inform groups (employees, contractors and suppliers) about anti-corruption and anti-bribery strategies, the entity may disclose communication tools and channels (e.g., leaflets, newsletters, dedicated websites, social media, direct interactions, unions or employee representatives).
			G1-4 – Incidents of corruption or bribery
			G1-6 – Payment Practices
4. General Meeting and shareholder relations	4.1. A company should enable shareholders to participate in a general meeting using electronic means of communication (e-general meeting), if this is justified by the shareholders' expectations notified to the company, provided that it is able to provide the technical infrastructure necessary to conduct such a general meeting.		
	4.2. The Company provides publicly available real-time broadcasts of the general meeting.		

Cont. table 1.

	4.9.1. Candidates for members of the supervisory board should be submitted in time to enable shareholders present at the general meeting to make informed decisions, but no later than 3 days before the general meeting; the candidates, together with all relevant materials, should be published immediately on the company's website.		
	4.11. Members of the management board and supervisory board participate in the general meeting, either on-site or via real-time two-way electronic communication, in a composition that allows them to comment on the matters on the agenda of the general meeting and to provide substantive answers to questions posed during the general meeting. The management board presents the company's financial results and other important information, including non-financial information, contained in the financial statements subject to approval by the general meeting to the participants of the annual general meeting. The management board discusses significant events related to the previous financial year, compares the presented data with previous years, and indicates the degree of implementation of the previous year's plans.		
5. Conflict of interest and related party transactions			
6. Salaries		**GOV-3 – Incorporating sustainability outcomes into incentive systems**	

Source: Own study based on Resolution No. 13/1834/2021 of the Supervisory Board of the Warsaw Stock Exchange S.A. of 29 March 2021 on the adoption of the "Best Practice for GPW Listed Companies 2021", 2024/9043 Corrigendum to Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council with regard to sustainability reporting standards (Official Journal of the European Union L, 2023/2772, 22 December *2023),* http://data.europa.eu/eli/reg_del/2023/2772/corrigendum/2024-07-29/oj

The principles contain direct references to digitalisation, while the requirements only make such a reference in Disclosure of Information G1-3 – Prevention and Detection of Corruption and Bribery in Appendix A. In fact, in the case of all ESRS 2 and ESRS G1 requirements, ICT can be used in the practice of disclosure and preparation of information, e.g. websites, management report published on the Internet.

6. Application of digital corporate governance on the example of Tauron Polska Energia S.A.

Digitalization at TAURON Polska Energia S.A. serves the implementation of both the WSE Best Practices and the ESRS Requirements. It encompasses all key areas of corporate governance, with a particular emphasis on cybersecurity and data protection. Digital technologies are used to increase the availability of information for stakeholders and enhance the efficiency of business processes through automation. Digitalization introduces modern technologies such as AI and data analytics. Among the key areas of digitalization in corporate governance are stakeholder communication and transparency. These include digital communication channels such as a website as the primary tool for publishing information on the application of the Best Practices, dedicated online sections for investor relations, publicly available real-time online broadcasts of General Meetings, and electronic forms for contacting investors. Another area is supplier and business process management, which includes digital financial and accounting systems, a dedicated digital application for managing supplier relationships, electronic invoices, and electronic purchasing systems supporting the Corporate Procurement Policy. Training and building corporate culture are achieved through e-learning and digital educational tools, such as those related to compliance and business ethics training, digital platforms for disseminating corporate codes and policies, and the Intranet as an internal communication tool. Tauron Polska Energia S.A. has an advanced cybersecurity system. This is reflected in a comprehensive approach to digital security based on the TAURON Group Cybersecurity Policy; IT/OT (Operational Technology) Systems Management; Security Incident Management Principles; Security Standards for the IT/OT Area; and the Business Continuity Plan (CRP) for terrorist threats to ICT systems. Innovations in data management include the development of AI (Artificial Intelligence) guidelines and the implementation of Data Governance.

Table 2.
The use of digitalization within the framework of the Corporate Governance Principles included in the Good Practices of WSE-listed companies and corporate governance requirements within the ESRS, as exemplified by Tauron Polska Energia S.A.

Principles of Corporate Governance – Good Practices	ESRS 2	ESRS G1
Chapters, rules		
Applied set of corporate governance principles In 2024, the Company was subject to the corporate governance principles contained in the Best Practices for GPW Listed Companies 2021 (Best	**Management Structure (GOV-1)** Information presented in the Management Board's Report	**ESRS 2 GOV-1 The Role of Administrative, Management, and Supervisory Bodies** Management Report (pp. 318 and pp. 159-164) **(G1.IRO-1) Description of processes for identifying and assessing significant impacts, risks, and opportunities**

Practices), adopted by the GPW Supervisory Board by Resolution No. 13/1834/2021 of March 29, 2021, which entered into force on July 1, 2021. Current information on the Company's compliance with the principles contained in the Best Practices is available on the Company's website at: https://www.gpw.pl/komunikat?geru_id=457865&title=TAURON+Polska+Energia+Sp%C3%B3%C5%82ka+Akcyjna+-+informacja+o+stanie+stosowania+Dobrych+Praktyk+2021 In an effort to apply the broadest possible scope of Best Practices, in 2024, in connection with the announcement of a new dividend policy together with the TAURON Group Strategy for 2025-2035, the adoption of new Internal Audit Regulations in the TAURON Group, and amendments to the Organizational Regulations, the Company began applying principles 3.6. (concerning the organizational and functional subordination of the person heading the internal audit function) and 4.14. (concerning the dividend payment rules). Updated information on the Company's application of the principles contained in the 2021 Best Practices was posted on the Company's website at the above-mentioned address on December 17, 2024. The set of corporate governance principles from which application was waived is presented in the Management Board's Report on Operations (pp. 102-104) along with explanations. **1. Information Policy and Investor Communication** Information presented in the Management Board's Report on Operations (pp. 97-98) and in: https://www.tauron.pl/tauron/relacje-inwestorskie https://www.tauron.pl/tauron/o-tauronie/raportowanie-esg https://nowaenergia.tauron.pl/ https://www.tauron.pl/tauron/relacje-inwestorskie/kontakt-dla-inwestorow/formularz	on Activities (pp. 113-138) **(GOV-1, GOV-2) ESG governance structure at the TAURON Group** Information presented in the Management Board's Report on Operations (pp. 159-163) **(GOV-3) Incorporating ESG-related performance into the incentive system** Management Board Report on Activities (pp. 163 and 140-147) **(GOV-4) Due Diligence Statement** Management Report on Activities (pp. 163-164) **Risk management and internal controls over sustainability reporting (GOV-5)** Management Board's activity report (pp. 164-165)	Management's Report on Activities (pp. 318-319 and pp. 177-180) **(G1-1) Business Conduct Policies and Corporate Culture** Management Board's report on activities (pp. 319-321) and on the website, intranet, electronic forms, e-mail addresses, e-learning training 1. TAURON Group's Code of Responsible Business, 2. TAURON Group's Compliance Policy, 3. TAURON Group's Anti-Corruption Policy, 4. TAURON Group's Human Rights Policy, 5. TAURON Group's Procedure for Reporting Irregularities and Taking Follow-Up Actions, 6. TAURON Group's Procedure for Counteracting Money Laundering and Terrorism Financing, 7. TAURON Group's Procedure for Assessing the Credibility of Contractors. **(G1-2) Supplier Relationship Management** Management Board's report on operations (pp. 321-322) and digital financial and accounting systems, dedicated digital application, electronic invoices. 1. TAURON Group Corporate Procurement Policy 2. Code of Conduct for Business Partners of TAURON Group Companies **(G1-3) Prevention and detection of corruption and bribery** Management Board's report on activities (pp. 322-323) and website, intranet, e-learning training 1. Rules for accepting and giving gifts at the TAURON Group 2. Rules for preventing conflicts of interest at the TAURON Group **(G1-4) Incidents involving corruption or bribery** Management Board's Report on Activities (pp. 323-324) **(G1-5) Political influence and lobbying activities** No information in the Management Board's Report on Activities **(G1-6) Payment Practices** Management Board's Report on Activities (p. 324) **Safety Management System** Management Report on Activities (pp. 324-326) Security management is divided into substantive areas, including: 1. Security Management System, 2. Information Security, 3. IT/OT Systems Security, 4. Physical Security, 5. Security Incidents. Corporate regulations specifically regulate specific aspects of security in a given area of operation:

2. Management Board and Supervisory Board Information presented in the Management Board's Report on Operations (pp. 98-99) **3. Operation of Internal Systems and Functions** Information presented in the Management Board's Report on Operations (p. 99) **4. General Meeting and Shareholder Relations** Information presented in the Management Board's Report on Operations (pp. 100-101) The Company has provided publicly available Real-time broadcast of each General Meeting in 2024 and at: https://www.tauron.pl/tauron/relacje-inwestorskie/walne-zgromadzenie **5. Conflict of interest and related party transactions** Information presented in the Management Board's Report on Activities (pp. 101-102) and at: https://www.tauron.pl/tauron/relacje-inwestorskie/wykaz-istotnych-transakcji **6. Remuneration** Information presented in the Management Board's Report on Activities (pp. 102 and pp. 140-147)		1. TAURON Group Security Management System Policy – general document, 2. TAURON Group Information Classification and Handling Policy, 3. TAURON Group Physical Security Policy, along with a set of detailed requirements for physical security, 4. TAURON Group Cybersecurity Policy, 5. TAURON Group OT Policy, 6. TAURON Group OT System Management Principles, 7. TAURON Group IT System Management Principles, 8. Comprehensive set of security standards for the IT/OT area, 9. TAURON Group Security Incident Management Principles, 10. TAURON Group Task Force Cooperation Principles in the Event of CRP Alert Levels Announced in the Event of a Terrorist Threat to ICT Systems, 11. Requirements for Designers and Contractors of Technical Security Systems and Fire Alarm Systems in TAURON Group, 12. Guidelines for the use of Unmanned Aerial Vehicles in the TAURON Group, 13. Principles for the reuse and secure destruction of information media in the TAURON Group. In 2024, guidelines were developed for AI and Data Governance.

Source: Own study based on the Management Board's report on the operations of Tauron Polska Energia S.A. and Tauron Capital Group for the financial year 2024 and the websites of Tauron Polska Energia S.A. and Tauron Capital Group

Tauron Polska Energia S.A. Tauron demonstrates a mature approach to the digitization of corporate governance. It combines compliance requirements with modern technological solutions, enabling effective management and transparent reporting.

7. Discussion

This article presents the range of digital technologies used in corporate governance. Artificial intelligence (AI) is among them, and is used for board diversity analysis, real-time monitoring, decision-making support, regulatory compliance, audit process improvement, and shareholder engagement. Blockchain is another technology, which ensures transparency and security of corporate processes, data immutability and decentralization, verification

automation, and addressing ESG reporting challenges. Big Data, which positively impacts board oversight, social responsibility, and fraud detection, is another key technology. The analysis also highlights other technologies, such as IoT systems and digital twins, cloud platforms, ERP systems, and distributed ledger technology (DLT) solutions.

The article also maps the ESRS requirements to corporate governance principles. It indicates that most of the ESRS requirements can be supported by ICT, particularly in the area of information disclosure via websites and digital reports. In the case of TAURON Polska Energia S.A., digitalization in the implementation of the WSE Best Practices includes, among others, communication with stakeholders via corporate websites, dedicated investor relations sections, real-time online broadcasts of General Meetings and electronic forms for contact with investors.

TAURON Polska Energia S.A. implements digital solutions as part of the implementation of ESRS requirements within digital financial and accounting systems, electronic purchasing systems, websites and intranet, electronic forms, e-learning training, Cybersecurity Policy, IT/OT systems management, Security incident management principles, Business Continuity Plan for terrorist threats to ICT systems, AI guidelines, Data Governance.

Based on the analysis, it can be concluded that corporate governance is evolving towards digitalization. It involves the integration of digital technologies with traditional management structures. This evolution is not optional, but is becoming an imperative for competitiveness. Digitalization in corporate governance goes beyond simple process digitization and encompasses, among others, artificial intelligence, blockchain, big data, and IoT.

The main barriers to implementing digital corporate governance include high costs, technological complexity, lack of specialist knowledge and internal resistance to change.

8. Summary

The analysis indicates that the digitalization of corporate governance is an inevitable transformational process. It is fundamentally changing the way modern enterprises are managed. The analysis of the TAURON Polska Energia S.A. case study confirms the practical application of integrating digital technologies with corporate governance requirements in accordance with the WSE Best Practices and ESRS standards. Digital technologies can significantly improve the functioning of management and supervisory bodies by, among other things, increasing transparency, efficiency, and compliance with regulatory requirements.

As part of the practical implications for businesses, the analysis highlights the need to develop a corporate governance digitalization strategy that takes into account industry specifics. There is also a need to invest in the digital competencies of management and supervisory board members, as well as implement integrated digital platforms supporting all aspects of corporate

governance. Another aspect is the need to update the regulatory framework to incorporate the capabilities of digital technologies, develop guidelines for the secure use of AI and blockchain in management processes, and create cybersecurity standards for digital corporate governance. Furthermore, assessing digital maturity as a criterion for assessing the quality of corporate governance is becoming crucial.

The research has limitations. Among them, the analysis of only a single case study based on a single financial year limits the generalizability of the results and prevents the assessment of long-term trends. Comparisons with international practices outside the Polish capital market were also not made. The focus was on compliance aspects without a thorough analysis of the economic effectiveness of digitalization.

Further research could focus on various areas. This could include analyzing corporate governance digitalization practices across various economic sectors, as well as international comparisons of digital solutions in corporate governance. Interesting issues could include assessing the impact of corporate governance digitalization on corporate financial performance or developing digital maturity models for corporate governance.

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BUDGETING FOR THE FUTURE: RELATIONSHIP BETWEEN INTENSITY OF BUDGETING METHODS AND SUSTAINABILITY PERFORMANCE

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Purpose: This research empirically assesses the relationship between corporate budgeting methods and sustainable performance.
Design/methodology/approach: The analysis utilized Ordinary Least Squares regression, the Random Forest model, and the Explainable Artificial Intelligence technique SHAP on a global sample of 399 budgeting practitioners.
Findings: The findings indicate that alignment with competitive strategy is the most significant positive predictor of sustainability performance. In contrast, high environmental uncertainty exerts a significant negative influence on these outcomes. Budgeting methods serve as essential tools for implementing and monitoring organizational strategy. The results demonstrate a significant positive association between intensive use of Budgeting in a Variable Costing System, Flexible Budgeting, and Bottom-Up Budgeting, and sustainability performance. Intensive application of budgeting in Variable Costing enhances the visibility and immediate accounting of direct costs, such as materials, energy usage, and waste disposal, during production. This approach supports efficiency, discourages overproduction, and reduces environmental footprints. Bottom-Up Budgeting fosters employee engagement and uncovers specific, small-scale opportunities for cost reduction and efficiency that are often overlooked by senior management. The analysis also reveals that Activity-Based Budgeting and Budgeting using a functional cost structure may negatively impact sustainable performance, as these methods do not adequately distinguish between critical environmental costs or reflect waste discharge. However, the study provides a nuanced view of this relationship by operationalizing organizational structure quality; specifically, the findings reveal that the negative impact of Activity-Based Budgeting is significantly mitigated in organizations characterized by efficient communication channels, clear decision-making processes, well-defined role accountability, and employee empowerment. The application of the following budgeting methods demonstrates greater similarity among each other than with the remaining approaches: Bottom-Up Budgeting and Participative Budgeting, Budgeting in a Variable Costing System and Budgeting using a functional structure of costs, Rolling Budgeting and Performance-Based Budgeting, Flexible Budgeting, and Beyond Budgeting. In contrast, the intensity of usage for Static Budgeting differs substantially from all other methods.

Research limitations/implications: This study addresses a gap in the literature regarding the impact of budgeting methods on sustainable performance.
Practical implications: It provides practical insights for managers seeking to enhance sustainability through budgeting approaches.
Originality/value: This paper provides the first empirical evidence linking the intensity of usage budgeting methods and sustainable performance. The methodological approach is the first to employ Machine Learning (ML) techniques such as Random Forest, SHAP, and Hierarchical Clustering.
Keywords: budgeting, budgeting methods, management accounting, sustainability, machine learning.
Category of the paper: Research paper.

1. Introduction

Sustainability, which refers to the impact on the environment or society, has become a crucial part of organizations. In the European Union (EU), numerous initiatives are being undertaken to support the transition to a circular economy. An example is the European Green Deal (EGD), an attempt to transform the EU economy to achieve climate neutrality by 2050 (Dahl, 2021). Approved in 2020, it sets more than 175 directives and regulations that establish clean energy investment, climate tech innovation, carbon pricing, and sustainability reporting for public companies (Buysing Damsté et al., 2024).

However, reporting is the final stage of business processes. At the beginning of the road, there is always a plan for allocating resources to achieve organizational targets. A budget is a comprehensive financial plan that outlines the expected path for achieving an organization's financial and operational objectives (Yilmaz, 2018). Budgeting is the process of obtaining a budget (Obi, 2015).

Presently, the integration of sustainability considerations represents a critical emerging focus within the corporate budgeting paradigm. Although corporate strategy is the primary driver of corporate behavior, budgeting is considered a crucial tool for implementing and monitoring that strategy, as well as fulfilling various additional responsibilities (Nguyen et al., 2018). Therefore, the budgeting methods play an essential role as a facilitator or barrier to executing the adopted strategy.

The relationship between budgeting methods and attaining sustainability goals has attracted attention in contemporary management discourse. While organizations strive to reach financial profitability and environmental liability, the meaning of the budget extends beyond simply allocating resources and managing costs. Effective budget methods are essential to promoting sustainable practices that align with social and environmental objectives. Management accounting's ability to develop, implement, and perfect these budget methods positions it as a crucial facilitator of sustainability initiatives.

Previous literature emphasizes the crucial role of innovative management tools, particularly in budgeting, in achieving sustainable results. For example, Vărzaru et al. (2022) highlight how advanced frameworks, such as beyond budget, zero-based budget, and activity-based budgeting, can improve organizations' ability to respond to environmental challenges. These innovative approaches incorporate environmental and social performance metrics into their budget processes, encouraging a more holistic perspective that prioritizes sustainability and traditional financial metrics.

Empirical tests support the thesis that the various budget methods can significantly affect both financial and sustainability metrics. Kihn (2010) claims that adopting participatory budget practices, which involve the parties concerned throughout the organization, can lead to greater responsibility and the resolution of innovative problems related to allocating resources for sustainable initiatives. The findings of numerous studies also emphasize the role of particular corporate budgeting methods in supporting sustainability objectives within enterprises. These methods include flexible budgeting (Hansen et al., 2003), rolling budgeting (Håkonsson et al., 2013), incremental budgeting (Lee et al., 2016), zero-based budgeting (ZBB) (Okoh et al., 2023), budgeting under variable costing (Burritt, Schaltegger, 2001), activity-based budgeting (Hossain, Hasan, 2024), top-down budgeting (Kim, Park, 2006), bottom-up budgeting (Ugalde Vasquez, Naranjo-Gil, 2020), and beyond budgeting (Bogsnes, 2016; Matějka et al., 2021).

These findings underscore the crucial role of individual budgeting methods in advancing the Sustainable Development Goals (SDGs). However, a comprehensive evaluation is lacking — one that simultaneously examines the application of various corporate budgeting methods. Such an analysis could identify which methods most effectively support sustainability goals, determine those with the highest impact, and classify groups of budgeting methods with similar characteristics. This gap represents a significant research opportunity in management accounting, which the authors aim to address in this study.

The need for an investigation into adopting different budget methods is underlined by the transformations within corporate environments led by the imperative for sustainability. Organizations are aware of the pressure to align their operations with environmental expectations and request a critical examination of how budget methods influence their ability to achieve sustainability while maintaining financial objectives. Therefore, future research should investigate the specific budget methodologies employed in various sectors and their impact on sustainability and financial health.

The literature search, conducted using the terms “budgeting methods” and “sustainability” in the bibliographic databases Scopus, clearly confirms the research gap. The link between budgeting and sustainability in the literature is dominated by theoretical papers and case studies, with a significant lack of large-scale, quantitative survey data that tests these relationships across multiple companies, sectors, and countries.

The paper is divided into sections: Section 1 is an introduction, and Section 2 presents the literature review. Section 3 outlines the methodology employed in this research, and Section 4 presents the results. Section 5 is a discussion. Finally, Section 6 draws conclusions and recommendations for future research.

2. Literature Review

Understanding how budgeting aligns organizational priorities with sustainability targets bridges the gap between theoretical concepts and management practices. Derchi et al. (2013) demonstrate that integrating environmental concerns into budgeting depends on technical expertise, external pressures, and internal readiness. Christ and Burritt (2013) emphasize the need for innovation in budgeting processes to better address environmental costs. This resonates with Dunk (2012), who links budgeting's planning and control aspects to environmental performance. Schaltegger and Csutora (2012) emphasize the importance of carbon accounting, advocating for rigorous accounting practices that extend beyond compliance to proactively pursue sustainability.

Lueg and Radlach (2016) argue that robust management accounting supports financial and sustainability objectives through stronger resource allocation and performance measurement. Similarly, Lavia López and Hiebl (2015) note that incorporating sustainability considerations in management accounting can enhance overall financial performance. Digitalization further intensifies this relationship. Rikhardsson and Yigitbasioglu (2018) highlight the role of business intelligence in improving the accuracy of both financial and sustainability reporting. Table 1 provides potential advantages of budgeting for sustainable development.

Table 1.
Variable literature

Variable	Description, literature
SD1	Budgeting fosters resource optimization and reduction (Obi, 2015; Yilmaz, 2018; Fortuna, 2021)
SD2	Budgeting drives cost reduction (Argyris, 2013; Obi, 2015)
SD3	Budgeting supports the adaptation of the business model to environmental needs (Abernethy, Brownell, 1999; Szczypa, 2016)
SD4	Budgeting helps lower carbon emissions (Goulder et al., 2010; Kotnik et al., 2017)
SD5	Budgeting extends product lifecycles (Dunk, 2012; Westkämper, 2000)
SD6	Budgeting allocates funds for green investments (Burritt, Schaltegger, 2001; Unruh et al., 2016)
SD7	Budgeting boosts productivity and curbs waste (Kotnik et al., 2017; Brink et al., 2018)

Source: own work.

Under the right conditions, even traditional budgeting can incorporate sustainability metrics to elevate environmental and social goals alongside financial targets (Baumgartner, 2014). A culture of flexibility can enable innovative sustainability projects to flourish (Hansen et al., 2003). Recent shifts also highlight a growing recognition of financial tools as catalysts for sustainable development (Balstad, Berg, 2020).

Grossi et al. (2020) observe that more rigorous budgeting can effectively integrate sustainability considerations into decision-making processes. Similarly, Burritt and Saka (2006) demonstrate that detailed environmental cost tracking leads to better resource efficiency and improved sustainability performance. However, smaller enterprises often face resource constraints that impede sophisticated budgeting (Pelz, 2019). When rigid adherence to traditional methods hinders experimentation, more flexible or rolling approaches may be more beneficial (Bogsnes, 2016; Ekholm, Wallin, 2000).

Incremental Budgeting supports gradual resource adjustments and can foster long-term environmental objectives, but it may discourage radical innovation (Weston, Nnadi, 2023). Zero-based Budgeting (ZBB) encourages strategic questioning of expenditures, thus boosting sustainability investments (Okoh et al., 2023). However, ZBB may demand significant implementation resources (Allen, Clifton, 2023). A balanced approach remains vital to align accountability with sustainable growth (Appannan et al., 2023).

Static Budgeting can limit agility and slow responses to environmental demands (Ekholm, Wallin, 2011). Flexible Budgeting adapts better to sustainability initiatives, assuming the organization can handle added financial complexity (Al-Baghdadi et al., 2021). Rolling forecasts allow organizations to refine plans regularly in line with evolving sustainability goals (Okeke et al., 2024). Flexibility is essential in sustainable services, as it allows organizations to adapt to changes in their environment, such as new regulations or changes in consumer preferences towards more sustainable products. For example, as defined by Cowell et al. (2020), flexible budgets are important for implementing biological monitoring in protected areas, which is increasingly vital as environmental concerns intensify.

Variable Costing clarifies cost structures but may mislead managers when fixed expenses are high (Burritt, Schaltegger, 2001). The analysis of variable costs can lead to increased financial services for manufacturing companies when sustainability measures are integrated into the budget. This integration enables organizations to align their budget activities with sustainability, supporting the efficient use of resources and minimizing waste. Functional Costing aids budget precision at the department level but risks siloed thinking that undermines collaboration on sustainability programs (Sanford, 2009). Activity-Based Costing (ABC) pinpoints environmental cost drivers, potentially improving both ecological and financial performance (Maiga et al., 2014; Hossain, Hasan, 2024), although implementation can be complex (Jänkälä, Silvola, 2012). Integrating advanced technology may help, but it also requires cultural shifts and a commitment from stakeholders (Al-Kawaz et al., 2023).

Top-down budgeting can expedite decision-making for sustainability but might limit lower-level inputs (Kim, Park, 2006). Bottom-up methods encourage stakeholder involvement, often leading to superior environmental outcomes and stronger innovation (Ugalde Vasquez, Naranjo-Gil, 2020). Participatory processes can also enhance employee acceptance of sustainability measures (Bartocci et al., 2023).

Performance-based Budgeting (PBB) ties funding to defined goals, potentially increasing accountability for sustainability (Huy, Phuc, 2022). However, narrow metrics can lead to data manipulation and sideline long-term ecological concerns (Mauro et al., 2021). The Beyond Budgeting model offers adaptability and transparency, encouraging local teams to act on sustainability priorities (Bogsnes, 2016; Matějka et al., 2021). Resistance to change and the need for new competencies continue to be challenges (Amini et al., 2019).

Traxler et al. (2020) find that rigorous budgeting frameworks are correlated with better environmental performance, supporting the argument that management accounting has a direct influence on sustainability practices. Vale et al. (2022) further assert that incorporating sustainability into management accounting can enhance governance structures and create shareholder value.

The literature suggests that aligning budgeting methods with sustainability amplifies organizations' capacity to balance financial efficiency with social and environmental stewardship. Integrating modern budgeting practices with a sustainability lens pushes beyond traditional cost-control paradigms, fostering long-term corporate resilience. These insights pave the way for further exploration of how diverse organizational contexts shape the role and efficacy of intensive budgeting in achieving sustainable development goals.

Enterprises employ various budgeting methods, classified according to various criteria, and may even apply multiple approaches under the same criterion. A thorough review of the literature indicates that the intensive use of diverse corporate budgeting methods — both conventional (e.g., variable costing-based budgeting, function-based cost budgeting, incremental budgeting, flexible budgeting) and modern (e.g., ZBB, participatory and bottom-up budgeting, activity-based budgeting (ABB), rolling budgeting, beyond budgeting) — supports the achievement of enterprises' sustainable development goals.

However, comprehensive studies that examine multiple budgeting methods across different classification criteria and comparative assessments of how various budgeting methods aid in achieving corporate sustainability remain scarce. Moreover, the degree of similarity in using different budgeting methods (i.e., identifying groups of budgeting methods with comparable levels of application intensity) has not been investigated. These underexplored areas are crucial for assessing how budgeting methods enable enterprises to pursue sustainability, particularly since companies often employ multiple budgeting methods concurrently. This gap in the research leads to the following questions:

Q1: What is the relative importance and independent contribution of a firm's budgeting method in explaining its sustainability performance?

Q2: Are there groups of corporate budgeting methods whose application intensities are similar?

According to the theory of contingencies, previous research suggests that contextual factors, including organizational structure quality, environmental uncertainty, and support for competitive and functional strategies (e.g., sales, production, procurement), influence

a company's performance (Piosik, Karmańska, 2023, 2025). Analysis of the previous studies enables the formulation of the following research question:

Q3: What is the relative importance and independent contribution of environmental uncertainty, competitive strategy, and structure quality in explaining a firm's sustainability performance?

3. Methods

The survey questionnaire was developed based on a literature review. It was emailed to 37600 companies between August 2023 and April 2024, targeting managers, chief accountants, and accounting specialists involved in budgeting. The base population of our study consisted of 399 respondents from 58 countries, mainly in Europe. Table 2 presents the distribution of the sample.

Table 2.
Distribution of the sample members

Company size	**Frequency**	**Percentage**
Very Small micro-enterprise (less than ten employees)	89	22.3
Small enterprise (10 to 49 employees)	91	22.8
Medium-sized enterprise (50-249 employees)	91	22.8
Large enterprise (250 employees and more)	128	32.1
Dominant sector of operational activity	**Frequency**	**Percentage**
Trade	75	18.8
Industry	79	19.8
Service	213	53.4
Financial institution	32	8.0
Localization	**Frequency**	**Percentage**
Europe	306	76.7
Asia	43	10.8
North America	29	7.3
Africa	11	2.7
Oceania	7	1.7
South America	3	0.8

Source: own work.

Based on the variables described in Table 1, the study calculated a sustainable score as the sum of respondents' ratings for all the items. According to literature, for example, Warmbrod (2014), if Likert items use the same scale, the responses can be summed to create a composite score for each individual.

Control variables are usually included in regression analyses to estimate the causal effect of a treatment on an outcome (Hünermund, Louw, 2023). Specifically, in this study, the inclusion of control variables serves two primary, interrelated purposes: mitigating omitted variable bias and increasing the precision of the primary coefficient estimates. The regression model was augmented with a set of control variables, including BS - support of competitive strategy and

functional strategies, SQ - quality of the organizational structure, EU - environmental uncertainty.

To assess the relationships between variables, we employed Ordinary Least Squares (OLS) regression, with machine learning techniques, specifically the non-linear Random Forest (RF) algorithm, complemented by the SHAP method for model interpretability and explanation. All models were implemented using Python and its libraries. This hybrid approach allows for capturing both linear trends (OLS) and complex, non-linear interactions (RF).

4. Results

The intensity of usage of individual budgeting methods was measured using a 5-point Likert scale. The responses are coded as follows: (1) not at all - the budgeting method is not used in the company; (2) low intensity, rarely - the budgeting method is used infrequently or on a limited basis; (3) moderate intensity - the budgeting method is used occasionally but not consistently, (4) high intensity - the budgeting method is used frequently and consistently, (5) always - the budgeting methods are intensively and consistently applied in the company.

Table 3 presents the results, frequencies, and volatility measures.

Table 3.
Intensity of usage budgeting methods

Variable		Frequency					Mode	Median	Average
		1	2	3	4	5			
Conventional budgeting method									
IB	Incremental Budgeting	53	53	124	133	36	4	3	3.115
TB	Top-Down Budgeting	50	64	100	133	52	4	3	3.183
VCB	Budgeting in the Variable Costing System	101	58	103	94	43	3	3	2.799
FSB	Budgeting using a functional structure of costs	79	52	100	115	53	4	3	3.028
STAT	Static Budgeting	107	69	94	78	51	1	3	2.742
FLEX	Flexible Budgeting	60	62	115	113	49	3	3	3.073
Modern budgeting method									
ZBB	Zero-Based Budgeting	101	69	117	82	30	3	3	2.677
BB	Bottom-Up Budgeting	107	68	87	91	46	1	3	2.752
PBU	Participative Budgeting	89	64	112	91	43	3	3	2.837
ABB	Activity-Based Budgeting	86	47	113	114	39	4	3	2.932
ROLL	Rolling Budgeting	79	55	113	102	50	3	3	2.972
BEYO	Beyond Budgeting	120	57	119	78	25	1	3	2.576
PBB	Performance-Based Budgeting	66	52	122	123	36	4	3	3.028

Source: own work.

Regarding the intensity of usage, Top-Down Budgeting (TB) emerged as the most prevalent method, recording the highest mean (3.183) and a mode of 4.0. This suggests a clear predominance of hierarchical, centralized budgeting approaches among the surveyed enterprises. Conversely, Beyond Budgeting (BEYO) demonstrated the lowest adoption level

(mean = 2.576, Mode = 1.0), indicating that this framework may be perceived by respondents as structurally difficult to implement within current organizational settings.

In the next step, the respondents were asked to indicate the extent to which budgeting in their company supports its sustainable performance. The responses in the questionnaire are coded using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

A target variable, sustainable score (SUS), was calculated as an individual's summated score of SD1-SD7 items. The results, frequencies, and volatility measures are presented in Table 4.

Table 4.
Intensity of usage budgeting methods

Variable	Frequency					Mode	Median	Average
	1	2	3	4	5			
SD1	26	30	82	186	75	4	4	3.637
SD2	13	45	95	175	71	4	4	3.617
SD3	17	47	122	144	69	4	4	3.504
SD4	61	96	119	83	40	3	3	2.862
SD5	32	58	131	133	45	4	3	3.253
SD6	38	69	128	115	49	3	3	3.170
SD7	33	81	123	109	53	3	3	3.170
SUS							23	23.213

Source: own work.

As Table 4 shows, the respondents' top advantages of budgeting in support of sustainability were resource optimization and reduction, cost-cutting, and the adaptation of the business model to environmental needs.

The analysis further confirms that contextual factors significantly shape sustainability outcomes. Specifically, organizational structure quality (SQ), environmental uncertainty (EU), and the support for competitive and functional strategies (BS)—all measured on a 5-point Likert scale—serve as critical determinants of performance. The descriptive analysis of contextual factors reveals a sample characterized by high strategic maturity and structural stability. Business Strategy Alignment (BS) exhibits a pronounced negative skew (left-skewed distribution), with nearly 40% of respondents reporting high or very high alignment, indicating that budgeting functions primarily as a strategic execution mechanism rather than an isolated accounting task. Organizational Structure Quality (SQ) measures internal governance efficacy, characterized by efficient communication, transparent decision-making, clear accountability, and employee empowerment. The variable SQ demonstrates a strong central tendency with a mode of 3.0 (n = 182). The distribution is also negatively skewed, as 33.6% of practitioners reported high structural integrity compared to 20.8% indicating low quality. Conversely, Environmental Uncertainty (EU) presents positively skewed (right-skewed) distribution, where only 26.8% of the sample experiences high turbulence, while 35.3% operate under relatively stable conditions.

The results of OLS Regression (Table 5) demonstrate while strategic alignment across functional areas (sales, production, and procurement) acts as a robust driver of sustainability, environmental uncertainty remains a significant barrier that managers must navigate. Additionally, the model identifies specific budgeting methods that exert either a significant positive or negative influence on sustainability performance.

Table 5.
Results of OLS Regression

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	17.508	2.405	7.280	0.000***
ZBB (Zero-Based Budgeting)	0.369	0.223	1.656	0.099*
TB (Top-Down Budgeting)	0.396	0.226	1.749	0.081*
BB (Bottom-Up Budgeting)	0.541	0.215	2.516	0.012**
VCB (Variable Costing Budgeting)	0.891	0.217	4.114	0.000***
FSB (Functional Structure Budgeting)	-0.496	0.231	-2.149	0.032**
ABB (Activity-Based Budgeting)	-1.956	0.710	-2.757	0.006***
STAT (Static Budgeting)	-0.361	0.203	-1.777	0.076*
FLEX (Flexible Budgeting)	0.559	0.234	2.386	0.018**
EU (Environmental Uncertainty)	-0.610	0.237	-2.576	0.010**
BS (Business Strategy Alignment)	1.251	0.276	4.538	0.000***
SQ (Organizational Structure Quality)	-0.729	0.684	-1.065	0.288
ABB × SQ (Interaction Term)	0.654	0.210	3.117	0.002***
Model Summary				
Observations	399			
R-squared	0.299			
Adjusted R-squared	0.277			
F-statistic	13.73			
Prob (F-statistic)	< 0.001			

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: own work.

Our model is highly significant, as the F-statistic of 13.73, with an associated p-value (Prob (F-statistic)) of 1.00×10^{-23}, provides conclusive evidence that the set of independent variables collectively explains a significant portion of the variance in the dependent variable SUS.

R-squared indicates that the model explains 29.9% of the variance in the target variable. While this value might appear modest, it is considered satisfactory in the context of social sciences. According to Ozili and Ozili (2022), an R-squared of at least 10% is acceptable provided that most predictors are statistically significant. This threshold acknowledges that human behavior—driven by individual self-interest, group dynamics, and emotions—is inherently complex, making it difficult, if not impossible, to predict with absolute precision.

The minimal difference between the R-squared and Adjusted R-squared of 27.7% confirms that the model is not over-specified; the included variables are meaningful contributors.

The coefficients reveal the specific significant relationships between the predictors and the dependent variable SUS. The variables BB (β = .541, p = .012), VCB (β = .891, p < .001), FLEX (β = .559, p = .018), and BS (β = 1.251, p < .001) all have a significant positive impact on the dependent variable. Support for competitive and functional strategies demonstrates the most substantial positive influence. Among budgeting methods, Variable Costing, Flexible Budgeting, and Bottom-Up Budgeting are associated with significant positive impacts on sustainability performance. We also found negative significant effects: FSB (β = -.496, p = .032), ABB (β = -1.956, p = .006), and EU (β = -.610, p = .010). The methods Activity-Based Budgeting and Budgeting using a Functional Structure of Costs have a negative relationship with the sustainability performance. However, we found that the interaction effect ABB x SQ remains positive and highly significant (β = .654, p = .002). This confirms that the organizational structure quality moderates the negative effect of ABB. As SQ increases, the negative impact of ABB on the sustainability performance diminishes. The results also indicate that environmental uncertainty EU has a negative and significant relationship with sustainability performance (β = -.610, p = .010). While SQ (p = .288) is not statistically significant as a main effect, its role is primarily confirmed as a moderator in the model.

The resulting regression model is presented with the following equation:

$$SUS = 17.508 + 0.369(ZBB) + 0.396(TB) + 0.541(BB) + 0.891(VCB) - 0.496(FSB) - 1.956(ABB) - 0.361(STAT) + 0.559(FLEX) - 0.610(EU) + 1.251(BS) - 0.729(SQ) + 0.654(ABB\ x\ SQ) + \varepsilon \quad (1)$$

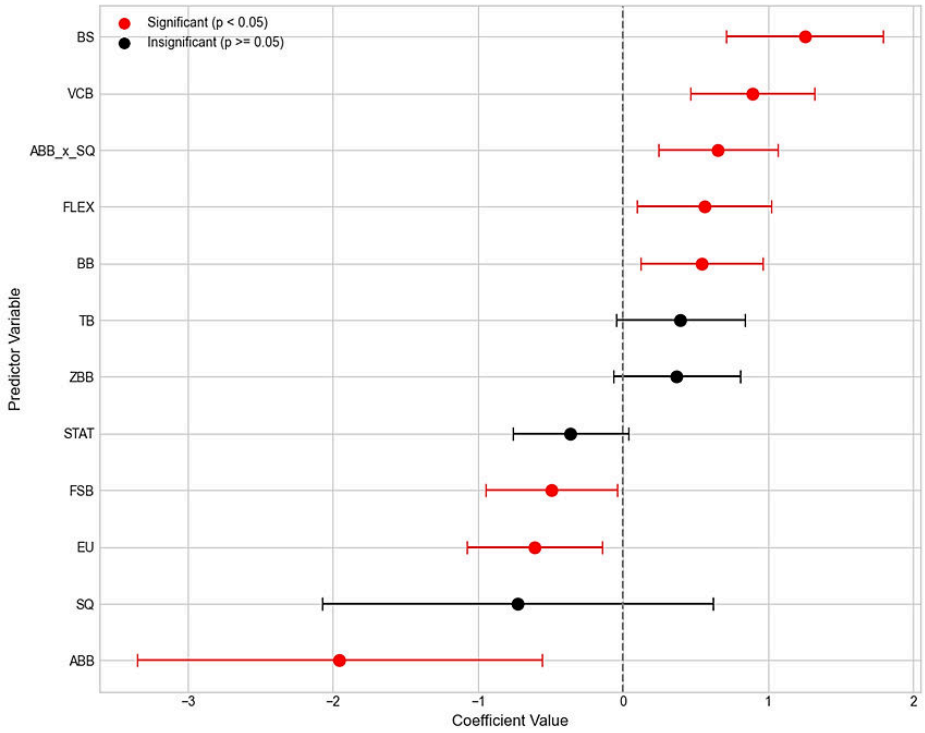


Figure 1. OLS Model Coefficients by Statistical Significance.

Source: own work.

The forest plot (Figure 1) visualizes the results of the OLS regression model. It displays variables, coefficient estimate (the dot) and the 95% confidence interval, that are the most important and reliable predictors in the model (the red dots, $p < .05$) and which variables appear to have no statistically detectable effect (the black dots, $p \geq .05$). The vertical line ($x = 0$) represents a zero effect, where the predictor variable has no statistical relationship with the outcome variable SUS.

A Random Forest (RF) algorithm was also implemented; however, it exhibited lower predictive power compared to the linear model, with an R-squared value of 0.18. It suggests that the relationship between predictors and the dependent variable in the sample are predominantly linear, with a lack of substantial non-linear complexities or high-order interactions that would typically favor machine learning algorithms. In the next step, the SHAP technique explained which features were most important in driving the predictions and how they interacted to produce the final result. The beeswarm plot (Figure 2) displays an information-dense summary of how the top features in a dataset impact the model's prediction (Lundberg, 2023).

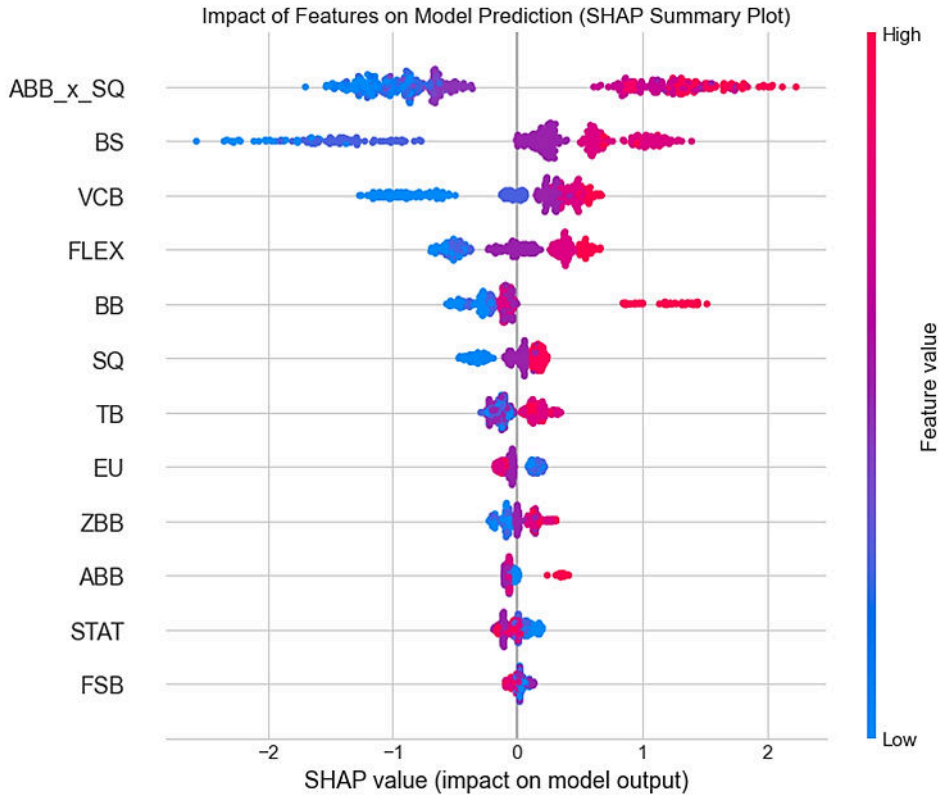


Figure 2. OLS Model Coefficients by Statistical Significance.

Source: own work.

It is visible that Budgeting in Variable Costing System, Flexible Budgeting, and Bottom-Up Budgeting (BB) are the three top methods that have a positive impact on the final prediction.

Subsequently, the ML algorithm Hierarchical Clustering was employed to group input variables into a tree of nested clusters of similar objects (Figure 3). In this model, we exclusively considered the intensity of use of specific budgeting methods as input variables; we did not incorporate control variables.

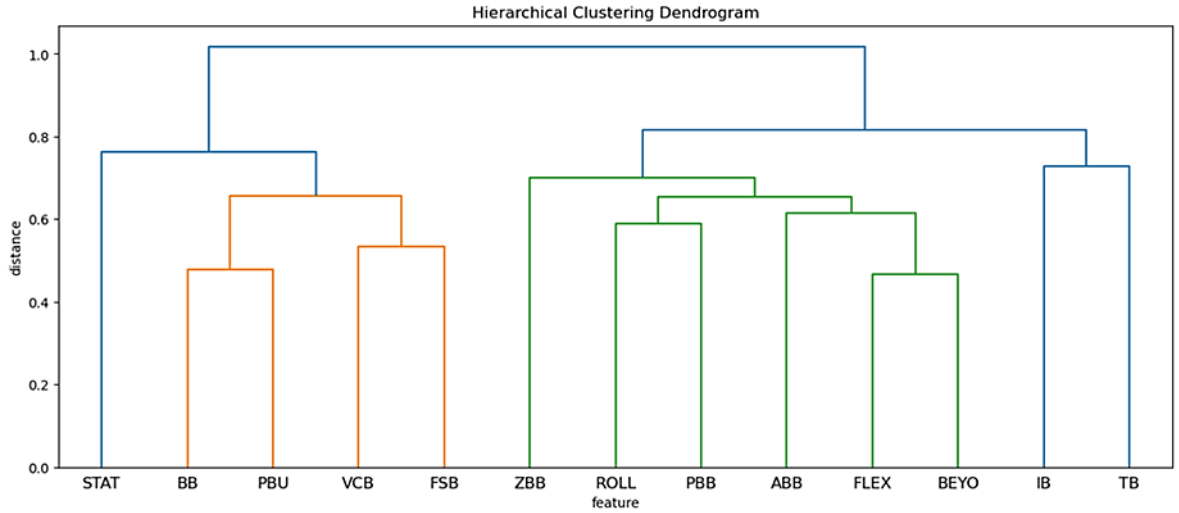


Figure 3. Hierarchical clustering of the budgeting methods.

Source: own work.

This dendrogram visually groups features (the intensity of usage specific budgeting methods) based on their informational similarity and redundancy as perceived by the model. FLEX and BEYO are clustered low. This means that the intensity of use of these two methods is highly correlated. PBU and BB, as well as VCB and FSB, also exhibit similar patterns of usage. Meanwhile, leaf STAT is substantially different from all of the other clades. It remains on a distinct branch and is only joined to the other clusters at a very high distance. This indicates that the usage pattern of STAT is not redundant with other budgeting methods.

5. Discussion

The first research question has been addressed positively. The results indicate that an overarching strategy exerts the most substantial positive influence on sustainability performance, whereas budgeting methods vary in their effectiveness. These findings are consistent with existing literature, as traditional budgeting methods have been criticized. For example, Qu et al. (2022) observed that such methods often fail to provide the necessary information for environmental economic management decisions.

The findings confirm that specific budgeting methods, including Budgeting within a Variable Costing system, Flexible Budgeting, and Bottom-Up Budgeting, can universally enhance sustainability performance. This effect remains robust across various strategies and

under uncertain conditions. In a Variable Costing system, fixed manufacturing overhead is excluded from the product cost of production. The primary accountability measure for managers is the contribution margin, calculated by subtracting variable costs from sales revenue. Consequently, this approach aligns financial incentives with resource efficiency, thereby reducing overproduction, minimizing material waste, and improving energy efficiency.

Extensive use of Flexible Budgeting also strongly supports sustainable strategies. This dynamic approach adapts to changes in production volume, market volatility, and environmental uncertainty, allowing for seamless adjustments. Flexible Budgeting facilitates the alignment of budget allocations with actual performance, helping to isolate waste attributable to production volume.

In Bottom-Up Budgeting, employees at the operational level, who possess detailed and practical knowledge of specific processes, resource utilization, and waste generation, are responsible for constructing the budget. In contrast to top management, who prepare Top-Down Budgeting, lower-level managers and staff can establish more realistic targets and incorporate opportunities for eco-efficiency. Furthermore, involvement in the budgeting process increases engagement and accountability, as individuals feel responsible for the execution of the budget.

The results indicate that two budgeting methods, Activity-Based Budgeting and Budgeting based on a Functional Structure of Costs, can have a negative impact on sustainability performance. Activity-Based Budgeting enables companies to divide the production process into distinct activity centers, allowing them to estimate and plan resource consumption for each center. However, this approach does not account for waste discharge or its environmental impact (Qu et al., 2022). In response, Qu et al. (2022) introduced Material Flow Cost Accounting - Activity-Based Budget, which transforms a purely operational budget into an environmental-economic budget, thereby generating both environmental and economic benefits for companies. The findings further suggest that the quality of organizational structure moderates the negative impact of Activity-Based Budgeting (ABB) on sustainability performance. Companies that extensively use ABB should therefore promote efficient communication, clear decision-making processes, well-defined roles and accountability, employee empowerment, and other elements that enhance the quality of organizational structure.

In budgeting systems that use a functional structure of costs, expenses are grouped by department, which can obscure critical environmental costs because they are not identified as distinct cost drivers, as it is possible in Variable Costing systems. Additionally, managers tend to focus solely on their departmental budgets. However, effective sustainability management requires a holistic, system-wide approach. The data suggest that respondents perceive functional costing as equivalent to absorption costing.

Effective budgeting should evolve, responding swiftly to financial and operational changes (Ekholm, Wallin, 2011). While our findings do not dismiss the importance of static budgeting (master budgets), they reinforce earlier conclusions by Sivabalan et al. (2009), which show that most organizations integrate flexible and rolling budgets alongside annual budgets, rather than replacing them.

Our findings reveal two key factors: support of the competitive strategy emerges as the most significant positive predictor of sustainability performance. Conversely, a high level of environmental uncertainty is shown to have a significant negative impact on these outcomes. Thus, we have positively addressed the third research question.

The usages of the following methods are more similar to each other than they are to the others: Bottom-Up Budgeting and Participative Budgeting, Budgeting in a Variable Costing System and Budgeting using a functional structure of costs, Rolling Budgeting and Performance-Based Budgeting, Flexible Budgeting, and beyond budgeting. Meanwhile, the intensity of usage of Static Budgeting is substantially different from all the other methods.

In this way, we have addressed the second research question. As anticipated, the usage intensity of Bottom-Up Budgeting and Participative Budgeting exhibits apparent similarities. Yet, in line with our findings from the first research question, the mere involvement of managers, employees, and potentially external stakeholders—though beneficial for sustainability outcomes (Bartocci et al., 2023)—is outweighed by the stronger influence of bottom-up information flow, i.e., decentralizing the budgeting process.

We also observed a marked resemblance between Budgeting in a Variable Costing System and budgeting that employs a functional cost structure. Identifying cost variability under variable costing (in a functional framework) rather than a process-oriented approach, such as activity-based costing, substantially improves sustainability performance. This contradicts studies emphasizing the key role of budgeting within alternative costing systems (Maiga et al., 2014; Hossain, Hasan, 2024; Al-Kawaz et al., 2023), although the limited adoption of ABC in practice may explain these discrepancies.

Corporate budgeting methods such as Rolling Budgeting and Performance-Based Budgeting also share important commonalities. However, their role appears to be mainly supportive.

Finally, we identified notable parallels between Flexible Budgeting and Beyond Budgeting. This finding aligns with other research indicating that Beyond Budgeting promotes agility and flexibility, enabling teams to align decisions with long-term objectives (Bogsnes, 2016; Matějka et al., 2021).

6. Conclusions

The findings suggest that sustainability cannot be achieved solely through operational instruments, such as budgeting methods; instead, it must be integrated into the firm's overall strategy. Conversely, environmental uncertainty serves as a significant barrier, demonstrating a strong negative association with sustainability performance.

The literature review and empirical results do not identify a single universal budgeting method that positively influences sustainability. Although traditional budgeting methods have been widely criticized in academic literature, they remain prevalent in practice. Consequently, organizations are advised to enhance traditional budgeting approaches rather than eliminate them (Nguyen et al., 2018). The regression analysis identifies Variable Costing Budgeting, Flexible Budgeting, and Bottom-Up Budgeting as the primary drivers of sustainability performance. Among the tested frameworks, these three methods yielded the highest significant coefficients, indicating their critical role in supporting sustainable organizational outcomes. Conversely, Functional and Activity-Based Budgeting appear to hinder performance in the studied context, suggesting that rigid or overly complex systems may impede sustainable organizational outcomes.

This study addresses a significant methodological gap in the literature regarding the impact and intensity of budgeting method usage on sustainable performance. It offers empirical evidence through a quantitative survey methodology and employs robust statistical analyses, including OLS regression, Random Forest, and SHAP.

These findings may help practitioners understand the relationship between budgeting and sustainability. Managers seeking to enhance sustainable performance should focus on direct strategies supported by flexible budgeting tools. Intensive use of Budgeting within a Variable Costing system is recommended, as it improves the visibility and immediate accounting of costs, such as direct materials, energy usage, and waste disposal, during production. This approach supports efficiency, discourages overproduction, and reduces environmental footprints. Additionally, Bottom-Up Budgeting can increase employee engagement and reveal specific, small-scale opportunities for cost reduction and efficiency that are often not apparent to senior management.

The results offer a foundation for future surveys focused on budgeting, particularly within the small and medium-sized enterprise (SME) sector. However, these results should be interpreted with caution due to several limitations, including a small sample size. Additionally, the research relies on self-reported data, which may introduce biases or inaccuracies in reported usage and beliefs, and is based on a single-source survey. The use of a 5-point Likert scale in the questionnaire further restricts the range of responses and may not capture the full nuance of respondents' attitudes.

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EVALUATION MODEL FOR LOCAL CIVIL DEFENCE TRAINING IN POLAND

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Purpose: the primary purpose of this paper is to propose a comprehensive evaluation model for local civil defence trainings in Poland, aligned with the new legal requirements introduced by the Act on Civil Protection and Civil Defence of 2024 and the Regulation of 2025. The study aims to bridge the methodological gap between the statutory obligation to conduct evaluation and the lack of standardized tools for its implementation, ensuring that training contributes effectively to building societal resilience.
Design/methodology/approach: the research employs a qualitative approach based on three pillars-content analysis of the new legal acts (Act of 5 December 2024 and Regulation of 6 February 2025), systemic interpretation of these regulations in the context of strategic state security goals, and logical analysis and synthesis of literature.
Findings: the article identifies that effective civil defence evaluation requires a dichotomy of approaches: a managerial level focusing on decision-making and planning, and an operational level focusing on task execution and stress inoculation. The paper presents a developed model comprising specific evaluation indicators for both levels, a training evaluation report template based on continuous improvement.
Research limitations/implications: the primary limitation is the prospective and theoretical nature of the model, resulting from the novelty of the legislation (2024/2025) and the current absence of empirical data from trainings conducted under the new regime. Furthermore, a model is designed for specific trainings requirements (local authorities and general population).
Practical implications: the proposed model provides training providers and local government units with ready-to-use methodological tools to fulfill statutory obligations regarding training evaluation.
Social implications: by shifting the focus from procedural compliance to practical resilience (preparedness, stress inoculation, team resilience), the model contributes to increasing the real safety of the population. It supports the development of a more resilient society capable of appropriate behavior during threats, which is the ultimate goal of the civil protection system.
Originality/value: this paper offers the first theoretical evaluation framework adapted specifically to the new Polish legal order in civil protection. Its value lies in adapting advanced crisis management evaluation concepts (HSEEP, OECD) to local-level training, addressing the specific inadequacy of standard business training evaluation models.
Keywords: civil protection, civil defence, training evaluation.
Category of the paper: conceptual paper.

1. Introduction

Civil protection is understood as a system composed of public administration authorities responsible for ensuring the safety of the population by protecting human life and health, property (including animals), infrastructure essential for meeting basic needs, cultural assets, and the environment in situations of threat. These authorities are referred to as *civil protection bodies*, while the entities performing the related tasks are defined as *civil protection entities*. The system also includes civil protection resources (Act of 5 December 2024 on Civil Protection and Civil Defence, 2024).

Civil defence encompasses the tasks defined in Article 61(a) of the Additional Protocol to the Geneva Conventions of 12 August 1949 relating to the protection of victims of international armed conflicts (Protocol I), adopted in Geneva on 8 June 1977 (Journal of Laws 1992, item 175; Journal of Laws 2015, item 1056). Its purpose is to protect the civilian population from threats arising from military operations and their consequences (ibid.).

The Polish legal system formally separated these two concepts with the drafting and entry into force of the Act on Civil Protection and Civil Defence. In addition to introducing new definitions, the Act established a fundamental shift in the approach to building social resilience to extraordinary events. This shift consists of mandatory training delivered at intervals specified in the Act and in the implementing regulation on training programmes (Regulation of the Minister of the Interior and Administration of 6 February 2025 on training programmes in civil protection and civil defence and requirements for training providers, 2025).

The programmes define a standard structure of training assumptions, including training objectives, thematic scope, minimum teaching hours, instructional methods (with particular emphasis on practical components), and expected learning outcomes. It should be stressed that the regulation on training programmes does not specify how to assess the fulfilment of training assumptions, apart from a general requirement to verify the training objective through practical tasks, activities, case studies, or the acquisition of knowledge related to the training content. As a result, there is substantial interpretative freedom regarding how to verify achievement of the training objective in relation to the strategic aims set out in the Act. Moreover, evaluation freedom would be a vital problem for trainings which are led for local level of Civil Defence and for training companies which do not have any guidance on how to conduct an evaluation.

2. Theoretical and legal framework

The legal framework for civil protection training in Poland is defined in Chapter 6 of the Act on Civil Protection and Civil Defence. The legislation introduces an obligation to organise training aimed at enhancing qualifications in the field of civil protection and civil defence for staff employed in offices serving civil protection authorities, as well as other local government organisational units and municipal auxiliary bodies (op.cit.). The statutory purpose of these trainings is explicitly oriented toward competence development of personnel responsible for civil protection tasks.

Pursuant to the Act, civil protection and civil defence training must be delivered at minimum in the following intervals:

1) for individuals performing the function of territorial civil protection authorities – within three months of taking office, and thereafter at least once a year,
2) for other civil protection authority personnel, as well as state secretaries and undersecretaries of state performing civil protection tasks – within six months of assuming the function,
3) for persons carrying out tasks related to civil protection and civil defence – at least once a year,
4) for persons assigned civil defence mobilisation duties – within six months of receiving the assignment.

In addition, the Act provides that civil protection authorities may organise training for civil protection entities, associations, business operators, and the general population, thus creating a framework for the voluntary extension of competence-building (op.cit.).

The regulation specifies both the structure and requirements of training programmes. It distinguishes nine groups of participants:

1) ministers, secretaries of state, undersecretaries of state, and heads of central offices,
2) provincial governors and regional marshals,
3) county governors (starosts),
4) commune heads, town mayors, and city mayors,
5) staff in offices serving civil protection authorities and other local government units,
6) persons with civil defence mobilisation assignments,
7) personnel of civil protection entities – facultative,
8) members of associations and business operators – facultative,
9) the general population – facultative (ibid.).

Each training programme specifies:

1) the training objective,
2) the target group,
3) the organisational form,

4) the thematic scope,
5) the method of verifying achievement of the training objective (ibid.).

The Regulation further imposes specific obligations on training providers, which include, but are not limited to, the preparation of a training evaluation report, accompanied by the training quality evaluation questionnaires completed by the training participants.

At this point it is necessary to clarify the meaning of training evaluation in relation to the overarching training objective. A well-designed training programme is intended to produce measurable developmental effects among participants, including positive changes in awareness, skills, and ultimately competencies (Głowicki, 2015). In the field of civil protection and civil defence, such progress pertains primarily to enhancing preparedness for response - both at the managerial and operational levels of personnel tasked with executing civil protection functions. Therefore, determining how evaluation should be conducted and how the training process should be managed to ensure cyclical improvement becomes particularly significant.

Training is understood as a structured, disciplined sequence of stages, which typically include:

a) identification of training needs,
b) development of the training plan and programme,
c) delivery of the training,
d) assessment of training effectiveness (Kunasz, 2006).

Knowledge of expected learning outcomes, combined with the results of needs assessment, enables the design of an adequate programme, which in turn guides trainers toward clearly defined goals (Kunasz, 2006). Empirical studies indicate, however, that the stage which poses the greatest difficulty for organisations is the evaluation of training effectiveness (Kunasz, 2006). Preparation and delivery phases are assessed most positively, while the evaluation stage is often neglected or poorly executed. These findings constitute a basis for identifying and employing models that support effective management of both the training process and its evaluation.

The literature offers a number of definitions of evaluation, several of which are synthesised by Głowicki (2015):

1) evaluation is an assessment of the value of an intervention based on predetermined criteria, aimed at determining its effectiveness and analysing its impact on specific structural problems,
2) evaluation is a systematic study using diverse methods, involving data collection, analysis, assessment, and dissemination of results, with the objective of estimating the quality and value of processes and outcomes of public interventions,
3) evaluation is a systematic investigation of events occurring during a programme or resulting from it, intended to improve the programme itself and others with similar goals,

4) evaluation is a systematic assessment of the value or characteristics of a programme, activity, or object according to specific criteria, conducted to improve, develop, or better understand them.

Measurement of training effectiveness is therefore an essential element of a systematic training model and a key component of managing employee competence development (Głowicki, 2015). Across definitions, shared characteristics of evaluation include its criterion-based nature, systematic approach, and primary purpose—continuous improvement of the training process. As Prior and Roth (2016) emphasise, learning should be understood not as an isolated outcome, but as an ongoing process.

Standard evaluation practices typically rely on several well-established models, most commonly applied in organisational settings (Głowicki, 2015):

1) Kirkpatrick model – a four-level approach assessing reaction, learning, behaviour, and results. While widely used and systematic, it does not always allow unambiguous attribution of results solely to training.
2) Hamblin model – expands Kirkpatrick's model by adding two levels related to organisational and environmental outcomes, incorporating broader contextual influences.
3) Phillips model (ROI) – introduces a fifth level of evaluation: return on investment, involving quantification of financial and non-financial benefits.
4) Brinkerhoff model (Success Case Method) – focuses on identifying the most and least successful cases of training application, offering a qualitatively rich understanding of facilitating and inhibiting factors.

It should be noted that these models operate at a general level, applying broadly to organisational training across diverse sectors. Civil protection training, by contrast, is embedded in the domain of public safety and therefore requires a more specialised evaluative approach. Legal requirements in this field emphasise:

1) periodicity of training,
2) practical orientation,
3) assessment of learning outcomes through practical tasks,
4) systematic evaluation (op.cit.).

Therefore, a comprehensive evaluation model for civil protection cannot rely on a single source of authority but must integrate these distinct layers. The legal framework establishes the mandatory boundary conditions (the 'why' and 'when'), while established business models offer a proven structural skeleton for the assessment process (the 'how'). However, to ensure these tools are effective in a life-saving context, they must be saturated with crisis management specifics-such as the SMARTER criteria and OECD standards defined in domain-specific literature. Consequently, the proposed approach aims to synthesize these elements, moving from simple procedural compliance to a resilience-oriented evaluation.

Given the scarcity of research on evaluation methods specifically tailored to civil protection and civil defence training, it is necessary to refer to related models developed within the field of crisis management. Bralewski et al. (2024) distinguish the following phases of the exercise and evaluation cycle:

1) design phase - identification of system gaps and capabilities requiring improvement,
2) planning phase - defining scenario, context, type and form of exercise, and the composition of exercise teams,
3) organising phase - study visits to the exercise site to identify limitations affecting evaluation implementation,
4) evaluation phase - briefing of evaluators, fulfilment of legal requirements regarding data collection, securing consents, and deployment of observers,
5) implementation phase - reviewing the report, forwarding recommendations, determining procedures and timelines for improvements, and verifying their effectiveness during subsequent exercises.

Empirical findings indicate that evaluation in crisis management is often reactive and compliance-oriented rather than embedded in a continuous improvement cycle. Among 160 respondents employed in crisis and disaster management structures, only 25% believed that current legislation clearly specifies the required civil emergency planning documents (Zwęgliński, 2023). Fewer than 25% agreed that modifications to plans should be verified and validated through exercises (Zwęgliński, 2023). These results highlight a substantial gap in awareness regarding the significance of effective training management and evaluation in the development of societal resilience.

Zwęgliński (2023) identifies further systemic issues contributing to this state. Firstly, exercise organizers often lack sufficient methodological instruments to conduct objective evaluations, resulting in general and predictable conclusions that do not generate new knowledge about the system. This leads to the phenomenon of rational ignorance, where the cost of organizing a rigorous evaluation is perceived as higher than the expected benefits. Furthermore, the evaluation process is susceptible to numerous cognitive biases of observers and evaluators, such as the halo effect, confirmation bias, or the authority effect, which can distort data collection and analysis if not mitigated by a robust methodology.

Similar tendencies are observed in the business sector. Despite acknowledging the importance of evaluating training effects, organisations frequently implement evaluation in a superficial, spontaneous, or entirely omitted manner; nearly half of respondents indicated neglect of this stage (Jasiński, Janiak-Rejno, 2005). The division of responsibilities for evaluation is also unclear. According to the authors, effective evaluation requires:

1) raising broad training awareness among managers at all levels,
2) developing procedures and tools tailored to organisational needs,
3) initiating evaluation from the simplest actions (such as assessing participant reactions) and gradually expanding the scope,
4) ensuring systematic, consistent, reliable, and objective research.

To address the specific challenges of civil protection, Zwęgliński (2023) proposes a rational evaluation theory that structures the preparation phase. This approach necessitates designing evaluation in two distinct dimensions: dimension 1 (validity), which assesses the efficiency of actions taken by participants, and dimension 2 (reliability/meta-evaluation), which assesses the quality of the evaluation process itself to identify potential distortions. The preparation phase should therefore include defining "SMARTER" goals (Specific, Measurable, Achievable, Relevant, Timely, Exciting, Registered) and selecting appropriate criteria such as relevance, coherence, effectiveness, efficiency, impact, and sustainability, based on OECD standards as a tool for evaluation (Zwęgliński, 2023).

Furthermore, to ensure the evaluation contributes to systemic resilience, it is recommended to adopt advanced methodological standards derived from international best practices. The ETH Zurich Risk and Resilience Report highlights the necessity of moving beyond "single-loop learning" (correcting errors within existing norms) to "double-loop learning", which questions underlying policies and assumptions to foster deep adaptation (Prior, Roth, 2016). Practical implementation of this approach is supported by the HSEEP doctrine, which mandates that every evaluation must conclude not just with an After Action Report (AAR), but with a concrete Improvement Plan (IP). This plan must explicitly assign corrective actions to specific parties with defined deadlines, preventing the evaluation from becoming a passive document. Additionally, the Swedish Civil Contingencies Agency (MSB) emphasizes the need to distinguish between evaluating performance (adherence to procedure) and effect (impact on safety), as high procedural compliance does not always guarantee the desired safety outcome.

At this point, it is also worth noting that, in the context of building social resilience, the concept of *resilience training* is highly relevant and particularly useful for understanding the evaluation of training, as it encompasses

1) preparedness training,
2) stress inoculation training,
3) personal efficacy training,
4) resilience engineering training, and
5) team resilience training (Ketelaars et al., 2024).

In conclusion, the presented literature review provides a solid foundation for identifying the fundamental requirements for a new evaluation model. Consequently, the proposed framework focuses on measuring effects that explicitly contribute to building societal resilience, rather than merely assessing procedural compliance.

3. Research methodology

The research process employed a qualitative approach based on three complementary methodological pillars:

- content analysis - the primary method involved a critical analysis of source documents, specifically the Regulation of the Minister of the Interior and Administration of 2025 and the overarching Act on Civil Protection and Civil Defence. This analysis focused on extracting the core objectives of societal resilience relevant to training evaluation.
- systemic interpretation - the analyzed provisions of the Regulation were examined within the broader context of the state's strategic goals mandated by the Act. This method enabled the correlation of specific training requirements with the overarching objectives of the civil protection system, facilitating the development of a comprehensive evaluation strategy.
- logical analysis and synthesis - the final stage of research involved synthesizing findings from the legal and theoretical frameworks. This step allowed for comparing the main objectives of societal resilience with existing evaluation gaps, thereby isolating key evaluation criteria to be implemented in the proposed model.

The primary limitation of this study is the novelty of the legislation, resulting in an absence of empirical data from implemented Civil Defence training programmes in Poland under the new legal order. Consequently, the analysis is theoretical and prospective. Furthermore, existing evaluation processes described in related literature primarily concern organizational or crisis management issues, which, while connected to the basics of civil protection, do not fully address the specificities of the newly introduced resilience-oriented training.

4. Results

The initial step in developing the concept for the local-level model involved identifying the characteristics that, according to the Polish legislator, are essential for building societal resilience. This identification was based on an analysis of statutory provisions. Based on this analysis, the following areas for strengthening resilience, as defined in article 4, were distinguished:

- preparation of public administration bodies to implement tasks regarding civil protection and civil defense,
- preparation of the population for appropriate behavior in the event of a threat,
- actions related to the potential occurrence of a threat,
- actions related to the actual occurrence of a threat.

To ensure methodological robustness, assumptions of these statutory obligations into measurable indicators was conducted by translating general legal duties (e.g preparation of public administration) into observable behaviors (e.g. identification of national security threats in the local context). In addition, evaluation and skills attainment are observable through proper decision-making scenario as a result of the whole process. This process ensures that every evaluation indicator proposed in the model is directly rooted in specific provisions of Article 4 and the Regulation, reducing interpretative ambiguity.

The subsequent step involved defining the training levels against which the evaluation should be conducted. An analysis of the training program content allowed for the distinction of two levels: the managerial level (ranging from the ministerial level to the commune head/mayor) and the operational level (ranging from administration to the general population).

The distinction between these levels is based on the scope of the tasks defined in the regulation. The managerial level includes roles with authority to allocate resources, manage systems, and make strategic decisions (planning and command phase), while the operational level comprises roles responsible for the physical or technical execution of these decisions (execution phase). This differentiation allows for applying distinct evaluation metrics: strategic coherence for managers and task proficiency for operators.

Based on these defined training levels, the following objectives for building societal resilience were established:

- for the managerial level - the method for verifying the achievement of training objectives assumes the resolution of practical problems relevant to a specific level of state management in crisis situations (commune head, mayor, city president),
- for the operational level - the verification of the achieved training objective involves the execution of specific tasks and activities related to crisis response (administrative staff, personnel of civil protection entities, enterprises, individuals with mobilization assignments for civil defense, and the general population).

Subsequently, the key elements influencing evaluation and the building of societal resilience were extracted from the training curricula, encompassing the following criteria:

- managerial level - evaluation criteria include preparing training content to correspond with the implementation of operational planning and civil protection management in subordinate areas. This is characteristic of the municipal level of state security management regarding key aspects of civil protection and civil defense,
- operational level - evaluation criteria involve preparing content to ensure the practical preparation of individuals responsible for task execution and the acquisition of specific skills.

The evaluation criteria defined in this manner were mapped to methods identified in the literature, including evaluations based on OECD recommendations, continuous improvement based on double-loop learning, the HSEEP doctrine, and resilience training concepts in applicable areas.

The proposed evaluation model addresses both the managerial and operational levels, while accounting for the legal requirement regarding the practical dimension of training. Table 1 presents the proposed evaluation model for the managerial level:

Table 1.
Evaluation model for managerial level training

Evaluation area	Evaluation indicators	Evaluation methods according to OECD
Preparation of public administration bodies for the implementation of tasks related to civil protection and civil defense.	Identification of national security threats in the local context. Indication of institutions that can be utilized for civil protection response. Development of crisis communication in connection with the occurrence of a threat. Specification of principles for communication (telecommunication/networking) operations. Indication of types of cooperation.	Decision scenario based on the implementation of the task of updating the crisis management plan and the evacuation plan in connection with the occurrence of a threat. Implementation of the criteria of efficiency, relevance, and sustainability.
Preparation of the population for appropriate behavior in the event of a threat.	Indicate whether you possess a system for informing the population about threats. Indicate the forms of education used in the commune. Indication of social resilience mechanisms	Case study involving the examination of managerial awareness including what resources are possessed in the commune (municipality) and how are used. Implementation of the criteria of efficiency, effectiveness, and relevance.
Actions related to the possibility of a threat occurring.	Indication of the scope of risk assessment. Indication of resources and competencies related to threat response. Indication of whether the commune possesses evacuation and shelter areas, and cultural assets subject to evacuation. Ensuring the creation of material and financial reserves for carrying out civil protection and civil defense tasks. Indication of civil protection entities used for response. Securing financial resources and civil protection assets.	A decision-making game encompassing a scenario related to the occurrence of a specific threat. The game should measure the following indicators: knowledge of the threat's impact on the use of civil protection resources and entities, the necessity of evacuation and securing, and the distribution of civil protection resources. The evaluation criterion is the activation of all known procedures related to informing and evacuation. Implementation of the criterion of coherence.
Actions related to the occurrence of a threat.	Practical resolution of problems related to the occurrence of a threat, including: Alarming (warning); Informing (public notification); Response; Identification and implementation of protection methods against chemical, biological, radiological, and nuclear (CBRN) hazards; Hazards resulting from natural forces and wildlife; Ensuring the functionality of infrastructure essential for the commune operations; Distribution of humanitarian aid	A decision-making game encompassing a scenario where elements related to threat response actions are indicated by the training participant. The criterion for effectiveness is making the largest possible number of accurate decisions from the perspective of threat response. Implementation of the criterion of impact.

Source: own preparedness.

This model, prepared for the evaluation of managerial level training, allows for the verification of whether the training was conducted using practical methods, alongside the identification of the competency areas necessary for planning and managing civil protection at individual administrative levels.

The next stage in preparing the evaluation model focuses on training for the operational level. In the context of building societal resilience, the operational level incorporates the concept of resilience training, which develops the resilience of training participants in the training areas indicated by the regulation. It thus corresponds to the objectives specified in article 4 of the Act regarding operational preparation. Table 2 specifies the evaluation requirements for training at this level:

Table 2.
Evaluation of operational level training

Evaluation area	Evaluation indicators	Evaluation methods according to OECD
Preparedness training	Covers preparation for foreseeable events, including learning protocols and procedures. Relates to the early recognition of threats and the application of planned systems involves a set of planned procedures and actions in case of a threat, aimed at protection (preparation).	Practical verification of standard operating procedures, which contain references to municipal crisis management plans and foreseeable threats. Implementation of the criteria of efficiency and effectiveness.
Resilience engineering training	Interventions aimed at enhancing professionals' understanding of resilient systems and their role in contributing to resilient performance.	Practical verification of standard operating procedures, which contain references to municipal crisis management plans and foreseeable threats. Implementation of practical tasks covering the fulfillment of assigned roles within civil protection. Implementation of the criteria of relevance and sustainability.
Personal efficacy training	Develop the personal skills of professionals in demanding work roles, so that they can perform the duties linked to the very nature of their work in an effective and efficient way.	Individual practical tasks performed under time pressure or simulated difficulty. Implementation of the criteria of efficiency and effectiveness.
Stress inoculation training	Introduce of brief intermittent stress exposure.	Simulation exercises with introduced stressors (e.g., noise, information overload, time constraints). Implementation of the criterion of impact.
Team resilience training	Enhance the ability if a team is ready to maintain performance when faced with known or unknown interferences.	Group decision-making games or field exercises requiring cooperation under uncertainty. Implementation of the criterion of coherence and effectiveness.

Source: own preparedness according to Ketellars (2024).

The Operational Level Evaluation Model focuses primarily on assessing the preparation and identification of practical skills among training participants.

The next stage of the research was the preparation of a template for the training evaluation report, which aligns with the assumptions of the continuous improvement concept, as indicated by Prior & Roth, the HSEEP model, and MSB guidelines. The report template is contained in Table 3.

Table 3.
Proposal of evaluation raport

Evaluation area	Identified problem	Post-training conclusions (single-loop)	Systemic conclusions (double-loop)	Improvement plan	Responsible
Preparation of public administration bodies for the implementation of tasks related to civil protection and civil defense.	Identification of national security threats in the local context.	Participants in the decision-making game did not indicate all potential threats in relation to local hazards.	As part of the training system's operation, emphasis should be placed on the relationship between strategic documentation and local threats.	Analysis of the national security strategy regarding local threats and subsequent implementation into the practical training dimension.	

Source: own preparedness.

The final stage of the evaluation model construction process, which closes the legal requirements set out by the regulation, was the development of the training participant questionnaire. The proposed participant questionnaire is based on the assumption of building societal resilience, meaning whether the training addresses this need. This is not a satisfaction survey, but a tool for streamlining the process of continuous improvement of the training process. The questionnaire is presented in Table 4.

Table 4.
Evaluation survey

Question	Answer
Did the training topics and threats correspond to the real risks occurring in your commune/unit?	Scale 1-5 (1 = completely inadequate, 5 = very accurate/realistic)
How do you rate the proportion of practical activities to theoretical sessions?	Scale 1-5 (1 = too much theory, 5 = optimal amount of practice)
To what extent did the training raise your practical response skills?	Scale 1-5 (1 = no change, 5 = significant increase in confidence)
How do you assess your ability to execute procedures immediately after the training?	Scale 1-5 (1 = still unable to perform, 5 = able to execute independently)
Which of the training methods used were the most valuable for understanding the subject?	Open question:
After the training, do you feel motivated to independently deepen your knowledge in the field of civil defense?	Scale 1-5 (1 = no, it's just an obligation, 5 = yes, I see the need)
Did you notice any gaps or errors in the plans/procedures currently in force in your unit during the training?	Yes/No (if yes, please briefly describe in the last question)
What specific changes in procedures or equipment do you suggest implementing in your unit following this training?	Open question:

The questionnaire for participants, developed in this way, not only allows for the identification of problematic areas but also enables the distinction of the most effective methods and resources, which constitute essential feedback in the process of training improvement.

5. Discussion

The presented evaluation model for training in civil protection and civil defense constitutes a response to a fundamental gap in the training process. To date, no model has been developed that enables the implementation of evaluation principles by the entities carrying out the training. This represents a significant contribution to the development of security sciences and manifests a practical approach that streamlines processes within the operation of training businesses in the area of civil protection.

The developed model has a strong grounding in the relevant literature and attempts to translate abstract legal requirements into scientific and practical domains. A key element, crucial from the perspective of evaluating civil protection training, is the departure from classical models used in training assessment in favor of an approach utilized in the field of crisis management. Classical models address the needs of enterprises and the goals indicated in their policies, whereas civil protection training is intended to build societal resilience and raise awareness at specific levels of management in this area.

Accordingly, a literature review, systemic analysis, and logical analysis of legal provisions, evaluation assumptions used in crisis management, were conducted, and logical evaluation indicators referring to two levels - managerial and operational - were distinguished.

It is essential to point out that both the managerial and operational levels are based on the main objectives of the Act defined in Article 4. However, the practical evaluation of training for the managerial level is based directly on the assumptions of the Act, while the evaluation of the operational level relies on the concept of resilience training, which builds the actual response skills of individuals designated to perform implementation functions in civil protection. Therefore, the evaluation focuses respectively on the verification of managerial capabilities and the verification of operational capabilities. Furthermore, the evaluation is based on the criteria indicated by OECD, HSEEP, as well as the single-loop and double-loop concepts, which allow for a shift away from the paradigm of evaluation as merely an assessment of training that has taken place, towards training defined by continuous improvement of both the process itself and the entire system.

The evaluation model itself focuses on identifying practical measurement indicators that refer to the legal requirement for the practical dimension of civil protection training and tools that enable training entities to prepare training in a way that best meets practical requirements.

However, significant limitations in the development of the model concept must be highlighted. The presented model is prospective and theoretical. The lack of empirical data from training already conducted under the new legal regime currently prevents the verification of its effectiveness in practice, which constitutes an area for further research.

Another limitation is the model's design focus: managerial level training for commune heads, mayors, and city presidents, and the operational level ranging from administrative staff to the general population. This is related to the perspective of the model's practical implementation for entities conducting training based on market principles.

6. Conclusions

The analysis of the legal and theoretical framework surrounding the new civil protection regulations in Poland allows for the formulation of several key conclusions regarding the evaluation of training processes.

Firstly, the study identifies a significant methodological gap in the current legal state. While the Act on Civil Protection and Civil Defence and the Regulation of 2025 impose an obligation to evaluate training, they do not provide standardized tools for its implementation. The proposed model fills this gap by offering a structured framework that integrates statutory requirements with practical evaluation methodology.

Secondly, the research demonstrates the necessity of differentiating evaluation strategies based on the target group. The unitary approach is insufficient; effective evaluation requires a distinct separation into the managerial level (focused on decision-making, planning, and system coherence) and the operational level (focused on task execution, stress resistance, and technical skills). This dichotomy ensures that evaluation criteria are adequately matched to the specific roles performed within the civil protection system

Thirdly, the proposed model shifts the paradigm of training assessment from standard business models towards a resilience-oriented approach grounded in crisis management doctrines (HSEEP, OECD standards). By incorporating "double-loop learning", the model transcends simple error correction, enabling the identification of systemic flaws in crisis management plans and procedures. Consequently, the training evaluation report becomes a tool for upgrading the entire local safety system rather than merely archiving a completed training.

Finally the study provides practical utility for training entities operating in the market. The developed tools, including the evaluation report template and the participant questionnaire, are designed to meet the specific practical dimension requirements of the new legislation. Furthermore, considering that some training providers may lack advanced methodological expertise, it is recommended to implement the proposed model incrementally. Providers should begin with the basic verification of participant reactions and key knowledge acquisition using

the simplified questionnaire (Table 4) before advancing to complex behavior and results assessments based on Table 3. This stepped approach allows for gradual capacity building among local training entities.

However, it must be noted that the presented model is currently theoretical and prospective. Due to the recent introduction of the regulations, further research involving empirical verification and calibration of the proposed indicators based on data from future training implementations is required.

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QUALITY MANAGEMENT OF FUNCTIONAL FOOD BASED ON INSTANT OATMEALS: PROPERTIES, SAFETY AND CONSUMER PERCEPTION

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Purpose: The aim of this article was to assess the quality, safety, and functional properties of three instant oatmeal variants and determine their relevance in quality management processes for functional foods. The study sought to identify key parameters influencing stability, microbiological safety, and consumer acceptance.
Design/Methodology/Approach: Three flavored instant oatmeal variants were analyzed using physicochemical methods (moisture content, water activity, flow properties, bulk and tapped density, Hausner and Carr indices), microbiological assays (total count, molds and yeasts, indicator bacteria, Salmonella spp.), sensory evaluation (10-person panel), and sorption analysis based on isotherms and BET parameters (Vm, SSA). The selected methods enabled interpretation of results within a HACCP-based quality management framework.
Findings: Statistically significant differences ($p < 0.05$) were observed between variants in water activity, moisture content, selected flow parameters, and sorption characteristics. All products exhibited low water activity ($aw < 0.40$), confirming high microbiological stability. The strawberry variant showed the highest hygroscopicity and sorption surface area, indicating greater sensitivity to storage humidity, whereas the apple–cinnamon variant demonstrated the lowest water activity and the most favorable flowability indices. Microbiological analyses confirmed compliance with safety criteria, with no Salmonella spp. detected and indicator microorganisms below critical limits. Sensory attributes received high ratings (≥4.4), although overall acceptance remained moderate, suggesting that flavor–texture integration plays a decisive role in consumer perception.
Research limitations/conclusions: The study was limited to one product category and three variants, restricting generalization. The relatively small sensory panel may also affect robustness. Future research should include products from different manufacturers, storage-condition analyses, and advanced sorption modeling (e.g., GAB).
Practical and social implications: The results support manufacturers in optimizing formulation, drying, mixing, and packaging processes, particularly regarding moisture control and barrier properties. They also emphasize the role of functional foods in promoting healthy dietary habits.

Originality/value: The study proposes an integrated quality-management model linking physicochemical, microbiological, sensory, and sorption parameters with HACCP-based Critical Control Points. It demonstrates that measurable indicators such as water activity, Vm, SSA, microbiological status, and flowability can serve as operational tools for risk assessment, storage prediction, and process control. The framework may be transferable to other instant functional foods.
Keywords: instant oatmeal; functional food; quality management; food safety.
Article category: Research paper.

1. Introduction

Functional foods are currently one of the fastest-growing segments of the global food market, driven by consumers' growing health awareness, changing lifestyles, and the search for products that combine nutritional value with convenience (Diplock et al., 1999; Roberfroid, 2002). By definition, functional foods have a documented, beneficial effect on health beyond their basic nutritional value (Roberfroid, 2002). The growing popularity of this category aligns with global trends related to the prevention of diet-related diseases, increased physical activity, and the search for products that support well-being.

Among functional foods, oat-based products, including instant oats, occupy a special place. Thanks to their high dietary fiber content, especially β-glucan, they exhibit lipid-lowering, hypoglycemic, and immunomodulatory properties (Whitehead et al., 2014; Rasane et al., 2013). Numerous studies also confirm the antioxidant and anti-inflammatory effects of oat bioactive components and their beneficial effects on the intestinal microbiota (Gibiński et al., 2005). From the consumer's perspective, instant oatmeal is perceived as a healthy, nutritionally valuable, and easy-to-prepare product, which is reflected in the survey results presented in this empirical study.

However, instant products, as low-water foods, pose a technological and qualitative challenge. Their shelf life and microbiological safety are determined primarily by water activity, hygroscopicity, and sorption properties (Labuza, 1980; Fontana, 2008). In the case of instant oatmeal, these parameters influence not only microbiological stability but also the tendency to caking, texture changes, rehydration capacity, and the sensory qualities of the final product. The phenomenon of intense moisture sorption is typical for products based on cereal flakes and flours.

Managing the quality of instant products therefore requires monitoring a range of physicochemical (water activity, bulk density, angle of repose), microbiological, and sensory parameters. HACCP, GMP, and GHP systems emphasize the need to control critical points in the manufacturing process and continuously assess the safety of products with reduced AW (Codex Alimentarius, 2003). At the same time, it is consumer perception, including assessment

of taste, texture, nutritional value, and ease of preparation, that determines the final acceptance of the product and its market success (Granato et al., 2020; Kaczorowska, Rejman, 2021).

Despite numerous publications on the properties of oats and functional foods, there is still a lack of studies presenting an integrated quality assessment of instant oatmeal, encompassing physicochemical, microbiological, and sensory analysis, from a quality management perspective. This study, based on a comprehensive evaluation of three instant oatmeal variants available on the market, fills this research gap. The aim of the study was to conduct a multidimensional analysis of the quality of instant oatmeal, including physicochemical properties, microbiological safety, sensory characteristics and sorption properties, and to assess their importance for the quality management processes of functional foods.

2. Material and Method

The research material consisted of three flavor variants of instant oatmeal: oatmeal with chocolate (I), oatmeal with apple and cinnamon (II), and oatmeal with strawberries (III). The products studied belong to the instant breakfast food category and were manufactured in Poland. All samples came from the same product line and were available in general retail stores.

2.1. Methods of Physicochemical Analysis

Physicochemical analysis included determining parameters crucial for the quality and shelf life of instant products, including water content, water activity, flow properties, and product density. The selection of methods was based on their high suitability for assessing the quality of oat products and their importance for the microbiological and technological stability of food.

2.1.1. Determination of water content and activity

The moisture content was determined using the thermal drying method to constant weight at 104°C, in accordance with commonly applied procedures for the analysis of cereal-based products. Water activity (a_w) was measured with an AquaLab 4TE analyzer (Decagon Devices, USA) with an accuracy of ±0.003, at a temperature of 20 ± 2.5 °C. Each measurement was performed in triplicate to ensure the representativeness of the results.

2.1.2. Determination of selected physicochemical properties

The angle of repose and the angle of repose were determined using methods used to assess the flow properties of food powders. The static angle of repose (CA) was determined based on the geometry of the cone of repose, while the kinetic angle of repose (AR) was determined using the inclined surface method, using a constant sample volume. These parameters describe the product's flowability and susceptibility to movement, which is important in characterizing instant powders (Leśmian-Kordas, 2001; Ruszkowska, Wiśniewska, 2017; Beakawi Al-Hashemi et al., 2018). The assessment of physicochemical properties was supplemented by

measurements of loose and tapped bulk density, conducted in accordance with the PN-ISO 8460:1999 standard. The obtained values were used to calculate two indices: the Hausner index and the Carr index, which classify powders in terms of their ability to flow and their susceptibility to clumping (Abdullah & Geldart, 1999; Samborska et al., 2011).

2.1.3. Microbiological Parameter Determination

The microbiological evaluation of instant oatmeal included the determination of key microbial groups, in accordance with the requirements for low water activity foods. Analyses were performed in accordance with applicable ISO standards, using surface and deep plating methods and selective microbiological media. The following parameters were determined: total aerobic mesophilic microorganism count (ISO 4833), yeast and mold count (ISO 21527), coliforms and Escherichia coli (ISO 16649; ISO 4832), Enterobacteriaceae (ISO 21528), Staphylococcus aureus (ISO 6888), presumptive Bacillus cereus (ISO 7932), and detection of Salmonella spp. according to the PN-EN ISO 6579-1:2017-04/A1:2020-09 standard. Samples were prepared by performing a series of decimal dilutions, and the results were expressed as colony-forming units (CFU/g). The scope of the analyses meets the microbiological safety requirements for instant products and allows for a comprehensive assessment of their health-related quality.

2.1.4. Sensory Analysis

The sensory evaluation of instant oatmeals was conducted with a panel of 10 trained assessors using a five-point hedonic scale. The analysis covered attributes essential for product perception: appearance, color, aroma, taste, and texture. Samples were prepared according to the manufacturer's instructions and served under conditions ensuring a neutral sensory environment, at room temperature, under daylight illumination, and in random order. The results were presented as mean scores from the panelists, which enabled comparison of the sensory profiles of the individual flavor variants.

2.2. Determination of Sorption Properties Governing Storage Stability

The sorption properties of the instant oatmeals were determined using the static desiccator method, establishing water vapor sorption isotherms within the water activity range aw = 0.07-0.92. The tests were carried out under controlled relative humidity conditions generated by saturated salt solutions, in accordance with procedures described for highly hygroscopic products (Tańska et al., 2017).

2.3. Systemic Approach to Quality Management and Critical Control Points (HACCP) in the Evaluation of Instant Oatmeals

To ensure a comprehensive assessment of the quality and health safety of instant oatmeals, elements of a systemic quality-management approach were incorporated, based on GHP/GMP principles, HACCP hazard analysis, and the requirements of ISO 22000. Inclusion of these elements in the research methodology stems from the fact that the evaluated physicochemical,

microbiological, sensory, and sorptive parameters constitute key indicators used in practice to monitor and supervise the quality of instant products.

The parameters analyzed in this study correspond to critical control points in food safety evaluation:

- water activity and moisture content — critical limits for microbial growth,
- flowability and density parameters — related to quality control of mixing, transport, and packaging processes,
- microbiological load — verification of CCP effectiveness during processing and packaging,
- sensory evaluation — monitoring the consistency of organoleptic quality in line with consumer expectations,
- sorption properties — assessment of storage stability and product durability.

Integrating the HACCP-based systemic approach into the research methodology allows the results to be interpreted not only in terms of product characteristics but also in relation to compliance with critical food safety requirements. Consequently, the analysis is directly linked to quality-management practice, forming an integral part of the evaluation of functional food products.

3. Results and Discussions

3.1. Evaluation of Water Content and Activity

Water content and water activity are among the most important parameters determining the storage stability and safety of instant products. They directly influence the rate of biological, chemical, physical, and microbiological processes occurring in food (Labuza, 1980; Fontana, 2008). In powdered products such as instant oatmeal, low water content and low water activity are essential for maintaining high shelf life and resistance to quality changes. The measurement results are summarized in Table 1.

Table 1.
Water content and activity of the tested products

Product	Water content [g/100 g. s.m.]		Water activity [-]	
	M	SD	M	SD
Product I	8.587[b]	0.019	0.388[b]	0.0004
Product II	7.487[a]	0.028	0.277[a]	0.0006
Product III	8.724[b]	0.040	0.354[b]	0.0004
	Value „p"			
	0.000		0.000	

M – Mean; SD – standard deviation, Explanatory notes: Mean values denoted with the same letter do not differ significantly in the LSD test.

Source: own research.

In the analyzed instant oatmeals, a low moisture content (7.49-8.72 g/100 g d.m.) and very low water activity (0.277-0.388) were found, which is characteristic of powdered products with high storage stability (Labuza, 1980; Fontana, 2008). The lowest moisture content and water activity were recorded for product II — the apple–cinnamon oatmeal — indicating its highest resistance to moisture adsorption and the lowest risk of quality deterioration. Higher moisture and water activity values in the strawberry and chocolate variants may result from differences in the composition of flavor additives and their water-binding capacity.

Compared to the literature on powdered products, including milk powder (3.34-3.68 g/100 g d.m.), the analyzed oatmeals exhibited higher moisture levels; however, their aw values remained much lower than those reported for cereal brans (aw 0.525-0.643), confirming their high storage stability (Domian, Lenart, 2000; Jensen et al., 2005).

Statistical analysis revealed significant differences in both moisture content and aw between the variants ($p < 0.05$), with the apple–cinnamon oatmeal differing significantly from the other two products.

The results confirm that all instant oatmeals meet microbiological safety criteria, and aw < 0.4 eliminates the risk of pathogen growth, which was validated by the microbiological tests. These parameters are crucial in quality management and HACCP systems, where moisture content and water activity serve as critical limits for monitoring food safety and shelf-life stability. In the context of the study's objective—evaluating the quality and stability of functional instant oatmeals—the obtained results clearly confirm the high storage stability and safety of the analyzed products.

3.2. Evaluation of Selected Physicochemical Properties

The angle of repose and the angle of slide are fundamental parameters characterizing the flowability of powdered materials. The angle of repose reflects the ability of particles to freely flow; its higher value indicates reduced flowability and greater cohesiveness of the product. The angle of slide, in turn, defines the minimum inclination at which material begins to move; its magnitude depends on factors such as friction, moisture, and particle structure (Drzewieniecka, 2000). These parameters are essential for the stability of instant powders and their behavior during packaging, transport, and consumer use.

In the present study, product III — the strawberry oatmeal — exhibited the highest angle of repose (78.33°), while product II — the apple–cinnamon oatmeal — showed the lowest value (74.83°) (Table 2). All values were clearly higher than the natural angles reported for unprocessed grains: oats (21-54°), wheat (23-38°), or millet (20-25°). This indicates that the analyzed instant oatmeals had noticeably poorer flowability than cereal grains, which results from their powdered structure, functional additives, and hydrothermal processing that affects particle surface and shape. Statistical analysis showed no significant differences between the products ($p > 0.05$), confirming similar flow characteristics across all flavor variants.

Table 2.
The angle of repose and dumping of the tested products

Product	Angle of repose [^{0}]		Angle of repose - rough surface [°]		Angle of repose - smooth surface [°]	
	M	**SD**	**M**	**SD**	**M**	**SD**
Product I	75.00	5.48	40.00^b	0.000	22.50^c	2.739
Product II	74.83	32.34	35.00^a	0.000	16.67^b	2.582
Product III	78.33	2.58	34.17^a	2.041	13.33^a	2.582
	p					
	0.938		0.000		0.000	

M – Mean; SD – standard deviation; Explanatory notes: Mean values denoted with the same letter do not differ significantly in the LSD test.

Source: own research.

In the assessment of the angle of repose, the highest values were recorded for product I – the chocolate-flavored oatmeal, both on the smooth surface (22.50°) and the rough surface (40.00°), which indicates greater cohesion and higher frictional resistance in this product (Table 2). The lowest angles of repose were obtained for product III – the strawberry-flavored oatmeal, suggesting better flowability and easier particle movement. Compared to extruded cereal porridges, which are characterized by angles of repose ranging from 23.3° to 29.7°, the values obtained on the smooth surface were similar, whereas those measured on the rough surface were significantly higher, confirming the greater susceptibility of instant oatmeals to interactions with the substrate and their tendency to hinder movement.

Statistical analysis showed significant differences between the tested products for the angle of repose on both rough and smooth surfaces ($p < 0.05$), indicating variations in particle structure and differing behavior of the products during dynamic processes.

The next stage of the study involved determining the bulk and tapped densities and calculating flowability indicators: the Hausner ratio and Carr index (Table 3). These parameters reflect the structure of the powder, its degree of cohesion, the size of the interparticle pores, and its susceptibility to compression during transport or storage, all of which are crucial for quality assessment and the design of technological processes (Abdullah, Geldart, 1999; Samborska et al., 2011; Ruszkowska, Wiśniewska, 2017). Bulk and tapped densities were determined according to PN-ISO 8460:1999.

Among the instant oatmeals studied, the highest bulk and tapped densities were recorded for the strawberry-flavored oatmeal (0.414 and 0.509 g/cm^3), whereas the lowest values were obtained for the chocolate-flavored oatmeal (0.395 and 0.473 g/cm^3). These values fall within the typical range for powdered products and are comparable to literature data for milk powder (0.27-0.45 g/cm^3), the presence of which in the composition of the oatmeals may have influenced the obtained results (Samborska et al., 2011).

The Hausner ratio reached its highest value for product III – the strawberry-flavored oatmeal (1.229), indicating the highest cohesiveness and stronger interparticle forces. This trend was confirmed by the Carr index, which also reached its highest value (18.62) for this variant, suggesting lower flowability (Abdullah, Geldart, 1999). The most free-flowing

product was product II – the apple-and-cinnamon oatmeal, characterized by the lowest Carr index (16.23) and one of the lowest Hausner ratios. Statistical analysis revealed significant differences in bulk and tapped densities between the products ($p < 0.05$), while the Hausner ratio and Carr index showed no statistically significant differences ($p > 0.05$), indicating generally similar flowability characteristics across all flavor variants.

These results demonstrate that the tested instant oatmeals exhibit flow properties typical of instant food products, which are important from the standpoint of storage stability, dosing, and consumer convenience. The evaluation of these parameters aligns directly with the aim of the study, which included a comprehensive assessment of the quality and functionality of instant oatmeals as functional food products.

Table 3.
Bulk density and flow coefficients

Product	Loose density [g/cm^3]		Shaked density [g/cm^3]		Hausner's Co.		Carr's Index	
	M	SD	M	SD	M	SD	M	SD
Product I	0.395^a	0.004	0.473^a	0.007	1.199	0.022	16.57	1.525
Product II	0.403^{ab}	0.011	0.481^a	0.016	1.196	0.056	16.23	3.872
Product III	0.414^b	0.003	0.509^b	0.011	1.229	0.024	18.62	1.601
	p							
	0.001		0.000		0.268		0.253	

M – Mean; SD – standard deviation; Explanatory notes: Mean values denoted with the same letter do not differ significantly in the LSD test.

Source: own research.

3.3. Microbiological Assessment

Microbiological assessment is a key element in verifying the safety of instant foods, especially cereal products enriched with functional ingredients. The test determined the total microbial count (OLC), the number of molds and yeasts, and selected groups of indicator bacteria: Escherichia coli, coliforms, Enterobacteriaceae, Bacillus cereus, Staphylococcus aureus, as well as the presence of Salmonella spp., in accordance with applicable hygiene and sanitation requirements for food (Commission Regulation (EC) No. 2073/2005; PN-EN ISO 4833-1:2013; PN-EN ISO 6579-1:2017).

In all analyzed instant oatmeal samples, no Salmonella spp. were detected in 25g, which is a necessary condition for the safety of ready-to-eat cereal products. Furthermore, the counts of Staphylococcus aureus, Enterobacteriaceae, and E. coli in all variants were below the detection limit (<10 cfu/g), indicating that high hygiene standards were maintained during production and there was no secondary contamination (Silva et al., 2017).

Differences between the variants mainly concerned OLD, molds and yeasts, and the presence of Bacillus cereus. The highest total microbial counts were observed in the apple and cinnamon oatmeal (5.0×10^3 cfu/g), while the lowest were in the chocolate version (4.4×10^2 cfu/g). Molds and yeasts were also detected in two variants, strawberry and apple and cinnamon, which is typical for products with increased water activity due to fruit additions and

their hygroscopicity (Beuchat, 1981). The chocolate version showed no evidence of these pathogens (<10 cfu/g), suggesting greater microbiological stability of the raw materials used in this variant.

For Bacillus cereus, a known pathogen frequently found in cereal products, growth was observed in two variants: the apple and cinnamon oatmeal and the chocolate oatmeal, with values of 3.0×10^{1} and 2.4×10^{2} cfu/g, respectively. Only the strawberry oatmeal showed no evidence of this pathogen. However, all obtained results remain below the values considered hazardous for ready-to-eat foods, where the critical level is 10^{4} -10^{5} cfu/g (ICMSF, 2005).

The test results confirmed that the instant oatmeals tested met microbiological safety criteria and were within acceptable limits for low water activity cereal products. Minor differences between samples may be due to the presence of fruit additives, natural variability of raw materials and differences in their microbiological load, which is consistent with literature observations for plant-based products (Tournas et al., 2009).

Table 4.
Bulk density and flow coefficients

Product type/tested bacteria (jtk/g)	OLD	PD	EC	TC	EB	BC	SA	S
Product I	7.7*10^2	7.0*10^1	<10	2.0*10^1	<10	<10	<10	nw
Product II	5.0*10^3	1.0*10^2	<10	2.0*10^1	<10	3.0*10^1	<10	nw
Product III	4.4*10^2	<10	<10	<10	<10	2.4*10^2	<10	nw

OLD – total microbial count, PD – count of molds and yeasts, EC – count of Escherichia coli, TC – count of coliform bacteria, EB – count of Enterobacteriaceae, BC – count of Bacillus cereus, SA – count of Staphylococcus aureus, S – presence of Salmonella spp. in 25 g).

Source: own research.

3.4. Sensory evaluation

Sensory evaluation is a key element in analyzing the quality of instant products because it links technological parameters with subjective consumer perception and directly influences consumer acceptance and purchasing decisions (Lawless, Heymann, 2010). The study assessed the color, taste, aroma, texture, and overall acceptability of three flavored oatmeal variants. The results are presented in Table 5.

Table 5.
Sensory evaluation of the tested products

Product	Color	Taste	Smell	Consistency	Product Acceptance	Product Average
Produkt I	4.9	4.6	5.0	4.5	3.7	**4.54**
Product I	4.5	4.8	4.7	4.6	3.5	**4.42**
Product II	4.8	4.7	4.7	4.7	3.7	**4.52**

Source: own research.

Product I – oatmeal with chocolate – received the highest color rating (4.9 points), which may have been due to the intense, uniform color typical of cocoa additives. Product III – oatmeal with strawberries achieved a similar score (4.8 points), while product II – oatmeal with apple and cinnamon – received the lowest color rating (4.5 points). All products scored above 4.5 points, indicating the high visual appeal of the products, which is important for initial consumer perception (Szczesniak, 2002).

In the taste assessment, the oatmeal with apple and cinnamon achieved the best score (4.8 points), characterized by a natural sweetness and spice aroma. Oatmeal with chocolate received the lowest score (4.6 points), although this score still confirms high taste acceptance. All variants exceeded 4.5 points, indicating the very good sensory quality of the analyzed products. The chocolate oatmeal received the highest rating for aroma (5 points), while the apple and strawberry versions received identical scores (4.7 points). These results indicate that all variants presented a distinctive, intense aroma consistent with the product's flavor profile, a key attribute in instant foods (Drake et al., 2003).

In terms of texture, the strawberry oatmeal received the highest rating (4.7 points), while the chocolate variant received the lowest (4.5 points). All products were rated as soft, dense, firm, and springy, indicating the desired texture characteristic of oatmeal-based instant meals.

In overall acceptance, the chocolate oatmeal and the strawberry oatmeal received the highest ratings (3.7 points), followed by the apple and cinnamon oatmeal (3.5 points). Considering the average score for all parameters, the chocolate oatmeal received the highest score (4.54 points), followed by the strawberry oatmeal (4.52 points), and the apple and cinnamon oatmeal (4.42 points). This indicates that the chocolate variant is the most preferred product from the consumer's point of view, which is also confirmed by market observations regarding the high popularity of chocolate-flavored instant products (Rasane et al., 2015).

3.5. Evaluation of Sorption Properties

The sorption properties of the tested oats were determined based on sorption isotherms determined using the static desiccator method in the water activity range aw = 0.07-0.92. All products exhibited a sigmoidal isotherm shape characteristic of type II in the Brunauer, Emmett, and Teller (BET) classification, typical of foods high in biopolymers such as starch or fiber (Brunauer et al., 1938; Labuza, 1980) (Figure 1). This confirms the presence of hydrophilic fractions and the ability to bind water in multiple layers.

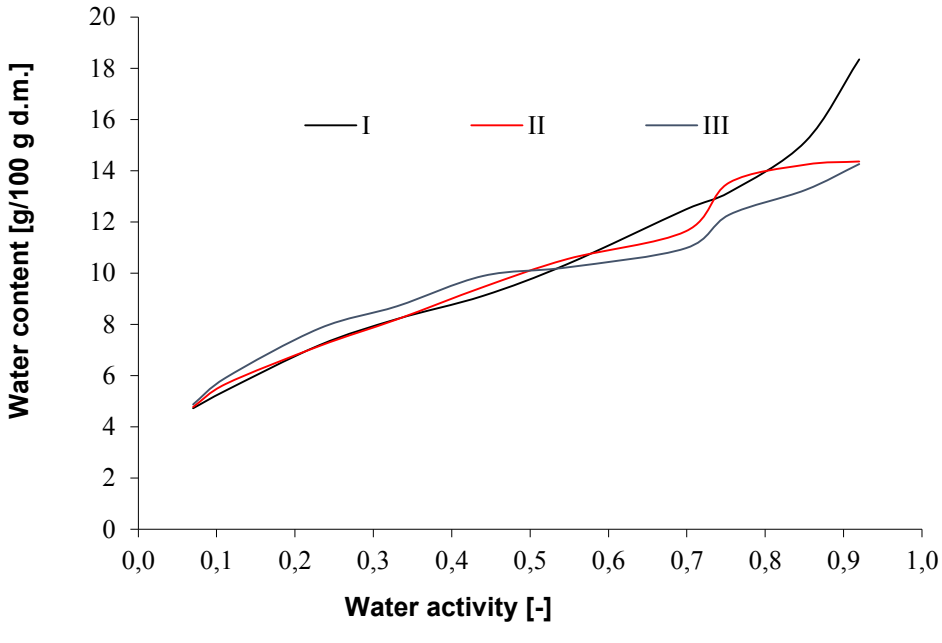


Figure 1. Sorption isotherm of the tested products determined in an environment with aw = 0.11-0.92, during 63 days, at 20°C, (I - oatmeal with chocolate, II - oatmeal with apple and cinnamon, III - oatmeal with strawberries).

Source: own research.

In area I (a_w = 0.07-0.44), the desorption process dominated, and the products differed significantly ($p < 0.05$) in terms of equilibrium water content. The highest hygroscopicity in this range was demonstrated by product III – oatmeal with strawberries, while the lowest was demonstrated by product I – oatmeal with chocolate. In area II (multilayer sorption), statistical differences were also found at aw = 0.55, indicating a different ability of particles to adsorb water. In the range aw = 0.70, the differences between the products were small and statistically insignificant ($p > 0.05$). In area III (capillary condensation), oatmeal with chocolate showed the highest hygroscopicity, which may be related to greater structural porosity and a higher number of sorption-active capillaries (Labuza, 1980; Wolf et al., 1985).

Table 6.
Statistical results of sorption properties

Water activity		Product I	Product II	Product III	„p”
0.07	M	4.590[a]	4.776[b]	4.971[c]	0.000
	SD	0.228	0.009	0.184	
0.11	M	5.396[a]	5.673[b]	6.000[c]	0.000
	SD	0.025	0.011	0,152	
0.23	M	7.154[a]	7.165[a]	7.834[b]	0.000
	SD	0.055	0.007	0.014	
0.33	M	8.220[a]	8.195[a]	8.741[b]	0.000
	SD	0.018	0.015	0.053	
0.44	M	9.122a	9.499[b]	9.869[c]	0.000
	SD	0.016	0.068	0.043	
0.55	M	10.39[a]	10,61[b]	10.98[c]	0.000
	SD	0.049	0.084	0.002	

Cont. table 6.

0.70	M	12.49	12.30	11.02	0.057
	SD	0.009	1.177	1.395	
0.75	M	13.14	13.60	13.08	0.495
	SD	0.044	0.098	1.392	
0.85	M	15.41^{c}	14.02b	13.24a	0.000
	SD	0.472	0.394	0.014	
0.92	M	18.60^{b}	14.42^{a}	14.45^{a}	0.000
	SD	0,450	0.104	0.316	

Source: own research.

Monolayer capacity (V_m) values, calculated using the BET equation, ranged from 5.75 to 6.23 g H_2 O/100 g dry weight (Table 7). The highest Vm was found for product III – oatmeal with strawberries, suggesting a greater number of polar sites available for water molecules, likely due to the addition of a fruit component rich in hydrophilic compounds. A similar trend was observed for the specific sorption surface area (SSA), the highest value of which was also obtained for the strawberry variant (218.79 m²/g) (Table 7). Differences between the products confirm the influence of raw material composition and flavor additives on sorption activity, consistent with previous reports for food powders (Rizvi, 1995; Al-Muhtaseb et al., 2002). The obtained results indicate that the hygroscopicity of instant oatmeal depends on both its composition and the initial water content, which is the driving force behind sorption processes. These parameters are crucial from a quality management perspective, as they determine storage stability, susceptibility to caking, and packaging requirements for instant products.

Table 7.
BET equation parameters and sorption specific surface area (SSA)

Product	V_m [g/100 g s.m.]	c_e [kJ·/mol^1]	R^2	SSA [m²/g]
Product I	5.8220	41.7037	0,9987	204.55
Product I	5.7538	52.4468	0,9991	202.16
Product II	6.2274	42.5575	0,9957	218.79

Explanatory notes: V_m - capacity of monomolecular layer, C_e - energy constant, R^2 - coefficient of determination, SSA - specific surface area of sorption.

Source: own research.

3.6. A Systematic Approach to Quality Management and Critical Control Points (HACCP) in the Assessment of Instant Oats

Contemporary quality assessment of instant products, including functional foods such as oats, requires the integration of laboratory test results with a systematic approach to quality and food safety management. According to classical quality concepts (Deming, 1986; Crosby, 1979) and the ISO 9000 definition, quality denotes a product's ability to meet defined requirements, with safety being one of its fundamental dimensions. In instant food production, each stage of the technological process can generate specific biological, chemical, or physical hazards, which is reflected in the risk analyses recommended by Codex Alimentarius and mandatory in HACCP systems (FAO/WHO, 2020). Therefore, the physicochemical,

microbiological, sensory, and sorption parameters analyzed in this study should be interpreted not only as descriptions of product properties but also as critical control indicators used in monitoring the quality and shelf life of instant products. This methodological approach allows for linking research results to the real-world requirements of industrial practice, reinforcing the applied and expert nature of the analysis.

The results of the studies conducted for instant oatmeal indicate that the analyzed quality parameters directly correlate with the requirements set by food safety management systems. Low water activity (aw < 0.40) and water content at levels typical of instant foods are within the critical limits described in the literature as necessary to ensure the microbiological stability of powdered products (Labuza, 1980; Fontana, 2008). The obtained results confirm the effectiveness of the drying and moisture stabilization steps, which correspond to critical control points (CCP 2) in the HACCP system (Table 9).

The flow properties of the products, such as loose and tapped density, the Hausner coefficient, and the Carr index, indicate the stability of the powder structure and the predictability of its behavior during mixing and packaging (Table 9). These parameters are crucial for process management because they influence dosing uniformity and minimize the risk of ingredient segregation, as confirmed by previous studies on powdered products (Teunou, Fitzpatrick, 1999; Abdullah, Geldart, 1999).

The results of the microbiological assessment showed full compliance with applicable food safety criteria, suggesting effective implementation of GHP/GMP principles and the proper functioning of the stages related to heat treatment and hygiene of raw materials (European Commission, 2005). The presence of Bacillus cereus in some variants confirms the importance of monitoring milk powder and flavorings, which, according to the literature, are considered high-risk raw materials (Granum, Lund, 1997). When assessing the storage stability of products based on sorption analyses, it was found that sorption isotherms with shapes typical of products with a high carbohydrate content (Brunauer type II) confirm their hygroscopicity and, at the same time, enable precise prediction of qualitative changes during storage (BET; Brunauer et al., 1938; Rockland, Beuchat, 1987). The vm monolayer and SSA parameters indicate differences resulting from flavor additives, which can provide a basis for optimizing recipes and packaging. Integration of research results with the HACCP approach indicates the consistency of instant product properties with food safety requirements: from the effectiveness of heat treatment (CCP 1), through moisture and aw control (CCP 2), control of raw materials and additives (CCP 3), to flow properties determining the stability of packaging processes (CCP 4) and shelf life (CCP 5) (Table 8). The obtained results confirm that the assessment of instant oatmeal in physicochemical, microbiological, sensory and sorption terms provides a comprehensive basis for managing the quality of functional products, in accordance with the requirements of modern safety systems.

Table 8.
Linking research parameters with critical control points (CCPs) in the instant oatmeal production process

CCP	Process Stage	Main Hazards	Applied Analytical Parameters	Relevance for Quality & Safety Management
CCP 1	Hydrothermal treatment, enzymatic stabilization	Biological: survival of pathogenic microflora, Bacillus cereus	OLD, PD, BC, S	Assessment of processing effectiveness and elimination of biological hazards
CCP 2	Drying and water activity stabilization	Biological: microbial growth; Chemical: degradation reactions	Moisture content, Water activity	Establishing critical limits for microbiological stability
CCP 3	Addition of milk powder and flavor additives	B. cereus, Enterobacteriaceae, E. coli, molds	BC, EB, EC, PD, sensory evaluation	Control of high-risk raw materials and production hygiene
CCP 4	Mixing and packaging	Physical: foreign bodies; Technological: bridging, segregation	Density, Hausner ratio, Carr index, flow angles, sensory (texture)	Ensuring uniformity and proper functioning of packaging lines
CCP 5	Storage and distribution	Biological and physicochemical: hygroscopicity, caking	Sorption isotherms, Vm, SSA, Ce	Determination of shelf-life, packaging requirements, and storage conditions

Source: own research.

4. Summary and Conclusions

The analysis of three commercial instant oats allowed for a comprehensive assessment of their quality from a physicochemical, microbiological, sensory, and sorption perspective. All tested products were characterized by low water content and low water activity ($aw < 0.40$), which guarantees high storage stability and minimizes the risk of microbial growth. These results confirm the proper maintenance of critical parameters typical of instant foods.

The microbiological assessment demonstrated compliance with all safety requirements – no Salmonella spp. was detected, while the number of indicator bacteria was below the detection limit. All products can be considered safe, and the slight differences between the variants were mainly due to the presence of flavor components.

Physicochemical properties, including the angle of repose, angles of repose, and density parameters, indicate the moderate flowability of the tested powders, typical of instant oat products. The Hausner coefficient and Carr index classified the oats as powders with stable flow properties, which is important for mixing and packaging processes. Sensory analysis confirmed high acceptance of all variants, with the chocolate oatmeal receiving the highest rating. All products received average scores above 4.4 points, indicating their good organoleptic quality.

The sorption properties, in turn, showed that the oatmeals tested were clearly hygroscopic, and the shape of the type II isotherms confirmed their ability to bind water, typical of carbohydrate-rich foods. BET parameters and specific surface area of sorption differed between variants, reflecting the influence of flavor additives on sorption capacity.

Incorporating the perspective of HACCP and GHP/GMP systems showed that the analyzed parameters correspond to key critical control points in the production of instant products, such as drying and stabilization of water activity, raw material hygiene, flow properties during packaging, and storage stability. This confirms the usefulness of comprehensive quality analysis in managing the safety and shelf life of functional foods. Based on the conducted research, it was found that all instant oatmeal products tested met quality and safety requirements, exhibited favorable sensory properties, and exhibited stability typical of low-water foods. The results can provide a basis for further research on recipe optimization, storage stability, and consumer perception of instant oat products. Producers should pay particular attention to:

1. Maintaining low water content and water activity ($a_w < 0.40$) to ensure high shelf life and microbiological safety.
   The study results confirm that low moisture and water activity levels are crucial for storage stability and the prevention of microbial growth. Therefore, producers should particularly monitor drying, stabilization, and hygiene parameters of raw materials, considering them critical control points in HACCP systems.
2. Improving flavor formulations and monitoring sorption properties, as flavor additives influence sensory acceptance and hygroscopic parameters of the product.
   The chocolate oatmeal received the best sensory evaluation, and the differences in sorption parameters between the variants confirm the effect of additives on water-binding capacity. This means that manufacturers should optimize the composition of flavor additives to increase consumer acceptance while also considering their impact on product stability and packaging requirements.

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THE IMPORTANCE OF GREEN COMPETENCES IN TODAY'S LABOUR MARKET – THE STUDENTS' PERSPECTIVE

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Purpose: The aim of the study is to identify the role of green competences in today's labour market from the perspective of future university graduates.
Design/methodology/approach: The study was preliminary and based on conducting a pilot qualitative study. It focused on green competencies, specifically assessing the awareness of future university graduates regarding environmental changes and the importance of these competencies in the labour market. This article presents selected results of a survey con-ducted among students of the Częstochowa University of Technology.
Findings: There has been a growing interest in green competences in recent years, which has been reflected in a sharp increase in the number of publications referring to this issue. The survey identified students' knowledge of the changes taking place in the labour market as a result of the growing importance of sustainable development. Future graduates defined green competences and assessed their importance for the industry they plan to work in. The general state of students' knowledge of the environmental and climate changes taking place in their environment and the educational needs for developing their green competences were identified.
Research limitations/implications: The main limitation is the small sample size, which restricts generalisation of the results. The sample was not diverse in terms of year of study and discipline, which limited analysis across groups.
Originality/value: The study adds to the existing knowledge on the importance of green competences in the labour market by showing the students' perspective, their opinion on the changes taking place in the labour market, their green competences and educational needs, increasing green competences of future graduates.
Keywords: green competences/skills, sustainability development, green transformation.
Category of the paper: Research paper.

1. Introduction

Increasing environmental challenges such as climate change, ecosystem degradation, and natural resource depletion have accelerated energy transformation processes as well as the development of renewable energy sources and green technologies. Sustainable development has become one of the most important concepts of the first half of the 21st century (Elmqvist

et al., 2019; Sitek, Tvaronaviciene, 2021), with the transformation towards green economies shaping new competences and jobs. The labour market and competences of the future are determined by environmental factors among other things. These include the level of environmental awareness among the population, the development levels of the circular economy and sustainable transportation, the degree of renewable energy source utilisation, and efforts to achieve climate neutrality (Dębkowska et al., 2022a). The shift towards a more sustainable circular economy will impact employment both in quantitative and qualitative terms (skills-wise) (Wegenberger, Ponocny, 2025; Sipa, Sitek, 2024). According to the International Labour Organization (ILO), the transition to a green economy may create millions of new jobs requiring specialist knowledge and skills, more specifically the so-called green competences (International Labour Organization, 2019). In order to achieve sustainability goals, employers from green industries are increasing the demand for employees with green competences. According to the Global Green Skills Report (LinkedIn, 2023), between 2023 and 2024 there was a 7.7% increase in the number of job adverts for positions related to ecology or requiring at least one green skill. According to the World Economic Forum (2020), the development of green competences not only contributes to environmental protection, but also enhances the labour market's resilience to future challenges such as automation and environmental crises. Thus, one of the priorities of labour market policies in many countries is to integrate green competences into education and training systems as well as employment strategies (Zwolińska et al., 2022). Environmental awareness, the ability to use new technologies, and the capacity to manage environmental protection projects raise professional value and increase employability (Cedefop, 2021). Individuals with green skills report an employment rate 54.6% higher than the overall workforce (LinkedIn Economic Graph, 2024).

Green transformation is, and will continue to be, affecting the Polish labour market. It is forecast that by 2030, 300,000 new jobs will have been created in Poland, linked to renewable energy sources, nuclear energy, thermomodernisation of buildings, electromobility, digitisation in a broad sense, and network infrastructure management (Konfederacja Lewiatan, 2022; Ścibich-Kopiec, 2024). Thus, it is necessary to provide future graduates with education that will equip them with appropriate green competences and skills to match the needs of present and future employers operating in green economy sectors (Nikolajenko-Skarbalė et al., 2021). As Wegenberger and Ponocny (2025) stress, identifying and understanding the necessary competences helps determine the demand for skills and facilitates better orientation of individuals and educational establishments.

The growing interest in green competences is evidenced by the increasing number of publications on the subject in recent years. In the Scopus database, the first papers on green competences or skills were recorded in 2012. The largest increase in the number of publications referring to the issue at hand was in 2024, when 89 papers were published. This represents an increase of 56 publications compared to 2023. Mainstream research streams focus on the conceptualisation of green competences, their relevance to sustainable development and

economic transformation, the identification of competency gaps and, to a small extent, the role of vocational and higher education in shaping them. As Urszula Gołaszewska-Kaczan and Julita Augustyńczyk (2025) note, the topic of green competences, in the context of higher education, is not yet widely represented in the academic literature. The vast majority of analyses to date focus on entrepreneurs, managers or employees.

To the best of the Author's knowledge, there are no studies that directly examine the significance of green competences and their development from the perspective of future higher education graduates in Poland, which constitutes a research gap in the context of green competences. Therefore, the main aim of this study was to identify the role of green competences in the current labour market from the perspective of future university graduates. The author conducted an initial verification of students' awareness of the growing importance of the concept of sustainable development and related changes in the labour market, in particular the increased demand for employees with green competences.

Further sections of the study present basic issues related to the addressed subject, an outline of the research concept, as well as the analysis and discussion of the research questions formulated as follows:

P1. Are students aware of the population's impact on the natural environment and what pro-environmental attitudes do they exhibit?

P2. How do young people perceive green competences and are these competences key to the industry in which they wish to pursue their professional careers?

P3. How do they assess their competences in the area of sustainable development?

P4. Would they like to develop green competences – and if so, which ones – in order to meet the growing demands of today's labour market?

The paper concludes with a conclusion.

The results obtained are an important addition to the existing state of knowledge regarding the importance of green competences and their development in the labour market from the students' perspective.

2. Literature review

The literature highlights significant variation in the concept of competences (Serafin, 2016; Mikuła, Domaradzka, 2020). The European Centre for the Development of Vocational Training (Cedefop, 2014) defines competences as the "ability to appropriately use learning outcomes in a particular setting (during study or at work, in professional or personal development) or proven ability to use knowledge as well as personal, social, or methodological skills in work or study situations and in professional career and personal development" (Cedefop, 2014; Sudolska et al., 2023). Mikuła and Domaradzka (2020) state that competences represent skills,

knowledge, personal qualities, and behaviours needed to effectively complete assigned tasks, which are inseparably connected with acting in specific situations. They are also perceived as decision-making powers assigned to specific positions or individuals, arising from formal organisational structures (Serafin, 2016). Furthermore, enhanced employability, personal fulfilment and development, social inclusion, sustainable lifestyles, conscious life management, and active citizenship require key competences. According to the recommendation of the European Council (EU, 2018), key competences are an integrated combination of knowledge, skills, and attitudes. Knowledge constitutes established facts, numbers, concepts, ideas, and theories which facilitate comprehension of a particular subject or field, whereas skills refer to the ability to perform actions and practically apply knowledge to achieve outcomes. Attitudes are understood as willingness and orientation to act or react to ideas, individuals, or situations.

Ismail et al. (2021) stress that it is thanks to employees equipped with knowledge, skills, and competences that enterprises can achieve their established goals and execute strategies. Increasingly, organisations strive to achieve their goals and implement strategies in a sustainable and environmentally friendly manner (Gorzeń-Mitka, 2024). As a result, the labour market is creating more and more so-called green jobs (Kozar, 2020), and green skills are gaining in importance (Antczak, Gajdos, 2023, Ziółkowska, 2024).

The literature lacks a single, widely accepted definition of green competences (Strachan et al., 2022; Kwauk, Casey, 2022; Sudolska et al., 2023). Cabral and Dhar (2019) argued that green competences are a reflexive, multidimensional concept comprising such elements as green knowledge, skills, abilities, attitudes, behaviours, and awareness. They noted that due to the ambiguity of this concept in academia, various terms such as sustainable skills, green skills, pro-environmental competences, and nature conservation competences are used interchangeably. Demssie et al. (2019) claimed that green competences refer to the integration of knowledge, skills, and attitudes that facilitate efforts to maintain human and natural resources required for social, environmental, and economic advancement of present and future generations. According to the OECD (2014), green competences are knowledge, skills, and attitudes necessary for supporting sustainable development, efficiently managing resources, and implementing environmentally friendly technologies. Cabral and Dhar (2021) further argued that green competences are hierarchical dispositional constructs comprising green knowledge, skills, awareness, attitudes, abilities, and behaviours. They include both technical abilities (e.g. renewable energy sources) and soft competences such as environmental awareness, sustainable work practices, and creativity in seeking innovative environmental solutions.

Green competences are most often used interchangeably with the term "green skills", which is also viewed as a broad and not entirely clear-cut concept (Wegenberger, Ponocny, 2025). According to Cedefop (2014), they refer to skills necessary for living in a society striving to reduce the negative human impact on the natural environment. General environmental skills aim at raising awareness and supporting activities that facilitate energy conservation and

promote pro-ecological attitudes. To apply standards and procedures aimed at protecting biodiversity and ecosystems, as well as reducing energy, natural resource, and water consumption, specific environmental (green) skills are required. Specialised environmental skills are utilised in developing and implementing environmentally friendly technologies such as renewable energy sources and recycling processes. According to the United Nations Industrial Development Organization (UNIDO, 2022), green skills comprise knowledge, abilities, values, and attitudes needed to live in, develop, and support a sustainable society that manages resources efficiently. The concept of green skills is often used synonymously with green jobs (Montanari et al., 2023) and sustainability competences (e.g. in GreenComp). As noted by Sudolska et al. (2023), analyses of different ways of conceptualising green competences allow differentiation into three basic elements: knowledge, skills, and attitudes.

The identification and provision of appropriate competences (skills) for green jobs can help harness significant potential for job creation while enabling enterprises and economies to achieve sustainability goals more effectively. However, when employees lack sufficient skills necessary to perform their duties effectively, or when their qualifications do not meet the requirements of a position, a competence gap emerges. This phenomenon also arises when employees have an appropriate level of qualifications yet lack specific types of skills (e.g. management) or experience to execute tasks effectively. The competence gap can occur at the level of an entity, organisation, sector, or at regional, national, and international levels (Cedefop, 2021). Nikolajenko-Skarbalė et al. (2021) note that economies transitioning towards a green economy are facing various challenges. These are determined by factors such as natural resources, the historical level of economic development, or climate conditions. Of equal importance are citizens' attitudes and awareness of the significance of efforts promoting a sustainable and ecological future. The varying levels of these factors indicate that the demand for green abilities and skillsets will differ between economies. According to the Green Skills Report (LinkedIn, 2024), between 2023 and 2024 the global demand for employees with green competences increased by 11.6%, whereas supply rose by 5.6%. Furthermore, the list of 10 countries with the largest gap between demand and supply growth included Poland. The largest gap between demand growth and supply growth of green talents was visible in Portugal, Great Britain, and Costa Rica. In each of these countries, demand is growing much faster than supply. In the case of Poland, this gap is the smallest (Kaura, 2024) (Figure 1).

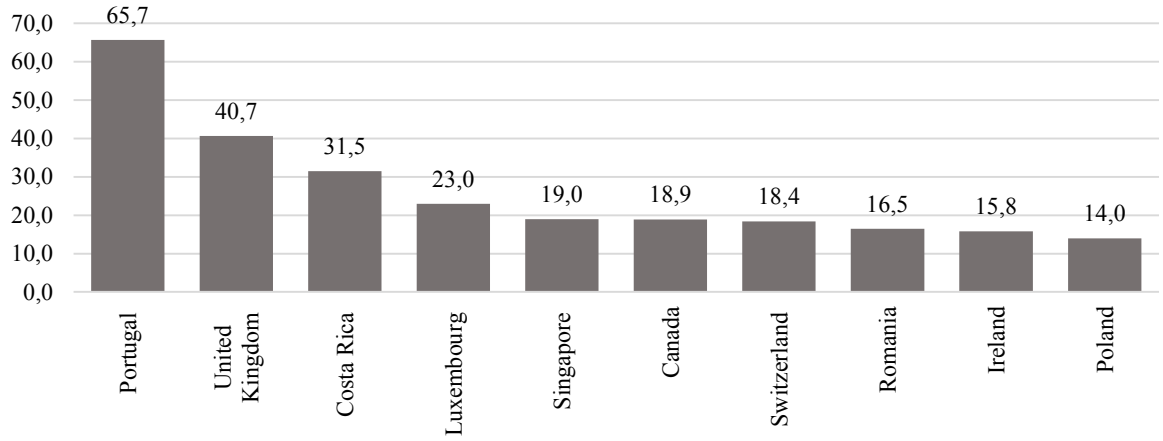


Figure 1. Top 10 countries with the largest gap in green talent demand versus supply growth from 2023 to 2024 (year over year).

Source: Kaura, 2024.

Moreover, it was pointed out that unless the supply of green competences doubles and current market trends remain unchanged, by 2050 the competence gap will have increased to 101.5%, and the achievement of sustainability goals will be at risk (LinkedIn Economic Graph, 2024). Thus, it is imperative to close the competence gap between labour market demand and the development of green competences among future university graduates. As Montanari et al. (2023) state, one possible way to equip employees and students with the knowledge, skills, and awareness necessary for sustainable development is competence-based education and training.

3. Methods

The research took the form of a pilot study. Its main aim was to examine the role of green competences in the current labour market from the perspective of future university graduates. It served as an initial assessment of students' awareness. Data for the pilot study were collected using a structured questionnaire that included questions on students' knowledge, skills, and attitudes towards sustainable development, with particular emphasis on the growing importance of green competences in shaping the labour market. For questions that required respondents to evaluate a particular issue, a five-point Likert scale was employed. The study was conducted in May 2025. This paper presents a preliminary assessment of students' awareness of the growing significance of sustainable development and related labour market changes, particularly the increasing demand for employees with green competences. The conclusions are based on statistical analyses of basic descriptive statistics, carried out using Microsoft Excel and Statistica 13. In total, data from 198 correctly completed questionnaires were analysed. The respondents were students of Częstochowa University of Technology.

4. Results and Discussion

The majority of the respondents were female (61.11%). Males accounted for 38.38%, and one person refused to answer the question related to sex. The overwhelming majority of the research sample were first-year students (80.30%). Fifth-year students accounted for 16.67%, while the remaining respondents were third- and fourth-year students. The research sample was dominated by students of economic studies (87.88%). Every tenth respondent was a student of technical subjects, while 1.52% studied natural sciences (Table 1).

Table 1.
Research sample characteristics (*N* = 198)

Category	Subcategory	*N*	%
Sex	Female	121	61.11
	Male	76	38.38
	I prefer not to answer	1	0.51
Study year	1st year	159	80.30
	2nd year	3	1.52
	3rd year	3	1.52
	5th year	33	16.67
Study type	Natural sciences (e.g. Biology, Chemistry, Geography, Physics)	3	1.52
	Technical: (e.g. Engineering, Information Technology, Architecture)	21	10.61
	Economic studies (e.g. Management, Finances, Economics)	174	87.88

Source: own study.

Respondents evaluated their knowledge and skills in the field of natural environmental protection and ecology. Table 2 presents selected descriptive statistics. The analysis of the data revealed that the respondents evaluated their awareness of the human impact on the environment as high (average 4.08). However, agreement with the statement "Each of us has an impact on the natural environment" was lower, with an average rating of 3.88. It is worth noting that in the case of awareness of the human impact on the environment, 78.79% of respondents rather agreed or definitely agreed with the statement, while only 7.58% rather disagreed or definitely disagreed. For the statement "Each of us has an impact on the natural environment", the percentage of respondents who rather disagreed or definitely disagreed was higher (12.12%). What is concerning is that despite relatively high awareness of the human impact on environmental change, one third of respondents rather did not feel or definitely did not feel responsibility for environmental protection, while 31.82% had no opinion on the issue. Furthermore, the respondents generally did not promote engagement in environmentally friendly activities (average 2.52). Half of them rather or definitely did not promote such behaviours, and only 18.2% engaged in promoting eco-friendly attitudes. This result confirms the observations of Montanari et al. (2023), pointing to the phenomenon of declarative environmentalism - however, knowledge of environmental problems does not always translate into specific action.

Table 2.
Protection of the natural environment and ecology – evaluation of students' skills and knowledge

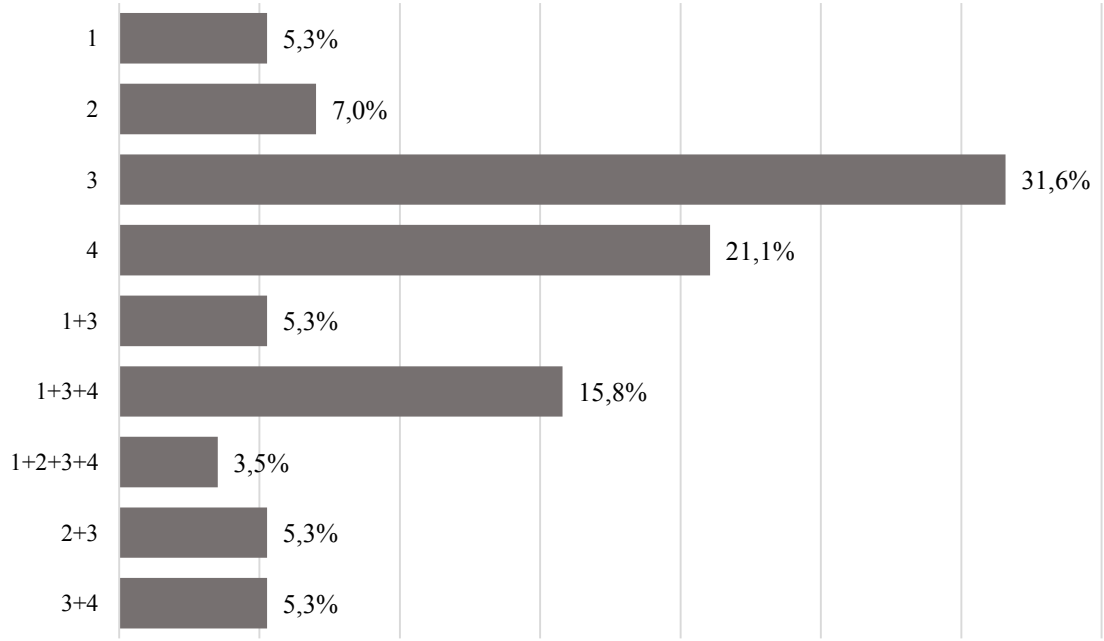
	Selected statistics						
	N	**Average**	**Median**	**Mode**	**Number of modes**	**Minimum**	**Maximum**
I am aware of the human impact on the natural environment	198	4.08	4	Multiple	78	1	5
I think that each of us has an impact on the state of the natural environment	198	3.88	4	4	75	1	5
I feel responsibility for the protection of nature	198	2.98	3	3	63	1	5
I can indicate the main causes of global warming	198	3.62	4	4	72	1	5
I know the basic environmental concepts (e.g. carbon footprint)	198	3.38	3	4	63	1	5
I follow news and articles connected with ecology	198	2.65	3	3	66	1	5

KEY: 1 – I definitely disagree; 2 – I rather disagree; 3 – I have no opinion; 4 – I rather agree; 5 – I definitely agree.

Source: own study.

Regarding knowledge of basic issues related to environmental protection and climate change, respondents were asked to evaluate their knowledge of key environmental concepts and the main causes of global warming, as well as to indicate whether they increased their knowledge in this area by following news related to ecology. The study revealed that over half of respondents (56.06%) were able to indicate the main causes of global warming, while almost one third had no opinion. The average rating in this category was 3.62. Knowledge of environmental concepts was rated slightly lower (average 3.38). This resulted partly from a relatively high percentage of "rather or definitely disagree" responses (22.73%) and fewer respondents (48.48%) indicating familiarity with environmental concepts. Nearly half of respondents (46.97%) did not follow any news related to ecology, while one third had no opinion. The average rating for this statement was 2.65.

The analysis of the data revealed that the overwhelming majority of students were not familiar with the concept of green competences. Only 28.79% (n = 57) indicated familiarity. Most of these respondents understood green competences as "practical skills connected with environmentally sound management" (98.25%) or "ability to act in support of sustainable development" (45.61%). Respondents were allowed to select several descriptions of the concept. The most frequently selected combination was "knowledge about climate change and its results", "practical skills connected with environmentally sound management", and "ability to act in support of sustainable development", chosen by 15.79% of respondents (Figure 2 presents the detailed distribution of responses).



Note:
1. Knowledge about climate change and its results.
2. Knowledge of the principles of a circular economy.
3. Practical skills connected with environmentally sound management.
4. Ability to act in support of sustainable development.

Figure 2. Understanding the concept of "green competences" (*n = 57*).

Source: own study.

The results show that despite the growing role of green competences in the economy (ILO, 2019; LinkedIn, 2023; Wegenberger, Ponocny, 2025), the terminology remains little recognised among students. Such a high percentage of people unfamiliar with the concept of "green competences" may be indicative of a gap in formal education that has not kept up with European standards.

The study also examined the extent to which students engaged in energy conservation, plastic reduction, or the use of renewable energy sources. The analysis showed that 63.64% saved electricity and water at home, 40.91% attempted to reduce plastic use in daily life, 39.39% chose local and seasonal products, and 37.88% used renewable energy sources such as photovoltaics or wind energy (Table 3).

The analysis revealed that over half of respondents (58.59%) noticed the growing importance of competences connected to environmental protection and sustainable development in the labour market, whereas 12.63% did not perceive this trend. Nearly three out of ten respondents indicated that they had no knowledge of the issue.

The study further indicated that students perceived the industries in which they anticipated pursuing future careers as requiring competences in environmental protection and sustainable development only to a limited extent. Only 7.58% of respondents reported that their chosen industry demanded such competences to a very large extent, while 15.15% believed they were required to a large extent. The average rating was 2.73 on a five-point Likert scale. These results

diverge significantly from the views of Irish students, who overwhelmingly (92%) agree or strongly agree that green skills are necessary to meet environmental challenges across industries (da Costa et al., 2025).

Table 3.
Students' attitudes towards activities promoting environmental protection

	Selected statistics						
	N	**Average**	**Median**	**Mode**	**Number of modes**	**Minimum**	**Maximum**
I save electricity and water at home	198	3.68	4	4	87	1	5
I choose local and seasonal products	198	3.21	3	3	75	1	5
I try to reduce my use of plastic in daily life	198	3.09	3	4	57	1	5
I encourage others to engage in environmentally friendly activities	198	2.52	2.5	3	63	1	5
I use renewable energy sources (e.g. photovoltaics, wind energy)	198	2.80	3	1	60	1	5

KEY: 1 – I definitely disagree; 2 – I rather disagree; 3 – I have no opinion; 4 – I rather agree; 5 – I definitely agree.

Source: own study.

Even lower ratings were recorded regarding the necessity of possessing green competences in future professional careers. Green competences were regarded as important by 1.52% of respondents and very important by 12.12%. Furthermore, one in five respondents considered green competences unimportant for their career. The results obtained are in line with those carried out among Generation Z, in whose opinion green competences are not crucial for their career development (Kozara, 2025). The low percentage of students perceiving the growing importance of green competences in the labour market contradicts forecasts indicating a dynamic growth in demand for such skills (Kaura, 2024; Polish Confederation Lewiatan, 2022; LinkedIn Economic Graph, 2024). This suggests, among other things, the existence of an information gap that may lead to a mismatch between the qualifications of graduates and the requirements of a sustainable economy. Furthermore, the fact that students of economics (who make up the majority of the sample) recognise that their future industry requires little in the way of such skills may suggest that they perceive "green competence" narrowly - as the domain of environmental engineers - overlooking the key role of sustainable finance, ESG reporting or green supply chain management, which are now a priority in the business sector.

Respondents also evaluated the importance of specific skills related to sustainable development for their future career paths. Table 4 presents selected descriptive statistics, while table 5 – the distribution of the responses. On a five-point Likert scale, "system and long-term thinking" was ranked highest, with an average of 3.65 and 62.1% rating it as important or very important. The median and mode for this variable were 4. Higher ratings were also given to "acting in the face of uncertainty" (3.47) and "cooperation for the promotion of sustainable development" (3.26). The least important, according to respondents, were the ability to predict

the outcomes of environmental activities (2.88) and knowledge of circular economy principles (2.97).

Table 4.
Evaluation of the usefulness of green competences in students' future professional careers – descriptive statistics

	Selected statistics						
	N	**Average**	**Median**	**Mode**	**Number of modes**	**Minimum**	**Maximum**
System and long-term thinking	198	3.65	4	4	75	1	5
Predicting the outcomes of environmental activities	198	2.88	3	3	60	1	5
Knowledge of the principles of a circular economy	198	2.97	3	3	66	1	5
Communication skills connected to environmental issues	198	3.00	3	3	63	1	5
Cooperation for the promotion of sustainable development	198	3.26	3	3	72	1	5
Acting in the face of uncertainty	198	3.47	3	3	72	1	5

Source: own study.

Self-assessment of competences and preferences for their development indicate that students rate soft skills such as systems thinking or responsibility for actions taken better, which is in line with the GreenComp approach (European Commission, 2022). More technical areas, such as the circular economy, are rated lower, which may be due to limited exposure to this subject matter in earlier stages of education.

Table 5.
Evaluation of the usefulness of green competences in students' future professional career – distribution of the responses

	Ratings					Total
	1	**2**	**3**	**4**	**5**	
System and long-term thinking	6.1%	9.1%	22.7%	37.9%	24.2%	100%
Predicting the outcomes of environmental activities	15.2%	22.7%	30.3%	22.7%	9.1%	100%
Knowledge of the principles of a circular economy	13.6%	19.7%	33.3%	22.7%	10.6%	100%
Communication skills connected to environmental issues	12.1%	22.7%	31.8%	19.7%	13.6%	100%
Cooperation for the promotion of sustainable development	9.1%	13.6%	36.4%	24.2%	16.7%	100%
Acting in the face of uncertainty	7.6%	7.6%	36.4%	27.3%	21.2%	100%

Source: own study.

The failure of students to notice the growing importance of green competences in the labour market was confirmed by responses to the question: Can the lack of green competences impact your employability? Nearly 40% believed the lack of such competences was irrelevant, 43.94% did not know whether such a relationship existed, and only 16.67% believed the lack of green competences could impact employability.

Students also self-assessed their green skills, with 1 signifying a very low level and 5 a very high level. The students rated their skills as moderate. The median for six out of seven variables was 3, and the average did not exceed 3.48. Table 6 presents selected descriptive statistics, while table 7 presents the distribution of the responses. "Responsibility for actions taken" was

rated highest (3.48 on a five-point Likert scale), with a median of 4, and 56.1% rating it high or very high.

Table 6.
Self-assessment of green competences – descriptive statistics

	Selected statistics						
	N	**Average**	**Median**	**Mode**	**Number of modes**	**Minimum**	**Maximum**
System and long-term thinking	198	3.32	3	4	72	1	5
Predicting the outcomes of environmental activities	198	2.94	3	3	87	1	5
Knowledge of the principles of a circular economy	198	2.73	3	3	78	1	5
Communication skills connected to environmental issues	198	2.86	3	3	78	1	5
Cooperation for the promotion of sustainable development	198	3.08	3	3	72	1	5
Acting in the face of uncertainty	198	3.15	3	3	81	1	5

Source: own study.

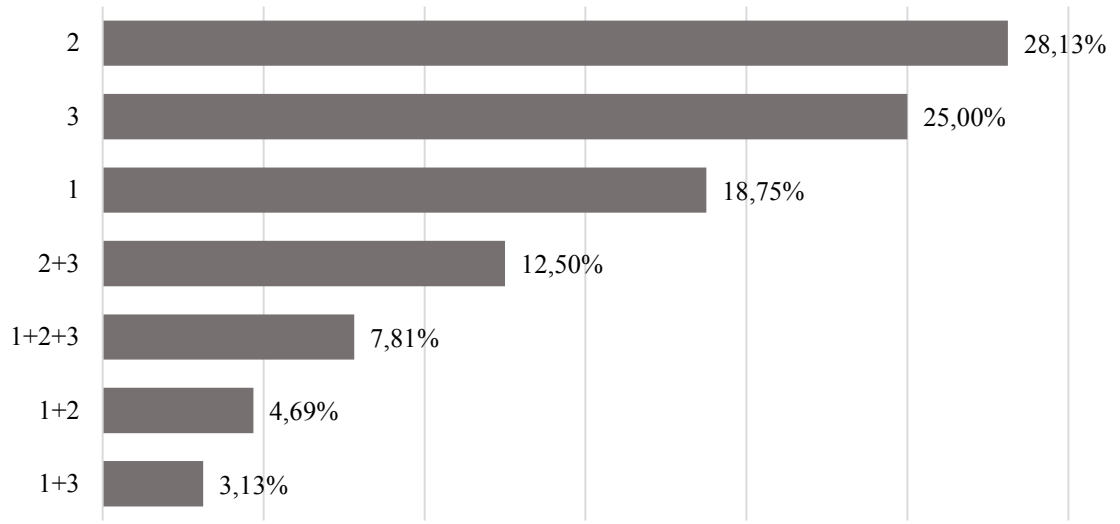
Skills rated below average included "predicting the outcomes of environmental activities" (2.94), "communication skills connected to environmental issues" (2.86), and "knowledge of the principles of a circular economy" (2.73).

Table 7.
Self-assessment of green competences – structure of the responses

	Ratings					Total
	1	**2**	**3**	**4**	**5**	
System and long-term thinking	3.0%	19.7%	30.3%	36.4%	10.6%	100.0%
Predicting the outcomes of environmental activities	7.6%	24.2%	43.9%	15.2%	9.1%	100.0%
Knowledge of the principles of a circular economy	15.2%	22.7%	39.4%	19.7%	3.0%	100.0%
Communication skills connected to environmental issues	13.6%	21.2%	39.4%	16.7%	9.1%	100.0%
Cooperation for the promotion of sustainable development	10.6%	18.2%	36.4%	22.7%	12.1%	100.0%
Acting in the face of uncertainty	4.5%	19.7%	40.9%	25.8%	9.1%	100.0%

Source: own study.

The overwhelming majority of respondents expressed a desire to develop green competences, with only six showing no interest. The most frequently indicated form of development was practical workshops (28.13%), followed by projects and internships in sustainability-oriented companies (25%), and e-learning courses (18.75%). Other respondents indicated various forms. (Figure 4) The choice of workshops, projects and internships by students as methods of developing green competences confirms that practical forms of development are the most effective, which is in line, for example, with the recommendations of the OECD (2014) or the opinion of Montanari et al. (2023).



Note:
1 - E-learning courses.
2 - Practical workshops at university.
3 - Projects and internships in sustainability-oriented companies.

Figure 4. Preferred forms of developing green competences.

Source: own study.

The indications of the students surveyed are consistent with the findings of international research, which has shown that students in Ireland feel overwhelmed by theory and insufficiently prepared for the practical implementation of sustainability strategies in the workplace (da Costa et al., 2025).

Students also indicated which competences they would like to develop further, measured using a five-point Likert scale (1 = no need; 5 = strong need). All averages were above 3, ranging from 3.18 to 3.74. The greatest need was expressed for developing system and long-term thinking (3.75), responsibility for actions taken (3.73), and ability to act in the face of uncertainty (3.71). The least demand was for predicting the outcomes of environmental activities (3.18). Table 8 presents selected descriptive statistics.

Table 8.
The need to develop green competences – descriptive statistics

	Selected statistics						
	N	**Average**	**Median**	**Mode**	**Number of modes**	**Minimum**	**Maximum**
System and long-term thinking	198	3.74	4	5	78	1	5
Predicting the outcomes of environmental activities	198	3.18	3	3	66	1	5
Knowledge of the principles of a circular economy	198	3.23	3	3	54	1	5
Communication skills connected to environmental issues	198	3.42	3,5	4	66	1	5
Cooperation for the promotion of sustainable development	198	3.50	3	3	63	1	5
Acting in the face of uncertainty	198	3.71	4	5	63	1	5
Responsibility for actions taken	198	3.73	4	5	63	1	5

Source: own study.

A comparative analysis of students' self-assessed green needs and their declared needs for further development (Figure 5) indicated that the competences receiving the lowest ratings did not coincide with those in which students expressed the greatest interest in further development.



Figure 5. Evaluation of existing green competences versus students' willingness to develop them. Source: own study.

Respondents mainly wished to enhance skills such as system and long-term thinking and responsibility for actions taken, which they also considered most important for their future careers.

5. Conclusions

Current economic transformations, as well as enterprises' efforts to comply with sustainable development principles, including the Paris Agreement, are key determinants of labour market changes, including the shift in competence profiles towards greener skills. Research into competences related to green jobs assists in identifying competence gaps and sheds light on the most important trends shaping the future of employment. The analysis allowed a preliminary verification of university students' awareness of the growing importance of sustainable development and related labour market changes, in particular the demand for employees with green competences. In the study, the majority of students declared high awareness of human

impact on the environment, but only 68% felt personal responsibility for its protection. Furthermore, only a small percentage actively promoted environmental activities, and engagement in actions such as energy saving, plastic reduction, or buying local products was moderate. This highlights a gap between students' knowledge and its application in practice.

Few students were familiar with the concept of green competences, most often understanding it as practical skills related to environmentally sound management. Although over half noticed the growing demand for such competences in the labour market, only one in five considered them important or very important in their chosen industries. Moreover, four in ten thought the lack of green competences would not affect employability. Students rated their green skills as moderate. Responsibility for actions taken and system thinking were rated highest, while circular economy knowledge and environmental communication were lowest. System and long-term thinking was the competence students most wished to develop, followed by acting in the face of uncertainty and cooperation for sustainable development. Less interest was expressed in developing the skill of predicting the outcomes of environmental activities and knowledge of the circular economy.

Thus, the results of the study indicate an urgent need for a revision of the curricula, especially in faculties that are not directly associated with ecology, energy technology or environmental protection. It is also necessary to intensify efforts to raise awareness of the importance of pro-environmental competences in present-day's labour market.

Universities should actively counter the misconception among students that green competences are of marginal use in their careers. In this context, it is particularly important to integrate sustainability content more widely into curricula, e.g. by including at least one sustainability-related module or practical assignment in each field of study. In addition, students' sense of agency needs to be increased, moving from knowledge-based education to action- and problem-based learning. In this area, the campus can, for example, be used as a space for environmental projects.

In response to the need for students to gain practical experience, universities should strengthen cooperation with local businesses, in terms of co-designing educational programmes, mentoring, internships or joint competence examinations. Developing microcredentials and short certification pathways linked to the European Qualifications Framework (Storonyanska et al., 2025) may also be an interesting solution. They increase the availability of expertise, lower barriers to entry and provide the flexibility important from a student perspective.

In addition, the standardisation and measurement of green competences by higher education institutions would make it possible to include the student's green competence in the diploma supplement. As a result, this would make it easier for graduates to cooperate with the labour market. Simultaneously, universities should invest in developing the competences of their

teaching staff, especially in terms of activation methods and practical tools used in green sectors of the economy.

In conclusion, it should be stressed that this was a pilot study aimed at verifying the research design and providing a preliminary exploration of the phenomenon. The project is not free from shortcomings. Random sampling was not applied due to the research issues and subject. The main limitation is the small sample size, which restricts generalisation of the results. The sample was also not diverse in terms of year of study and discipline, which limited analysis across groups. A more varied sample would allow comparative insights and more in-depth interpretation. Moreover, given known gender differences in environmental perceptions, future studies should consider comparative analysis by sex.

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THE ROLE OF ECOLOGICAL SUBSIDIES IN THE SUSTAINABLE DEVELOPMENT OF MUNICIPALITIES IN MAZOVIA

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Purpose: The aim of this study was to analyze the ecological needs of municipalities in Mazovia, taking into account selected indicators corresponding to the goals of sustainable development (social, economic, and environmental).
Design/methodology/approach: The study uses a descriptive and research method, primarily based on the analysis of statistical data and selected legal acts, as well as a literature review. The study consisted of two stages. The first stage involved a literature review, which provided the basis for selecting indicators corresponding to the goals of sustainable development. The next stage included analyzing selected indicators and planned amounts of ecological subsidies based on the Act on the Revenues of Local Government Units and the annex to the Regulatory Impact Assessment.
Findings: Municipalities that contain protected areas will receive financial support in the form of ecological needs (so-called ecological subsidies) starting in 2025. The research results indicate that the amounts of ecological subsidies are related to the type, weight, and area of the protected area.
Research limitations/implications: Due to the introduction of ecological subsidies in 2025, assessing their significance for local development in municipalities will only be possible in the coming years. Future research will focus on the experiences of municipalities benefiting from this form of support. Nevertheless, this study may represent an initial attempt to verify the availability of funds that support municipalities with legally protected areas.
Practical implications: This article presents original research on ecological subsidies for municipalities with protected areas. It may also serve to assess the level of acceptance of protrcted areas by local communities.
Originality/value: This paper has implications for both researchers and municipalities with protected areas and may serve as a starting point for developing analytical frameworks to assess the level of local development and the financing of other needs of local government units.
Keywords: protected areas, ecological subsidy, sustainable development.
Category of the paper: Research paper.

1. Introduction

Legally protected areas are areas of particular natural value, designated based on the provisions of the Act of 6 April 2004 on Nature Conservation (consolidated text Dz.U. 2024, item 1478, as amended). In 2023, there were 2,380 legally protected areas in Poland, including 23 national parks, 1,523 nature reserves, 126 landscape parks, 126 protected landscape areas, and 319 nature-landscape complexes. Additionally, there were 1,139 terrestrial Natura 2000 areas, including 190 Special Protection Areas for Birds and 949 Special Areas of Conservation (Ochrona środowiska, 2024). In 2023, the highest number of legally protected areas was in the following voivodeships: Mazowieckie (343), Pomorskie (337), Zachodniopomorskie (290), and Warmińsko-Mazurskie (270) – Figure 1.

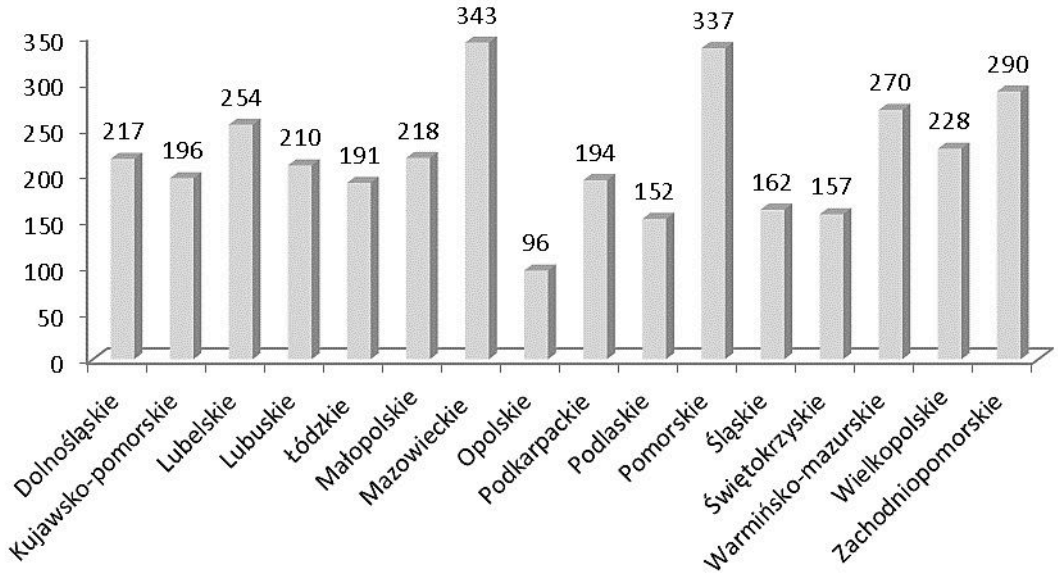


Figure 1. Number of legally protected areas in the voivodeships in 2023.
Source: Own research based on: Ochrona środowiska, GUS (2024).

2. Theoretical approach

The purpose of creating protected areas is, among other things, to preserve biodiversity and protect landscape values (Act of 6 April 2004 on Nature Conservation, consolidated text Dz.U. 2024, item 1478, as amended, art. 2.2). These areas are often perceived by local authorities as "problematic" areas, associated with restrictions on economic activity, local development, and a decrease in the income levels of local government units (hereinafter: JST). The fundamental issue is the acceptance of existing (and new) protected areas by local communities. These views have been reflected in proposals for establishing financial

compensation in the form of ecological subsidies for municipalities with protected areas. The discussion that began several years ago about the need to introduce this solution (in draft laws on JST revenues in 2012 and 2013) culminated in the JST revenue law of 2024 (Act of 1 October 2024 on the Revenues of Local Government Units, Dz. U. 2024, item 1572).

According to the Act of 1 October 2024 on the Revenues of Local Government Units (2024), ecological needs (also referred to as ecological subsidies) will be granted starting in 2025 to local government units (voivodeships, counties, cities with county rights, and municipalities) located in areas with protected zones (including national parks, nature reserves, landscape parks, and Natura 2000 areas). The planned amount for ecological needs in 2025 is approximately 1.5 billion PLN in total, of which about 1.1 billion PLN is designated for municipalities. The legislator's intention is to reduce barriers to the creation and development of protected areas and to promote sustainable development in the country.

Sustainable development is often equated with socio-economic development. The literature indicates that the level of this development is influenced by both national and local factors, including, among others, "geographical factors, demographic potential, wealth in capital, technical infrastructure, research and development activity, innovations, technical progress, an efficiently functioning healthcare system, universal access to education and high-level science, well-functioning state institutions, and a developed financial system" (Pawlas, 2017, p. 18). The goals of sustainable development are outlined in the document "Transforming Our World: The 2030 Agenda for Sustainable Development" (2015, hereinafter: Agenda 2030). The model of sustainable development for Poland is included in the National Regional Development Strategy until 2030 "Socially Sensitive and Territorial Sustainable Development" (2019, hereinafter: KSRR), and for Mazovia in the "Mazowieckie Voivodeship Development Strategy 2030+ Innovative Mazovia" (2022, hereinafter: SRWM).

The idea behind the actions in the National Regional Development Strategy (KSRR) is to support areas of strategic intervention (OSI), i.e., areas where local development is threatened due to the loss of significant socio-economic functions (e.g., negative demographic phenomena) and to reduce disparities in their socio-economic development (KSRR, 2019, p. 49). This model is significant for the Mazowieckie Voivodeship (hereinafter also referred to as Mazovia), which exemplifies the diversity in the level of development among municipalities in peripheral areas and those neighboring Warsaw (Łysoń, 2017).

3. Materials and Methods

The aim of this article is to analyze the planned amounts of ecological subsidies for municipalities in Mazovia with protected areas in 2025 and to attempt to answer the question of to what extent this form of support may impact local development. The subject of the research

consists of the municipalities of Mazovia that are eligible for ecological subsidies in 2025. Selected indicators corresponding to the goals of sustainable development (in social, economic, and environmental dimensions) were taken into account, namely: migration balances per 1000 residents, revenues and expenditures from municipal budgets, the area of protected areas, and the amounts of ecological subsidies for 2025.

The choice of the Mazowieckie Voivodeship as the area of study is motivated by its largest area in the country (11.4%), population (14.6%), and number of municipalities (314) (Statistical Yearbook of the Mazowieckie Voivodeship, 2024), as well as the highest amount of ecological subsidies for voivodeships, amounting to 15.1 million PLN (Szalast-Piwińska, 2024, p. 74).

The analysis of the planned amounts of ecological subsidies was conducted based on the Act of 1 October 2024 on the Revenues of Local Government Units (2024) and the annex to the Regulatory Impact Assessment (OSR) dated July 15, 2024. The types of protected areas, base rates per hectare of protected area, and their actual and calculated areas were taken into account. The desk research method was applied. The sources of information included reports from the Central Statistical Office (hereinafter: GUS), data from the Local Data Bank of GUS (hereinafter: BDL), Polish legal regulations, and relevant literature.

4. Research

In 2018, the Mazowieckie Voivodeship was divided into two statistical units: the Warsaw Metropolitan Region (hereinafter: RWS) and the Mazowieckie Regional Region (hereinafter: RMR). RWS includes 3 subregions, 9 counties, and the capital city of Warsaw, while RMR includes 6 subregions, 28 counties, and 4 cities with county rights (Radom, Płock, Ostrołęka, and Siedlce).

The analyses in the dimensions of sustainable development goals were based on data concerning selected municipalities in Mazovia for which the highest and lowest amounts of ecological needs are planned for 2025. Out of 258 municipalities eligible for ecological subsidies, a group of 24 municipalities was selected for further research, where the planned amounts of ecological subsidies will exceed 1 million PLN (Table 1), and 13 municipalities whose ecological subsidies will not exceed 1000 PLN (Table 2).

Table 1.
Studied municipalities in Mazovia - highest ecological subsidies in 2025

No.	Municipality	Region	OCH* area (%)	Ecological subsidy (thousand PLN)	Migration balance per 1000 residents	Total income (thousand PLN)	Total expenditure (thousand PLN)	Difference between total income and expenditure (thousand PLN)
1	Leoncin	RWS	72,5	6 205,50	4,3	41 821,65	51 986,89	-10 165,24
2	Leszno	RWS	67,5	4 463,00	11,1	92 057,32	103 833,99	-11 776,67
3	Czosnów	RWS	99,9	4 396,10	6,7	100 468,16	111 146,69	-10 678,53
4	Brochów	RMR	91,2	3 873,30	4,1	30 986,24	33 253,93	-2 267,69
5	Izabelin	RWS	85,9	3 458,90	7,1	85 963,16	113 716,16	-27 753,00
6	Kampinos	RWS	59,5	2 191,10	3,8	33 632,79	36 379,73	-2 746,94
7	Strzegowo	RMR	95,1	1 894,10	-7,9	49 639,43	63 092,14	-13 452,71
8	Pionki	RMR	99,9	1 852,40	-0,8	50 584,12	55 801,88	-5 217,76
9	Lubowidz	RMR	94	1 665,30	-6,1	45 383,18	46 977,71	-1 594,53
10	Maciejowice	RMR	99,9	1 629,60	-4,4	52 506,09	56 420,70	-3 914,61
11	Sadowne	RMR	100	1 369,30	1,6	45 324,10	45 399,15	-75,05
12	Gostynin	RMR	49	1 276,10	1,8	67 120,14	83 023,75	-15 903,61
13	Mrozy	RWS	84	1 274,60	7,6	52 923,18	55 069,52	-2 146,34
14	Glinojeck	RMR	87	1 251,20	-7,2	54 003,44	57 294,95	-3 291,51
15	Solec nad Wisłą	RMR	100	1 206,60	-0,7	32 850,83	33 912,40	-1 061,57
16	Nowy Duninów	RMR	78	1 195,60	-3,8	21 109,62	22 863,23	-1 753,61
17	Lutocin	RMR	100	1 174,00	-3,8	25 170,56	24 892,37	278,19
18	Wilga	RMR	100	1 104,60	4,7	39 737,78	42 285,35	-2 547,57
19	Kozienice	RMR	73	1 083,40	-2,7	237 906,33	253 640,21	-15 733,88
20	Lipowiec Kościelny	RMR	95	1 077,40	-1,6	30 570,51	32 335,95	-1 765,44
21	Jabłonna Lacka	RMR	76	1 075,00	-4,9	25 429,91	28 925,13	-3 495,22
22	Siemiątkowo	RMR	100	1 053,20	-11,9	23 781,38	29 431,36	-5 649,98
23	Sarnaki	RMR	56	1 052,50	-7	47 177,41	50 728,80	-3 551,39
24	Wyśmierzyce	RMR	97	1 027,50	-6	21 650,77	23 121,07	-1 470,30
					Total	**1 307 798,10**	**1 455 533,06**	**-147 734,96**

*PROTECTED AREAS (OCH)

Source: Own research based on: BDL (as of December 31, 2023); Annex to the Regulatory Impact Assessment (OSR) dated July 15, 2024.

Table 2.
Studied municipalities in Mazovia - lowest ecological subsidies in 2025

No.	Municipality	Region	OCH* area (%)	Ecological subsidy (PLN)	Migration balance per 1000 residents	Total income (thousand PLN)	Total expenditure (thousand PLN)	Difference between total income and expenditure (thousand PLN)
1	Sochaczew	RMR	0,01	0,93	-3,8	208 036,98	215 356,57	-7 319,59
2	Teresin	RMR	0,02	1,86	-2,8	95 232,60	101 680,53	-6 447,93
3	Chynów	RMR	0,05	4,65	4	59 807,92	64 180,14	-4 372,22
4	Sochaczew	RMR	0,05	4,65	8,4	72 631,84	75 364,70	-2 732,86
5	Potworów	RMR	0,08	7,44	-1	25 812,72	25 451,04	361,68
6	Sierpc	RMR	0,1	9,3	-4,1	96 062,99	95 553,91	509,08
7	Ciechanów	RMR	0,11	10,23	-0,7	308 338,38	302 698,83	5 639,55
8	Legionowo	RWS	0,28	26,04	1,2	289 223,07	309 921,24	-20 698,17
9	Poświętne	RWS	0,46	42,78	3,2	54 879,20	55 807,23	-928,03
10	Tczów	RMR	2,16	102,77	-0,4	30 087,93	31 234,67	-1 146,74
11	Lipsko	RMR	3,21	298,53	-4,7	56 816,45	62 680,20	-5 863,75
12	Błędów	RMR	6,49	603,57	-6,1	39 527,03	43 059,76	-3 532,73
13	Paprotnia	RMR	7,16	665,88	-6,7	32 370,11	32 634,73	-264,62
					Total	**1 368 827,22**	**1 415 623,55**	**-46 796,33**

*PROTECTED AREAS (OCH)

Source: Own research based on: BDL (as of December 31, 2023); Annex to the Regulatory Impact Assessment (OSR) dated July 15, 2024.

Social Dimension

According to the 2030 Agenda (2015), people are one of the most important aspects of the sustainable development goals. The KSRR (2019, p. 10) indicates that the quality of human capital is a key factor determining the level and potential for socio-economic development in the region. The SRWM (2022, p. 15) emphasizes that the attractiveness of the Mazovia region is determined by its demographic situation, including migration balances. In the municipalities of RMR, a negative migration balance indicates a loss of human capital, and thus a lower attractiveness of this region compared to RWS. This is confirmed by the data on migration balances in the studied municipalities (Table 1 and Table 2). A positive migration balance was recorded in all 8 municipalities of RWS in both tables (in 4 municipalities of RMR with the highest and 2 municipalities with the lowest amount of ecological subsidies). In the remaining municipalities of RMR with the highest amount of ecological subsidies, the negative migration balance ranged from -11.9 (rural municipality of Siemiątkowo) to -0.7 (urban-rural municipality of Solec nad Wisłą), while in the municipalities with the lowest amounts: from -6.7 (rural municipality of Paprotnia) to -0.4 (rural municipality of Tczów).

Economic Dimension

The main source of income for JST consists of own revenues, grants, and general subsidies from the state budget. In 2023, the total revenues of JST in the Mazowieckie Voivodeship amounted to 59,783.5 million PLN, of which 37.4% were revenues from municipalities. Meanwhile, the total expenditures of JST amounted to 64,556.1 million PLN, with 37.1% being municipal expenditures. In 2023, the average expenditure per capita in the municipalities of Mazovia was 7,458 PLN. The highest expenditures were recorded in the municipality of Ceranów (16,511 PLN), Wierzbno (14,846 PLN), and Paprotnia (13,712 PLN), while the lowest were in the municipality of Pionki (urban municipality; 5,163 PLN), Małkinia Górna (5,393 PLN), and Żuromin (5,395 PLN) (Budżety…, 2024).

The analysis of total revenues and expenditures of the studied municipalities indicates that in 2023, the budget deficit for these JST amounted to 147.7 million PLN in the group of municipalities with the highest amounts of ecological subsidies and 46.7 million PLN in the group with the lowest amounts of ecological subsidies (Table 1 and Table 2). The ratio of the deficit to total revenues for municipalities with the highest amounts of ecological subsidies was 11.3%, while for those with the lowest amounts, it was 3.4%.

A budget deficit occurred in 23 municipalities with the highest amounts of ecological subsidies (95.8% of the total). The ratio of the deficit to revenues for 4 municipalities in this group did not exceed 5%, while in 5 municipalities, this ratio was higher than 20%, with the highest being in the rural municipality of Izabelin, RWS (32%). A surplus was recorded only in the rural municipality of Lutocin (RMR), which did not exceed 2% of revenues. In the group of municipalities with the lowest amounts of ecological subsidies, a budget deficit occurred in 10 JST (out of 13 studied), which is 77% of the total. The ratio of the deficit to revenues for

these municipalities did not exceed 10%, and in 5 municipalities, this ratio was lower than 5%, with the lowest being in the rural municipality of Paprotnia, RMR (1%). A surplus was recorded in 3 municipalities (2 rural: Potworów and Sierpc, and 1 urban municipality: Ciechanów), but it did not exceed 3% of revenues.

Environmental Dimension

In 2023, protected areas in Mazovia accounted for 29.7% of the area of the voivodeship (Ochrona środowiska, 2024). The largest areas were protected landscape areas (23.5%) and landscape parks (4.6%). In 97 municipalities (out of 258 studied), protected areas occupied more than 50% of their area, including 100% in 13 municipalities (2 in RWS and 11 in RMR).

The base rate for calculating ecological needs for 2025 in the Act on the Revenues of Local Government Units (2024) is 310.00 PLN/ha of protected area for municipalities and cities with county rights, 70.00 PLN/ha for counties, and 35.00 PLN/ha for voivodeships (Act on the Revenues of Local Government Units, 2024, art. 84.2, letters a-c). The amount of the base rate will be determined annually, taking into account the indexation based on the price index of goods and services for the first half of the year preceding the budget year (Act on the Revenues of Local Government Units, 2024, art. 29.3). For calculations, data on the area of protected areas as of December 31, 2023, were used (Act on the Revenues of Local Government Units, 2024, art. 84.1). The amount of ecological needs is calculated according to the formula (Szalast-Piwińska, 2024, p. 72):

$$\text{Ecological Needs} = Sb \times Pp \quad (1)$$

where:
Sb - base rate per 1 ha of legally protected area (PLN),
Pp - calculated area of legally protected areas appropriate for a given category of JST (ha).

The calculated area of legally protected areas is determined using the formula:

$$Pp = (Poch \times W1) + (Poch \times W2) + (....) + (Poch \times Wn) \quad (2)$$

where:
Pp - calculated area of legally protected areas appropriate for a given category of JST (ha),
Poch - area of legally protected areas (ha),
W - weight of protection for legally protected areas: W1 - national park: 2; W2 - nature reserve: 1; W3 - landscape protection zones established within the boundaries of landscape parks or protected landscape areas: 0.6; W4 - landscape parks and protected landscape areas where at least five prohibitions have been established from among the prohibitions mentioned in art. 17, §1, points 1 and 4-9, and art. 24, §1, points 2 and 4-9 of the Nature Conservation Act: 0.3; W5 - landscape parks and protected landscape areas where at least one prohibition has been established from among the prohibitions mentioned in art. 17, §1, points 1 and 4-9, and art. 24, §1, points 2 and 4-9 of the Nature Conservation Act: 0.1; W6 - Natura 2000 area: 0.15.

If the area is covered by different types of protected areas, the area with the highest weight is used for calculating ecological needs (Act on the Revenues of Local Government Units,

2024, art. 29.6). For municipalities where the area of the national park is greater than 20% of their area or greater than 2,000 ha, an additional 40 million PLN has been allocated (Act on the Revenues of Local Government Units, 2024, art. 91.1).

In the group of studied municipalities, the highest ecological subsidies (over 1 million PLN) will be received by 24 municipalities, including 6.2 million PLN for the rural municipality of Leoncin (Table 1). The lowest (below 1000 PLN) will be received by 13 municipalities, including 0.93 PLN for the urban municipality of Sochaczew (Table 2). Among the municipalities with the highest amounts of ecological subsidies, the area of protected areas in 5 municipalities of RMR is 100% (rural municipalities: Sadowne, Lutocin, Wilga, and Siemiątkowo, as well as the urban-rural municipality of Solec nad Wisłą). However, the planned amounts of ecological subsidies for these municipalities do not exceed 1.5 million PLN. This is due to the actual area of protected areas and the weight of protection of the area. For example, the highest amount will be received by the municipality of Leoncin, where the area of protected areas is 72.5%, but approximately 9.7 thousand ha of national park has been designated (weight 2), about 335 ha of nature reserves (weight 1), 880 ha of landscape parks and protected landscape areas (weight 0.3), and about 568 ha of Natura 2000 areas (weight 0.15).

5. Results and conclusions

The ecological subsidy is a significant mechanism for financial support for municipalities with protected areas. It represents an opportunity for the development of municipalities and compensates for developmental limitations.

A key indicator of the situation in municipalities in the social dimension is, among other things, the migration balance. In all municipalities of RWS, a positive migration balance was recorded, regardless of the amount of ecological subsidy. In contrast, the majority of municipalities in RMR experienced a negative migration balance. This indicates a disparity in the situations of municipalities in RWS and RMR.

Economic analyses indicated that most of the budgets of the studied municipalities recorded a deficit. This affects, among other things, the limitation of local development and the financing of other needs of JST.

The results of the research in the environmental dimension indicate that the amounts of ecological needs are related to the area, rate, and weight of the protected area. The legislator did not restrict the ways in which municipalities can use the ecological subsidy. The assessment of its role in local development will only be possible after the experiences of municipalities benefiting from this form of support. To verify the anticipated acceptance of protected areas among local communities, systematic evaluation of the effectiveness of this support system will be necessary.

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SYSTEMIC FINANCIAL RISK OF THE POLISH ENERGY SECTOR UNDER MARKET, CLIMATE TRANSITION AND PHYSICAL STRESS

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Purpose: The purpose of this investigation is to develop and apply an framework that combines market, transition, and physical climate risks into a single systemic-risk measure in order to assess how these interacting shocks affect the financial vulnerability of energy sector.
Design/methodology/approach: To assess financial systemic risk, we used the extended SRISK framework and the GJR-DCC-GARCH model for four Polish systemically important energy companies. The analysis, covering the period 2009-2023, includes market, climate transition, and physical risk factors.
Findings: Investigation indicate that the market and climate-related risk is gaining prominence, especially when viewed against the backdrop of recent disruptions such as the COVID-19 pandemic and Russia's invasion of Ukraine.
Research limitations/implications: A key limitation of this study is its reliance on simplified proxies for transition and physical risks and on publicly available market data, which may not fully capture the operational complexities or evolving dynamics of the energy sector. Future research could incorporate more granular firm-level information and additional climate variables.
Practical implications: This study incorporates multiple external drivers of systemic risk, with particular emphasis on the growing influence of climate-related factors on the energy sector.
Social implications: The proposed framework enables the identification of systemic vulnerabilities—including those arising from climate change—thereby supporting policymakers in enhancing the resilience of the energy system to a wide range of potential shocks.
Originality/value: This research is the first to jointly integrate market risk, transition climate risk, and physical climate risk into a unified assessment of systemic financial risk for the energy sector.
Keywords: systemic risk, energy sector, climate transition risk, climate physical risk.
JEL Classification: Q40, Q54, G20, C53.

1. Introduction

Systemic risk refers to a situation in which a disturbance in a single company or a shock affecting part of a sector disrupts the functioning of the entire system, potentially causing widespread dysfunction. In the G-10 report published a quarter of a century ago, systemic financial risk is defined as "the risk that an event will trigger a loss of economic value or confidence in, and attendant increases in uncertainty about, a substantial portion of the system" (G-10, 2001). As this shows, awareness of systemic risk has existed for a long time. However, the last decade—shaped by ongoing globalization and the occurrence of major shock events in the global economy, such as the Covid-19 lockdowns—has brought a marked increase in interest in this area, particularly within the financial sector, where concerns were already visible after The Global Financial Crisis (subprime crisis) of 2007-2009.

Systemic financial risk can arise from several sources, including interconnectedness and contagion, common risk exposures, procyclicality and feedback loops, and macro-shocks or external stressors. While the first three factors are typical for the financial sector, the fourth also applies to the energy sector. Market stress—such as a significant decline in a broad market index—often leads to reductions in the capitalization of energy companies, and thus diminishes the economic value of their equity.

In the energy sector, external stressors also include those related to climate change, which has become one of the leading sources of systemic uncertainty, shaping both operational conditions and long-term strategic planning. Companies now face two interconnected forms of climate risk: transition risk, arising from regulatory pressure, technological shifts, and the move toward low-emission energy production; and physical risk, resulting from rising temperatures and increasing weather anomalies.

These risks no longer operate independently. Regulatory changes may amplify the effects of extreme weather, while physical disruptions can intensify the economic consequences of decarbonization policies. For energy producers—particularly those still dependent on fossil fuels—the combined impact can significantly affect market value and financial stability.

This study proposes a simplified framework that integrates market risk with climate-related transition and physical risks into a single measure (Dziwok, Szczepaniak, 2025a). The framework is adapted from the systemic risk measure SRISK, originally developed for the financial sector. The method is applied to the largest Polish energy companies, capturing how market and climate-related shocks may influence the stability of this strategically important segment of the Polish economy, and to the author's knowledge, this is the first study of its kind concerning the energy sector. The study adopts the working hypothesis that integrating market, transition, and physical climate risks provides a comprehensive framework for assessing systemic financial risk within the energy sector.

The central problem of this study is to evaluate how market, transition, and physical climate shocks jointly affect systemic financial vulnerability in the Polish energy sector. To address this, the SRISK framework is applied because it directly measures expected capital shortfall under extreme stress, making it well suited for systemic-risk analysis. However, standard SRISK considers only market risk. Therefore, to reflect the nature of the problem, we extend the methodology by incorporating climate-transition and climate-physical factors. The GJR-DCC-GARCH model is used to estimate time-varying betas and correlations between market and climate shocks, capturing the dynamic interactions that are essential to understanding systemic vulnerabilities. This methodological combination directly addresses the research aim of assessing multi-dimensional, interacting sources of systemic risk.

Using publicly available data, local proxy models for transition shocks were constructed based on a portfolio of stranded assets relevant to Poland's energy mix, while physical shocks were modeled using national temperature anomalies (Dziwok, Szczepaniak, 2025b). The objective is to provide a practical tool for assessing how market and climate risks accumulate within major Polish energy companies and how these risks jointly shape the sector's overall vulnerability.

The paper is organized as follows. Section 2 outlines the methodological framework. Section 3 describes empirical analysis of the Polish energy sector using proposed measure. Section 4 concludes the paper.

2. Methods

Research on market and climate-related risk has expanded rapidly as regulators, investors, and companies increasingly recognize that climate change can destabilize entire markets. Regulatory bodies such as the NGFS, ECB, and the Basel Committee on Banking Supervision (BCBS) have emphasized the need for climate stress testing (Basel Committee on Banking Supervision, 2022), while academic research has examined both transition and physical risks from multiple perspectives.

Most studies analyze these two forms of risk separately (Albanese et al., 2024; Bua et al., 2024; Zhou, Ma, 2025): transition risk arises from policy changes, technological innovation, and shifting demand for carbon-intensive products, whereas physical risk stems from extreme weather events and long-term environmental degradation.

However, recent work highlights the importance of integrating these perspectives, arguing that their interaction more accurately reflects real-world dynamics. Methods originally developed for financial institutions, such as SRISK (Brownlees, Engle, 2017), and CoVaR / ΔCoVaR (Adrian, Brunnermeier, 2016), have increasingly been adapted to climate-related

research questions (Lu et al., 2025). This study follows that trend but applies these concepts directly to energy companies, which are central to Poland's climate-transition challenge.

The proposed approach builds on the SRISK framework, where a firm's vulnerability increases when it loses value under extreme conditions. In this context, rather than interpreting the output in terms of regulatory capital requirements, we treat it as an expected capital shortfall under combined market and climate-related stress.

Following the standard factor model approach, for the energy company i's stock return at day t:

$$r_{i,t} = \beta_{i,t}^{m} \cdot r_{i,t}^{m} + \beta_{i,t}^{tr} \cdot r_{i,t}^{tr} + \beta_{i,t}^{ph} \cdot r_{i,t}^{ph} \tag{1}$$

where:

$r_{i,t}^{m}$ denotes market return,

$r_{i,t}^{tr}$ change of the climate transition risk factor,

$r_{i,t}^{ph}$ change of the climate physical risk factor,

$\beta_{i,t}^{m}$, $\beta_{i,t}^{tr}$, $\beta_{i,t}^{ph}$ are an indicators of sensitivity respectively to market, climate transition and physical changes.

The capital shortfall $CS_{i,t}$ of the companies i at day t is defined as:

$$CS_{i,t} = \overbrace{k\left(L_{i,t} + MC_{i,t}\right)}^{\text{required capital}} - \overbrace{MC_{i,t}}^{\text{current capital}} \tag{2}$$

where:

k is a capital adequacy ratio,

$L_{i,t}$ is value of the total liabilities,

$MC_{i,t}$ is the company market capitalization. For the i -th company the SRISK measure estimates the capital shortfall may face in the event of a shock over a specified time horizon h:

$$SRISK_{i,t} = \mathbb{E}\left[CS_{i,t+h} \middle| systemic\ event\right] \tag{3}$$

where $h = 6$ months. Finally:

$$SRISK_{i,t} = kL_{i,t} - (1-k)MC_{i,t} \exp\left(\beta_{i,t}^{m} \log(1-\theta^{m})\right) \tag{4}$$

where θ^{m} describe a level of market shock (Brownlees, Engle, 2017). For the system s:

$$SRISK_{s,t} = \sum_{i=1}^{N} SRISK_{i,t} \tag{5}$$

Extending this idea and following (Dziwok, Szczepaniak, 2025a, 2025b), the article proposes a measure of the systemic risk of energy companies $M|TrC|PhC|SRISK_{i,t}$:

$$M|TrC|PhC|SRISK_{i,t} = kL_{i,t} - (1-k)MC_{i,t} \exp\left(\beta_{i,t}^{m} \log(1-\theta^{m}) + \beta_{i,t}^{tr} \log(1-\theta^{tr}) + \beta_{i,t}^{ph} \log(1-\theta^{ph})\right) \tag{6}$$

where:
k is for the energy companies equity-to-asset ratio equal to 0.45,
θ^{tr} is a level of climate transition shock (measured through returns of a tailored stranded-asset portfolio, based on WIG-Mining and WIG-Fuels relative to the broad WIG index),
θ^{ph} is a level of climate physical shock (represented by deviations of Poland's 12-month rolling temperature from its 30-year climatological norm).

Time-varying betas are estimated using a multivariate GJR-DCC-GARCH approach (Glosten et al.,1993; Engle, 2002), allowing for changing correlations between market conditions and climate factors - an important feature, given that extreme events tend to occur jointly (Dziwok, Szczepaniak, 2025a; Jung et al., 2025), see Appendix.

3. Results

The empirical analysis focuses on the four largest Polish publicly listed energy companies: PGE, ENEA, ENERGA, and TAURON, see Appendix. The sample period spans 2009-2023, covering multiple regulatory cycles, episodes of macro-financial turbulence, and shifts in the European climate-policy landscape. This long horizon ensures that the estimated sensitivities capture both structural changes within the sector and shorter-term fluctuations in market conditions.

Market data for all listed companies and benchmark indices are obtained from LSEG, ensuring consistency in pricing, return construction, and data frequency. These data form the basis for estimating systematic exposures under financial and climate-related stress. Complementing the financial data, temperature records are sourced from IMiGW, the national meteorological institute, which provides high-quality, long-term observations. Monthly temperature anomalies are calculated relative to long-term climatological normals, enabling the identification of periods of acute physical stress.

Stress measures are defined along three distinct dimensions: market, transition, and physical:

- market stress is captured using tail events in the broad WIG index, where the 1% lower tail of monthly returns identifies episodes of severe market disruption.
- transition stress is represented by the performance of a stranded-asset portfolio—also evaluated at the 1% lower tail—intended to proxy regulatory shocks, accelerated decarbonization pressures, and shifts in investor sentiment toward carbon-intensive assets.

- physical stress is measured using the 1% upper tail of positive temperature deviations, reflecting extreme heat events that may affect production efficiency, electricity demand, and operational continuity.

Combining these elements, the study estimates company-specific betas for each stress category, providing a granular view of how individual firms respond to different forms of market and climate-related risk. These betas are subsequently aggregated into a total market-and-climate risk indicator that captures each company's joint exposure to market turmoil, transition pressures, and physical hazards. This integrated measure forms the empirical foundation for assessing heterogeneity in market and climate-risk sensitivities across the Polish energy sector and for evaluating how these sensitivities evolve over time.

Across the sample, companies with a traditional fuel-based profile (e.g., coal-dependent generators) exhibit greater sensitivity to transition shocks. Firms with stronger exposure to renewable technologies show milder reactions to stranded-asset risk but remain affected by physical temperature anomalies, which influence electricity demand, generation costs, and operational reliability.

The combined market-and-climate risk measure is consistently higher than any single risk component estimated in isolation. Periods such as The Global Financial Crisis, Eurozone Debt Crisis, the COVID-19 pandemic, and the post-2022 energy-security shock illustrate how climate-related risks interact with broader market volatility (see Figure 1). Sensitivity to transition shocks increased notably during debates on European energy policy, while sensitivity to physical risk rose in years with pronounced temperature anomalies.

Interestingly, during the energy-security crisis triggered by the war in Ukraine, the sector's exposure to transition risk temporarily declined as markets placed greater value on energy security and fossil-fuel capacity. In contrast, physical risk remained elevated due to persistent temperature anomalies.

4. Conclusions

Poland's energy companies are increasingly exposed to a complex set of market and climate-related risks whose interactions cannot be fully understood when examined separately. Transition shocks arising from decarbonization policies and regulatory tightening intersect with physical risks associated with rising temperatures and more frequent weather anomalies. Within the energy sector, these forces often act simultaneously, amplifying financial vulnerabilities, altering operating conditions, and reshaping long-term strategic prospects. As a result, an integrated analytical approach is required to capture the interconnected nature of these pressures.

To address this challenge, the study adapts systemic-risk measurement tools—traditionally applied in the financial sector—to the context of the energy industry. By combining these methods with Polish market data and detailed meteorological records, the analysis provides a transparent and accessible framework for evaluating market and climate-related threats. This methodological approach makes it possible to assess how firms respond to different forms of stress, whether triggered by abrupt policy changes or extreme environmental conditions.

The problem addressed in this study concerned the need to evaluate how market dynamics, transition risk, and physical climate shocks jointly influence systemic financial vulnerability within the energy sector. This requires a methodological framework capable of capturing both firm-level exposure to extreme market conditions and the dynamic interactions between multiple risk factors over time. The extended SRISK framework is employed because it directly measures expected capital shortfall during periods of systemic distress and is therefore uniquely suited to analysing the potential contribution of individual firms to system-wide fragility. However, accurately estimating SRISK under climate-related stress necessitates modelling time-varying betas and correlations between market, transition, and physical climate variables. For this reason, the GJR-DCC-GARCH model is integrated into the analysis, as it accommodates asymmetric volatility responses and evolving correlation structures that are characteristic of climate-driven financial shocks. By combining these two approaches, the methodology aligns closely with the research problem: it enables the quantification of systemic risk under heterogeneous and non-linear climate stress scenarios while reflecting the dynamic transmission channels through which climate factors interact with financial markets. This integrated modelling strategy thus provides a coherent and empirically grounded response to the study's core objective of assessing multidimensional systemic risk in a climate-constrained environment.

The empirical results reveal several important patterns. First, exposure to climate risk is heterogeneous across the WIG-Energy companies, reflecting differences in generation portfolios, balance-sheet structures, and strategic investment decisions. Second, transition and physical shocks propagate through distinct channels: policy-driven disruptions primarily affect asset valuations, expected cash flows, and regulatory compliance costs, while physical shocks influence operating performance, infrastructure resilience, and demand fluctuations. Third, when these shocks occur jointly, the resulting vulnerabilities exceed the impact of either risk factor in isolation, highlighting the importance of interaction effects.

This study contributes novel insights into the systemic financial risk of the Polish energy sector by demonstrating that market, transition, and physical climate shocks interact to amplify firm-level and sector-wide vulnerabilities. Unlike previous research that examines these risks in isolation, the integrated SRISK–GJR-DCC-GARCH framework developed here quantifies the combined impact of multiple stressors, capturing dynamic correlations and asymmetric volatility responses over time. The findings reveal heterogeneity in risk exposure across energy companies, with traditional fossil-fuel-based firms exhibiting heightened sensitivity to

transition shocks, while all firms remain vulnerable to extreme physical events. These results underscore the importance of considering the joint effects of policy-driven and environmental stressors in financial risk assessment. Methodologically, the study illustrates the feasibility of adapting systemic-risk measures from the financial sector to assess climate-related vulnerabilities in non-financial industries. Practically, the analysis provides policymakers and corporate managers with a tool to identify systemic weaknesses and prioritize resilience-building strategies, highlighting that neglecting the interaction between market and climate risks may lead to substantial underestimation of potential capital shortfalls. Overall, the research advances understanding of multidimensional risk propagation in energy markets and emphasizes the necessity of integrated approaches in both academic inquiry and risk management practice.

The significance of this research lies in its advancement of systemic-risk analysis by incorporating transition and physical climate shocks into a unified framework traditionally applied only to financial market stress. By adapting and extending the SRISK methodology through the integration of a GJR-DCC-GARCH model, the study provides the first empirical evidence on how heterogeneous climate-related shocks interact with market dynamics to shape systemic vulnerability within the Polish energy sector. This contributes to the broader field by bridging the methodological gap between climate finance, systemic-risk modelling, and energy economics, offering a replicable approach that can be applied to other sectors and national contexts. The findings have implications not only for academic discourse but also for regulatory practice, as they demonstrate the necessity of incorporating climate-sensitive parameters in macroprudential stress testing. Moreover, the insights obtained can inform the development of more accurate risk-monitoring tools, enhance the design of climate-related financial disclosures, and support policy initiatives aimed at managing transition pathways. The modelling strategy and empirical results may be further used to evaluate sectoral resilience under alternative climate scenarios, identify systemically important entities, and guide investment strategies that account for climate-market interdependencies. Collectively, the research broadens the analytical foundations for understanding climate-induced systemic risk and establishes a methodological blueprint for future studies seeking to quantify climate–market interactions in complex economic systems.

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Appendix

The beta coefficients for market risk $\beta_{i,t}^{m}$, transition climate risk $\beta_{i,t}^{tr}$, and physical climate risk $\beta_{i,t}^{ph}$ are derived as follows:

$$\begin{bmatrix}\beta_{i,t}^{m}\\ \beta_{i,t}^{tr}\\ \beta_{i,t}^{ph}\end{bmatrix}=\begin{bmatrix}\sigma_{m,t}^{2} & \sigma_{m,t}\sigma_{tr,t}\rho_{m,tr,t} & \sigma_{m,t}\sigma_{ph,t}\rho_{m,ph,t}\\ \sigma_{m,t}\sigma_{tr,t}\rho_{m,tr,t} & \sigma_{tr,t}^{2} & \sigma_{tr,t}\sigma_{ph,t}\rho_{tr,ph,t}\\ \sigma_{m,t}\sigma_{ph,t}\rho_{m,ph,t} & \sigma_{tr,t}\sigma_{ph,t}\rho_{tr,ph,t} & \sigma_{ph,t}^{2}\end{bmatrix}^{-1}\cdot\begin{bmatrix}\sigma_{i,t}\sigma_{m,t}\rho_{i,m,t}\\ \sigma_{i,t}\sigma_{tr,t}\rho_{i,tr,t}\\ \sigma_{i,t}\sigma_{ph,t}\rho_{i,ph,t}\end{bmatrix} \tag{7}$$

where:

$\sigma_{m,t}^{2}$, $\sigma_{tr,t}^{2}$, $\sigma_{ph,t}^{2}$ are conditional variance,

$\rho_{m,tr,t}$, $\rho_{m,ph,t}$, $\rho_{tr,ph,t}$, $\rho_{i,m,t}$, $\rho_{i,tr,t}$, $\rho_{i,ph,t}$ are conditional correlations.

The GJR-GARCH model for the conditional variance take the form:

$$\sigma_{i,t}^{2}=\omega_{\mathrm{V}i}+\alpha_{\mathrm{V}i}r_{i,t-1}^{2}+\gamma_{\mathrm{V}i}r_{i,t-1}^{2}I_{i,t-1}^{-}+\beta_{\mathrm{V}i}\sigma_{i,t-1}^{2} \tag{8}$$

$$\sigma_{m,t}^{2}=\omega_{\mathrm{V}m}+\alpha_{\mathrm{V}m}r_{m,t-1}^{2}+\gamma_{\mathrm{V}m}r_{m,t-1}^{2}I_{m,t-1}^{-}+\beta_{\mathrm{V}m}\sigma_{m,t-1}^{2} \tag{9}$$

$$\sigma_{tr,t}^{2}=\omega_{\mathrm{V}tr}+\alpha_{\mathrm{V}tr}r_{tr,t-1}^{2}+\gamma_{\mathrm{V}tr}r_{tr,t-1}^{2}I_{tr,t-1}^{-}+\beta_{\mathrm{V}tr}\sigma_{tr,t-1}^{2} \tag{10}$$

$$\sigma_{ph,t}^{2}=\omega_{\mathrm{V}ph}+\alpha_{\mathrm{V}ph}r_{ph,t-1}^{2}+\gamma_{\mathrm{V}ph}r_{ph,t-1}^{2}I_{ph,t-1}^{+}+\beta_{\mathrm{V}ph}\sigma_{ph,t-1}^{2} \tag{11}$$

where $I_{i,t}^{-}=1$ if $r_{i,t}<0$, $I_{m,t}^{-}=1$ if $r_{m,t}<0$, $I_{tr,t}^{-}=1$ if $r_{tr,t}<0$, $I_{ph,t}^{+}=1$ if $r_{ph,t}>0$, and 0 otherwise.

The conditional correlation of the volatility-adjusted returns

$$\varepsilon_{i,t}=r_{i,t}/\sigma_{i,t} \tag{12}$$

$$\varepsilon_{m,t}=r_{m,t}/\sigma_{m,t} \tag{13}$$

$$\varepsilon_{tr,t}=r_{tr,t}/\sigma_{tr,t} \tag{14}$$

$$\varepsilon_{ph,t}=r_{ph,t}/\sigma_{ph,t} \tag{15}$$

is

$$\mathrm{Cor}(\varepsilon_{\mathrm{i,t}})=diag\left(Q_{i,m,tr,ph,t}\right)^{-1/2}Q_{i,m,tr,ph,t}diag\left(Q_{i,m,tr,ph,t}\right)^{-1/2} \tag{16}$$

where the DCC model specifies the dynamics of the pseudo-correlation matrix $Q_{i,m,tr,ph,t}$ as

$$Q_{i,m,tr,ph,t}=(1-\alpha_{\mathrm{C}i}-\beta_{\mathrm{C}i})S_{i}+\alpha_{\mathrm{C}i}\begin{bmatrix}\varepsilon_{i,t}\\ \varepsilon_{m,t}\\ \varepsilon_{tr,t}\\ \varepsilon_{ph,t}\end{bmatrix}\begin{bmatrix}\varepsilon_{i,t}\\ \varepsilon_{m,t}\\ \varepsilon_{tr,t}\\ \varepsilon_{ph,t}\end{bmatrix}'+\beta_{\mathrm{C}i}Q_{i,m,tr,ph,t-1} \tag{17}$$

with the unconditional correlation of adjusted returns S_i.

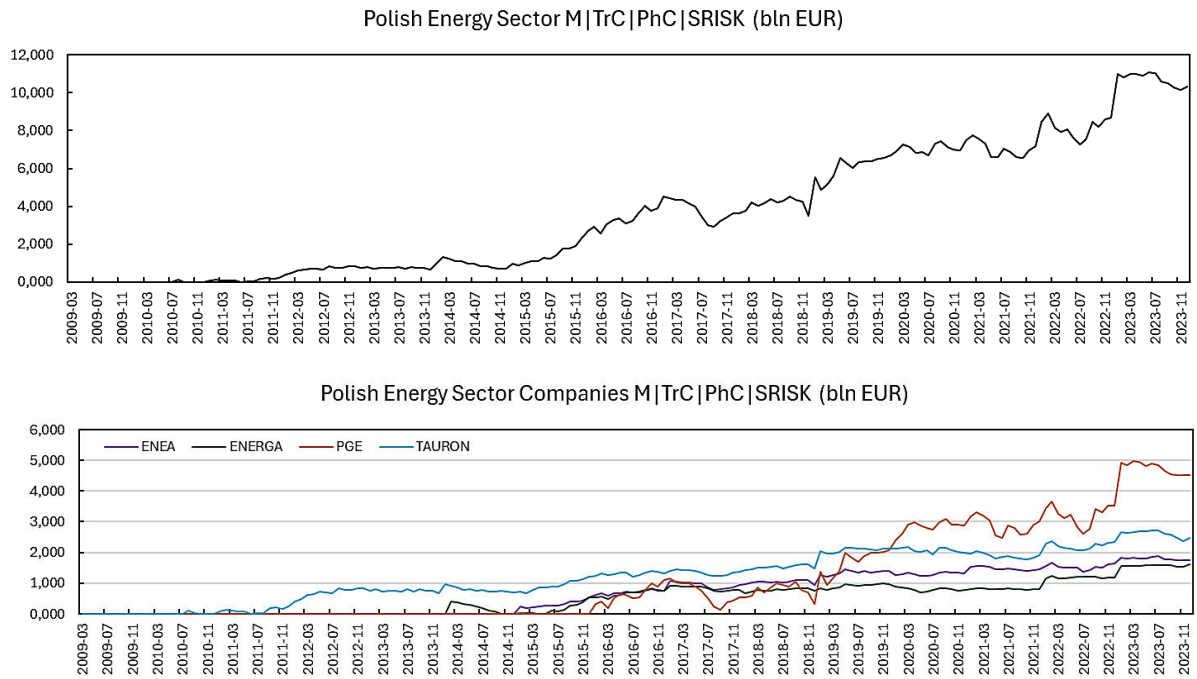


Figure 1. Systemic financial risk of The Polish Energy Sector and The Polish Energy Companies.

Source: Own elaboration.

Table 1.
Descriptive statistics

Company and risk factor	Obs.	Mean	Std. dev.	Minimum	Maximum
ENEA	178	-0.0006	0.1030	-0.2635	0.3006
ENERGA	119	-0.0052	0.0818	-0.2496	0.2167
PGE	167	-0.0065	0.1055	-0.3268	0.3993
TAURON	161	-0.0012	0.1113	-0.3027	0.5475
Market index WIG	178	0.0067	0.0540	-0.2292	0.1729
Stranded asset portfolio index	178	0.0004	0.0917	-0.2952	0.2586
Temperature anomaly index	178	0.0009	0.0665	-0.3061	0.1702

Source: Own elaboration.

Table 2.
GJR-GARCH estimation parameters

Company	α_{Vi}	α_{Vi} SE	γ_{Vi}	γ_{Vi} SE	β_{Vi}	β_{Vi} SE
ENEA	0.000002	0.005168	0.090563	0.001267	0.951035	0.006328
ENERGA	0.034350	0.004738	0.117323	0.007002	0.854697	0.002482
PGE	0.000002	0.003670	0.123712	0.007177	0.930830	0.001856
TAURON	0.264270	0.308196	0.000002	6.620957	0.478521	0.680511

Source: Own elaboration.

Table 3.
DCC-GARCH estimation parameters

Company	α_{Ci}	α_{Ci} SE	β_{Ci}	β_{Ci} SE
ENEA	0.000002	0.000030	0.000049	6.159022
ENERGA	0.000002	0.000000	0.000036	1.020475
PGE	0.000002	0.001719	0.000057	9.170844
TAURON	0.000002	0.002263	0.081686	7.806210

Source: Own elaboration.

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SOFT COMPETENCIES OF UNIVERSITY GRADUATES AND LABOUR MARKET NEEDS

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Purpose: The aim of the study is to identify which soft skills are most desired by employers, whether university graduates possess these competencies and at what level, as well as how students of the Faculty of Management and Quality Science at Gdynia Maritime University assess their own soft skills expected by employers and what ways of improving them, they identify during their studies.
Design/methodology/approach: Data were collected from both secondary and primary sources. The research method involved content analysis of reports and scientific publications related to the examined issue (secondary sources). For gathering empirical data, the auditory survey method and a questionnaire (instrument) were used. Primary data were reduced and analysed, followed by the formulation of conclusions and suggestions for future research, including the identification of a research gap. The study is a pilot study.
Findings: The study identified the most important soft competencies desired by employers among graduates. It was found that graduates possess these skills, but their level of development is insufficient. These findings were confirmed by the results of a pilot empirical study. Ways to improve soft skills during studies were indicated. Recommendations were developed for universities and the business environment to reduce the competency gap in the Polish labour market.
Research limitations/implications: The empirical research was limited by a small sample size and restricted generalisability. Secondary sources originated from different periods and industries.
Practical implications: Universities should more effectively provide their graduates with soft skills, including through dedicated courses (exercises, workshops), the use of activating teaching methods, and close cooperation with employers.
Social implications: Effective cooperation between the demand side (employers) and the supply side (universities and their students) regarding graduates' soft skills may contribute to the improvement of university curricula and the situation in the labour market.
Theoretical implications: Universities should conduct systematic, comprehensive scientific research to identify (anticipate) changes in the labour market with respect to graduates' soft competencies and indicate ways of improving them both within the university and in organisational practice.

Originality/value: A research gap has been identified and directions for future research in soft competencies of university graduates have been outlined.
Keywords: soft competencies/skills, hard competencies, higher education institutions (HEIs)/universities, higher education programmes, employers.
Category of the paper: Research paper.

1. Introduction

One of the measures of a country's economic condition is the synthetic social development indicator, the Human Development Index. In 2023, this indicator for Poland was 0.906, placing the country among the group of very highly developed nations. Compared to 1990, the average number of years of education among Polish citizens increased by 3.5 years in 2023 (with the expected duration rising by 4.6 years) (Human Development Reports, 2025). It has been demonstrated that Poles now spend more years in education than was the case at the end of the 20th century. Nevertheless, employers believe that university graduates lack the competencies sought after in the labour market (Tyrańska et al., 2021; Bergman Engineering Report, 2025). Research indicates that this situation occurs in other countries as well (Bankier.pl Report, 2022; Hernández-March et al., 2009; Kupczyk, Stor, 2017; Alanazi, Benlaria, 2023). Higher education institutions (HEIs) play a key role in ensuring that future employees possess the required competencies (Bašková, Struková, 2017; Alanazi, Benlaria, 2023; Tyrańska et al., 2021; Szczepańska-Woszczyna et al., 2014; Hyytinen et al., 2023; Szelągowska-Rudzka, 2018; Gawrysiak, Stępień, Polcyn, 2024), but according to entrepreneurs, they do not fully fulfil this role (Alanazi, Benlaria, 2023; Budnikowski et al., 2012; Wronowska, 2015; Strojny et al., 2021; Nakhleh, Hanini, 2022).

Competencies in the labour market have gained significance in the 21st century due to the advancement of modern technologies, primarily artificial intelligence (AI) and Industry 4.0 and Industry 5.0 (Leśniewicz, 2025; Piwowar-Sulej et al., 2025), as well as the need to adapt their achievements to enterprises (Bergman Engineering Report, 2025; Strojny et al., 2021). Technological progress causes rapid and difficult-to-predict changes in the labour market (Filipowicz, 2014; Wodecka-Hyjek, Tyrańska, 2021; Pesha, Kamarova, 2020). These, in turn, increase the requirements for university graduates in terms of both hard, professional competences (related to job position and occupation) (Future of Jobs Report, 2025; Piwowar-Sulej, Austen, 2025; Bašková, Struková, 2017; Czekaj, Tyrańska, Ziębicki, 2022; infuture. institute AGH Report, 2024), and soft, behavioural competencies (Fastnacht, 2006; Bergman Engineering Report, 2025; Ernst & Young, 2023; Igielski, 2024; Jagodziński, 2013; Jelonek et al., 2022) pertaining to individual personality traits, psychophysical characteristics, attitudes, behaviours, and relationships/interactions with other people (Dębkowska, 2022; Studiuj, UEK, 2024; Pesha, Kamarova, 2020). Paradoxically, the development of AI has led to an increased

demand for soft skills (Dębkowska, 2022; Future of Jobs Report, 2025; Bankier.pl Report, 2022), such as oral and written communication, negotiation, coping with stress or conflict situations, decision-making and creative problem-solving, independent action, and flexible thinking (Dyrla-Mularczyk, Pluciński, Borowiec, 2018).

The development of behavioural competencies has been observed since the 1980s (Czekaj, Tyrańska, Ziębicki, 2022). However, today's employees must be able to work together (synergistically leveraging their expertise, skills, and experience) as well as with non-human actors (automated systems and AI-powered machines) (Dębkowska, 2022; Piwowar-Sulej et al., 2025; Czekaj, Tyrańska, Ziębicki, 2022; infuture.institute AGH Report, 2024). According to the Future of Jobs Report (2025, p. 44), 'human labour and supervision over processes remain essential even in areas where generative AI (GenAI) may provide support for humans'. Entrepreneurs believe that in the future, soft skills will be more important than professional (digital and specialist) competences (Dębkowska et al., 2022).

Therefore, the following research objectives were adopted in this article:

- to identify which soft skills are most desired in the labour market (by employers),
- to determine whether university graduates possess these competencies and at what level,
- and to indicate how students of the Faculty of Management and Quality Science (FMQS) at Gdynia Maritime University – future graduates – assess their soft skills desired in the labour market and what methods of improvement they perceive during their studies.

To address the theoretical objectives (1 and 2), a literature review and content analysis of reports from research institutions and HR advisory organisations related to university graduate competencies in the labour market were conducted. The empirical section presents the results of a pilot study carried out among a purposefully selected group of full-time undergraduate students at FMQS at Gdynia Maritime University. The article concludes with a discussion including practical and theoretical implications as well as a summary.

As a result of the conducted research, a scientific gap was identified in the form of the limited number of in-depth, comparative empirical studies conducted in Poland that comprehensively diagnose discrepancies between soft competencies desired by employers (demand side) and the competencies possessed by graduates employed in these employers' companies, shaped by specific curricula (supply side). Until now, research has essentially been conducted either among students (university perspective) or among employers (Ziębicki, Walczak, 2024) (with the exception of the study by Macioł, Minkiewicz, 2008). To improve the educational system in HEIs, it would be advisable to simultaneously consider opinions from both perspectives. The identified research gap points to directions for further studies and constitutes the authors' contribution to the theory of management and quality sciences.

2. Theoretical framework

Competencies may be defined differently across various fields and scientific disciplines (Wojtczuk-Turek, 2008; Antczak, 2008). Within management and quality sciences — specifically the human resource management subdiscipline — and for the purposes of this study, competences are understood as the knowledge, skills, experience, personality traits, attitudes and behaviours of employees that enable them to act efficiently, fulfil organisational tasks and roles, and achieve organisational objectives in constantly changing professional situations (based on Walkowiak, 2004; Kupczyk, Stor, 2017).

From this definition, it follows that competencies refer to (Rakowska, 2007; Antczak, 2008; Armstrong, 2000; Pocztowski, 2018; Tyrańska et al., 2021; Dziewońska, 2016):

- the job position (functional approach) — fulfilling organisational roles and executing tasks according to established standards ("output" competences), and
- employee attributes (behavioural approach) — manifested by knowledge, skills, experience, and personality traits that ensure effective job performance and outstanding achievement ("input" competencies).

Competencies associated with the job (work area), which are necessary for an individual to be competent in their position (i.e., what one must be able to do to work in the role), are called professional or hard competencies (competence, competences; competency); these relate to professional proficiency. Competencies based on employee characteristics, individual predispositions, and behaviours that determine the fulfilment of assigned duties and high performance are known as behavioural or soft (no-cognitive) competencies (competency) (Piwowar-Sulej et al., 2025; Antczak, 2008; Pocztowski, 2018; Kupczyk, Stor, 2017; Oleksyn, 2010; Carter, Murray, Gray, 2011).

According to the Future Jobs Report by the World Economic Forum (National Soft Skills, 2025; Zaremba, 2021), 85 percent of professional success stems from well-developed soft skills. This finding was already formulated by Charles R. Mann in 1918 (!) and remains unchanged today (National Soft Skills, 2025). Similar conclusions emerged from Google's 2017 research (Bankier.pl Report, 2022). Behavioural competencies are often the most decisive factor in the employment of graduates (Raczyńska, Stachowska, 2014, 14; Bankier.pl Report, 2022). This view is held by 93% of employers surveyed by ZipRecruiter (Malinsky, 2022). Employers are actively searching for job candidates with soft skills (Wronowska, 2015).

'Competencies imply the ability to transfer what people know and understand to various contexts – i.e., different aspects of work.' (Armstrong, 2000, p. 244). They are a strategic resource for organisations, amenable to management to support organisational development and achieve competitive market positioning (Juchnowicz, 2014; Oczkowska, 2020; Tyrańska et al., 2021; Igielski, 2024; Szelągowska-Rudzka, Mackiewicz, Spodarczyk, 2024).

Organisations develop their own competency models tailored to their needs (Rakowska, 2007; Juchnowicz, 2014; Kupczyk, Stor, 2017; Filipowicz, 2014; Czekaj, Tyrańska, Ziębicki, 2022). They may also utilize competency catalogues (lists) created by various authors, research agencies, and HR consultants. An example list of professional and behavioural competencies, divided into personal, social (interpersonal), and managerial competencies, is presented in Table 1[1].

Table 1.
Classification of soft and hard skills

Behavioural (soft) competencies			**Professional (hard) competences**
Personal	**Social**	**Managerial**	
Independence	Relationship building	Building an effective organisation	professional knowledge
Work organisation	Knowledge and experience sharing	Team building	administration/ record keeping
Flexibility and agility/ acting in uncertain situations	Identification with the organisation	Staff assessment and development	acquiring external funding
Communication/ communicativeness	Customer orientation	Managerial courage	foreign language proficiency
Assertiveness	Emotional intelligence	Leadership	digital skills
Creativity	Negotiation	Motivating	project management
Analytical thinking	Teamwork/team collaboration	Managerial coaching	knowledge of new media
Professional development/ willingness to learn	Conflict resolution	Delegation	information management
Innovativeness	Approach to diversity management	Management by objectives	procedures – knowledge and application
Entrepreneurship	Openness to change	Planning	process management
Coping with stress		Organising	market research and analysis
Problem-solving		Controlling	business awareness
Decision-making		Strategic thinking	
Conscientiousness/ eliability		Information management	
Professional ethics		Change management	
Results orientation			

Source: Own elaboration based on: Filipowicz, 2014, pp. 100, 102; *Model Usługi Rozwoju Strategicznych Kompetencji dla MŚP*, 2013; Dębkowska et al., 2022, pp. 12-14; Piwowar-Sulej et al., 2025, p. 14.

Hard competences are associated with an individual's specific profession and the nature of their duties in the workplace. These vary across job categories (Filipowicz, 2014; MURSK, 2013). They are acquired through educational processes (or training) (Czekaj, Tyrańska, Ziębicki, 2022). Without mastering them at an appropriate level – and reinforcing them with soft competencies – success in today's labour market, as well as finding a satisfying job, would be impossible (Dębkowska et al., 2022; Tyrańska et al., 2021; Dziewońska, 2016).

[1] Other types of competencies are presented, for example, by: Piwowar-Sulej et al., 2025, pp. 14-16; Dębkowska et al., 2022, p. 13; Sidor-Rządkowska, 2006, pp. 22-26; Budnikowski et al., 2012, p. 5.

Managerial competencies pertain to a limited group of individuals in leadership positions. They may also be used by team leaders (for example, leadership, team building, delegation). Personal competencies characterize an individual and stem from their personal traits and predispositions, which determine work quality (approach and manner of task performance). These traits influence the development of social competencies, i.e., interpersonal contacts and relationships with coworkers and external stakeholders. Both these groups of soft competencies are universal (Wronowska, 2015). They are necessary for every employee (and in private life) (Dziewońska, 2016). According to a study conducted by the Warsaw School of Economics, the American Chamber of Commerce in Poland, and Ernst & Young, personal and interpersonal competencies are also the most important criterion used by employers when making decisions regarding the employment of graduates (Absolwent idealny, 2012).

The rapid development of technology, especially artificial intelligence (AI) and information processing (86%), robotics and automation (58%), and energy production, storage, and distribution (41%), creates new opportunities (and risks) for the economy (Future of Jobs Report, 2025, p. 5). It enables a transition from Industry 4.0 (combining automation and digitalization) to Industry 5.0, which is based on human–machine collaboration. This cooperation increases efficiency and productivity, lowers costs, and reduces waste. It requires that employees' professional competencies be reinforced with behavioural competencies (Martyński, 2025; Pesha, Kamarova, 2020). Even engineers, in addition to technical (specialist, professional) competences, must possess non-cognitive skills (Bergman Engineering Report, 2025; Dębkowska et al., 2022; Jagodziński, 2013; Dziewońska, 2016).

According to forecasts by Deloitte Access Economics (Bankier.pl Report, 2022), by 2030, 66 percent of all jobs will consist of occupations requiring behavioural competencies, and employer demand for these competencies will increase by 22 percent. 'Future professions, thanks to artificial intelligence and automation, will rely to a large extent on soft skills'. (Zaremba, 2021). Machines can perform simple tasks even better than humans, but they cannot replace humans where soft skills are essential. This is why the importance of these skills is growing, while the relative importance of professional competencies is decreasing (Dębkowska et al., 2022; Jelonek et al., 2022).

The selection of behavioural competencies that are most desired for different job groups (professions) depends on the specifics and context of a given organisation. Thus, scientific publications, research institute reports, and HR consulting agency documents present varying sets of these skills. Examples are presented in Table 2 and Table 3.

Table 2.
Behavioural competencies of HEIs' graduates desired by employers and developed for them by research and consulting institutions (examples)

Polski Instytut Ekonomiczny	The Graduate School at the University of Cincinnati	Bergman Engineering	World Economic Forum	Zip-Recruiter	Ernst & Young
Acting in situations of uncertainty	Reliability (you do what you say, you can be trusted)	Complex problem-solving	Analytical thinking	Communication skills	Empathy
People management	Engagement (you try to work as well as you can)	People management and coordination of their activities	Curiosity and lifelong learning	Ability to work independently	Ability to manage group dynamics
Collaboration with others	Motivation	Critical thinking	Mental resilience	Customer service	Creativity
Critical thinking	Problem-solving	Creativity	Leadership and social influence	Time management	Persuasion
Negotiation skills	Creativity	Emotional intelligence	Adaptation and cooperation	Project management	
Creativity	Communication	Evaluation skills	Creative thinking	Analytical thinking	
Emotional intelligence	Flexibility	Negotiation skills	Motivation and self-awareness	Flexibility	
Solving complex problems	Teamwork	Decision-making skills	Service and customer orientation	Planning	
	Leadership		Empathy and active listening		
	Time management		Talent management		
			Flexibility and agility		

Source: Own elaboration based on: Dębkowska et al., 2022, p. 27; Zaremba, 2021; Future of Jobs Report, 2025, pp. 35-37; Report Bergman Engineering, 2025; Malinsky, 2022; Ernst & Young, 2023.

Table 3.
Examples of soft competencies considered desirable in young higher-education graduates, according to employers and students/graduates, based on findings from various studies

M. Armstrong [a]	S. Macioł, B. Minkiewicz [a]	A. Budnikowski, D. Dabrowski, U. Gąsior, S. Macioł [a]	A. Pesha, T. Kamarova [a]	B. Ziębicki, M. Walczak/ A. Wodecka-Hyjek, M. Tyrańska [b]	R. Bašková, Z. Struková [a]
Team orientation	Independence at work	Effective communication	Interaction with people	Responsibility	Ability to use professional knowledge in practice
Communication	Problem-solving skills	Openness to learning and continuous development	Client orientation	Ability to organize own work	Organisation and planning
Problem-solving skills	Communication skills	Teamwork skills	Information management	Ability to communicate effectively	Setting priorities
Decision-making	Decision-making skills	Ability to define and justify priorities	High uncertainty operation	Teamwork	Bargaining (negotiation) skills
Relationship-building	Analytical skills	Ethical behaviour as a basis for action	Social intelligence	Decision-making skills	Independence, ability to take responsibility

Cont. table 3.

Persuasion and influencing others	Ability to work under stress	Responsibility	Mental flexibility	Independence	Ability to identify and solve problems
Customer focus	Teamwork skills	Work organisation and effective time management	Emotional intelligence	Flexibility and adaptability	Analytical thinking
Stimulating others' development	Critical thinking	Flexibilityand adaptability	Self-control and self-organisation	Openness to learning and continuous development	Information management
Creativity	Creativity	Ability to formulate and solve problems	Negotiating	Critical thinking (logical reasoning)	Time management
People management	Self-learning	Result orientation	The meanings understanding	Ethical behaviour	Ability to lead a team
Change orientation	Ability to lead a group	Ability to work under time pressure	System thinking	Tolerance for workforce diversity	Leadership skills
Information management	Negotiation skills	Logical thinking	Creative thinking and innovativeness	Creativity	Convincing and argumentation skills
Self-improvement		Ability to cooperate with people from different environments, countries, cultures	Project thinking and project management		Customer orientation
Assertiveness and self-confidence		Creativity	Learning		Self-control and stress resistance
		Analytical skills	Multilingualism, multiculturalism		Good writing and communication skills
		Decision-making skills			Assertiveness
		Empathy			Flexibility
		Project management skills			Self-knowledge
					Ability to work in intercultural/ international environment
					Innovation management
					Customer orientation

[a] According to their importance for employers.
[b] According to their importance for students.

Source: Own elaboration based on: Sidor-Rządkowska, 2006, pp. 27-28; Macioł, Minkiewicz, 2008, p. 166; Budnikowski et al., 2012, p. 9; Pesha, Kamarova, 2020, p. 67; Ziębicki, Walczak, 2024, p. 170; Wodecka-Hyjek, Tyrańska, 2021, p. 67; Bašková, Struková, 2017, p. 1571.

Entrepreneurs participating in research share their opinions and experiences with academics, research institutions, and universities. They have a direct impact on the creation of lists of behavioural competencies desired in the labour market (Budnikowski et al., 2012). They indicate which competencies their employees should possess to achieve organisational goals and build the organisation's competitive position (Pesha, Kamarova, 2020). For example,

the ranking of soft skills most expected by employers (score ≥4.00) for master's degree courses in Technology and Management in Construction at the Faculty of Civil Engineering, Institute of Construction Technology and Management, Technical University of Košice (Slovakia) includes: 'ability to use professional knowledge in practice; organisation and planning; priority setting; bargaining (negotiation) skills; independence and accountability; ability to identify and solve problems; analytical thinking; information management; time management; ability to lead a team; leadership skills; persuasive and argumentation skills; customer orientation; and self-control and stress resistance' (Bašková, Struková, 2017, p. 1571) (Table 3). Including academic staff from the Technical University of Košice in the research enabled recommendations regarding the further development of study programs, methods for engaging students, and increasing the alignment of their skills with labour market needs. Among engagement methods, techniques already used at the university held a significant place (Bašková, Struková, 2017).

The study by Macioł and Minkiewicz (2008), conducted in 2006 among graduates of the Warsaw School of Economics (SGH) and their employers regarding soft competencies sought in the labour market, yielded interesting findings. The order of these competencies by importance to entrepreneurs is shown in Table 3. The order assigned by graduates (immediately after graduation) differed (analytical thinking, independence, learning ability, problem solving, communication skills, critical thinking, teamwork, creativity, decision-making, stress management, group leadership, negotiation) and points to a competency gap. After gaining experience in a specific organisation as well as knowledge from studies and self-education, graduates developed these initially lacking competencies to levels equal to or sometimes exceeding (e.g., analytical and critical thinking skills) employer expectations (Macioł, Minkiewicz, 2008).

Research into the opinions of students at the Krakow University of Economics regarding employer expectations for their soft skills, conducted by Ziębicki and Walczak (2024, p. 171), found that students recognized the following as most important: responsibility (average score 4.4), self-organisation (4.38), effective communication (4.37), teamwork (4.33), decision-making (4.23), independence (4.21), flexibility and adaptability (4.20), openness to learning and continuous development (4.16), critical thinking/logical reasoning (4.01), ethical behaviour (3.91), tolerance for employee diversity (3.89), creativity (3.74)) (Table 3). The authors concluded that today's economics students increasingly value soft competencies, considering them more important than hard skills (Ziębicki, Walczak, 2024).

'Universities must understand employers' expectations regarding graduate readiness for entering the labour market (...); they must keep up with changing employer expectations to serve their graduates and the broader community effectively' (Alanazi, Benlaria, 2023, p. 3; also Report infuture.institute, AGH, 2024; Nakhleh, Hanini, 2022).

The "'ideal graduate' of a university – regardless of field – is someone who has acquired the following soft skills, considered universal for all graduates: effective communication, openness to learning and development, activity and engagement at work, teamwork, prioritization, ethical conduct, responsibility, organisational skills and effective time management, flexibility, and adaptability" (Budnikowski et al., 2012, p. 9). According to one-third of employers, the "ideal graduate" must above all possess personal and social competencies (Absolwent idealny, 2012).

Meanwhile, according to the Bankier.pl Report (2022), globally, university graduates possess labour-market-relevant soft skills but not to the degree expected by employers. Likewise, research by the Polish Economic Institute (PEI) indicates that creativity – one of the most frequently cited soft skills (Table 2 and Table 3) – is also the skill most lacking among graduates, with 48 percent of employers reporting this deficit. Other 'missing' (according to PEI) competencies "include collaboration (41%), critical thinking (36%), complex problem solving (33%), flexibility (32%), negotiation skills (28%), people management (25%), emotional intelligence (21%)" (Dębkowska et al., 2022, p. 22).

According to research for the National Centre for Research and Development, "young employees primarily lack competencies such as logical thinking, independent action, communication skills, engagement, willingness to take on challenges, and creativity, including courage to experiment" (Jelonek et al., 2022, p. 6).

Results from Budnikowski et al. (2012, p. 11) 'indicate that employers see the following soft skills as least developed in graduates: negotiation (3.0 on a five-point scale), project management (3.03), entrepreneurship (3.19), decision-making (3.30), organisation and effective time management (3.35), prioritization and justification (3.35), independence (3.47), empathy (3.50), problem formulation and solving (3.56)'.

The ManpowerGroup report from 2021 states that 81 percent of companies have difficulty recruiting employees with required behavioural competencies. Employers note that job candidates most often lack the ability for logical and critical thinking, problem solving, and initiative (25%). It is also difficult to recruit individuals demonstrating reliability, discipline, and responsibility for assigned tasks (35%).

Research by the Polish Development Fund and DELab at the University of Warsaw indicates that students and graduates of Polish universities are aware of the importance of behavioural competencies. At the same time, they rate university education as insufficient in enabling them to acquire these competencies, especially entrepreneurship, teamwork, and creativity—those most in demand on the labour market (Dębkowska et al., 2022), whose lack is reported by employers (Budnikowski et al., 2012; Dębkowska et al., 2022).

On the other hand, graduates with university degrees have an advantage because of the professional competencies acquired during their studies. As a result, once they become familiar with the specifics of the company, they can quickly adapt to employer expectations (Macioł, Minkiewicz, 2008). If, during their education, they also acquire soft skills, they can supplement

their professional knowledge and abilities more rapidly and create value for clients and organisations, contributing to organisational competitiveness (Juchnowicz, 2014; Wodecka-Hyjek, Tyrańska, 2021).

3. Methods

To address the first and second theoretical research questions, we analysed the literature and reports issued by research institutions and HR consulting agencies on the competencies of university graduates in the labour market. These studies applied diverse methods (quantitative, qualitative, and mixed methods), used various research instruments (questionnaire, interview guide), and involved different respondent groups (students, graduates, employers, and academic staff). All of them, however, focused on the soft competencies of graduates expected by employers and possessed by graduates to a limited extent. These findings provided the basis for discussion and comparison in the Discussion and Conclusions section and for reference to the results of the empirical study.

The aim of the empirical study was to assess, according to a purposefully selected group of full-time students at the Faculty of Management and Quality Science (FMQS) at Gdynia Maritime University,

- which of the examined soft skills they consider most desirable in the labour market,
- which of these skills respondents have mastered most effectively,
- and what possibilities they identify for improving these skills during their studies.

The study is a pilot study.

At the design stage, the research problem was conceptualized and defined (the occurrence of discrepancies between behavioural competencies of university graduates desired by employers/the labour market and their actual mastery by young people entering the labour market immediately after graduation). The study group was then selected, the auditory survey was chosen as the data collection method, and a questionnaire – used as the research instrument – was developed. The questionnaire covered soft skills most frequently indicated as desirable in the labour market and simultaneously acquired by respondents through elective courses during their studies at FMQS.

The following soft skills were assessed by students:

- Interpersonal communication.
- Decision-making.
- Teamwork.
- Group problem solving.
- Assertiveness.

- Coping with stress.
- Time management.
- Negotiation.
- Conflict resolution.
- Creativity.

The questionnaire also included demographic questions regarding gender, mode of study (full-time, part-time), and professional experience, as well as a question about the need for soft skills improvement during studies. Students were additionally asked to indicate the most effective form of classes for developing these skills in their opinion. Closed questions utilized a nominal scale and a composite attitude (positional) scale. The core of the positional scale is the nominal scale, where individual items from the competency list were evaluated using ordinal scales. The choice of measurement scale in closed questions determined the methods used for data reduction and analysis. The study presented data in tables and used frequency indicators as descriptive statistical methods during the data analysis stage. The results were then interpreted and conclusions drawn. As the study is pilot in nature, the findings and conclusions apply only to the researched population.

The research was conducted in 2023 and involved 60 third-year full-time students at FMQS, participating in elective courses: Interpersonal Communication and Creative Thinking Techniques. These courses develop behavioural competencies. Of the respondents, 70% were women. The majority (77%) had professional experience (including: 67% from part-time jobs, 25% from permanent employment). Their opinions can be considered more balanced and objective (Wronowska, 2015).

4. Results

First, students were asked – drawing on their professional experience – to indicate how desirable the assessed soft skills are in the labour market and to rate their own mastery of these skills (self-assessment). The results are presented in Table 4 and Figures 1-3.

Table 4.
Respondents' views on the usefulness (desirability) of individual behavioural competencies in the labour market and their self-assessment of proficiency in these competencies (average results)

The soft competencies examined	Usefulness of competencies	Self-assessment
Interpersonal communication	4,49	4,01
Decision-making	4,56	3,64
Teamwork	4,42	4,04
Group problem solving	4,29	3,92
Assertiveness	4,49	3,48
Coping with stress	4,70	2,78

Cont. table 4.

Time management	4,37	3,29
Negotiation	4,05	3,25
Conflict resolution	4,32	3,87
Creativity	4,27	3,67

Source: Own elaboration.

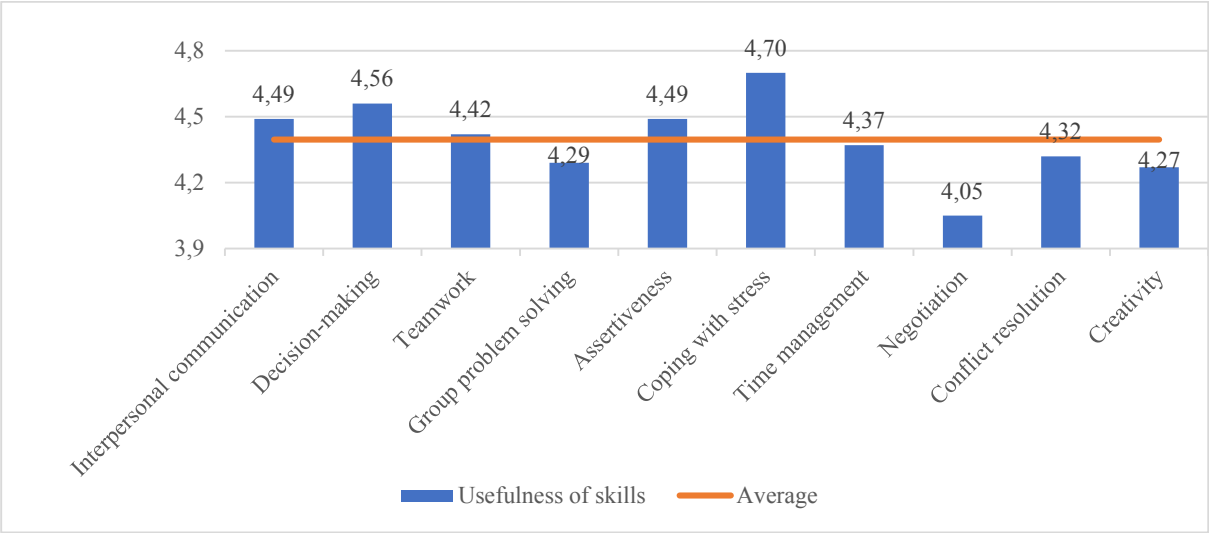


Figure 1. Soft skills most and least desired in the labour market according to the respondents.

Source: Own elaboration.

As shown in Table 4, there is a competency gap between labour market demand for the assessed skills and the level of mastery declared by students (self-assessment). For each soft skill, students' self-assessments were lower than the level desired by employers (i.e., above 4 on a five-point scale) (Fig. 1).

Coping with stress (mean rating 4.70) was considered by surveyed students to be the most desirable competency among employers (Table 3, Fig. 1). Next in the ranking were: decision-making (4.56), interpersonal communication and assertiveness (both 4.49), and teamwork (4.42). Negotiation, in the opinion of respondents, was the least valuable skill in the labour market (4.05). Also, below the average were: creativity (4.27), group problem solving (4.29), and conflict resolution (4.32) (Fig. 1).

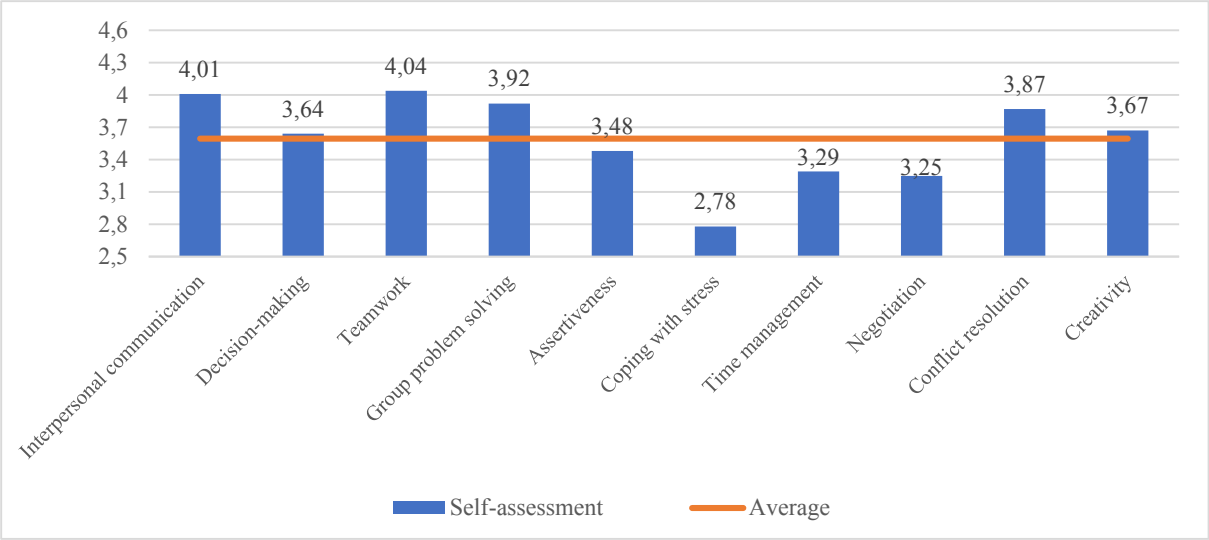


Figure 2. Respondents' self-assessment of their behavioural competencies

Source: Own elaboration.

In students' self-assessment, the highest scores were given to: teamwork (4.04), interpersonal communication (4.01), group problem solving (3.92), and conflict resolution (3.87) (Fig. 2).

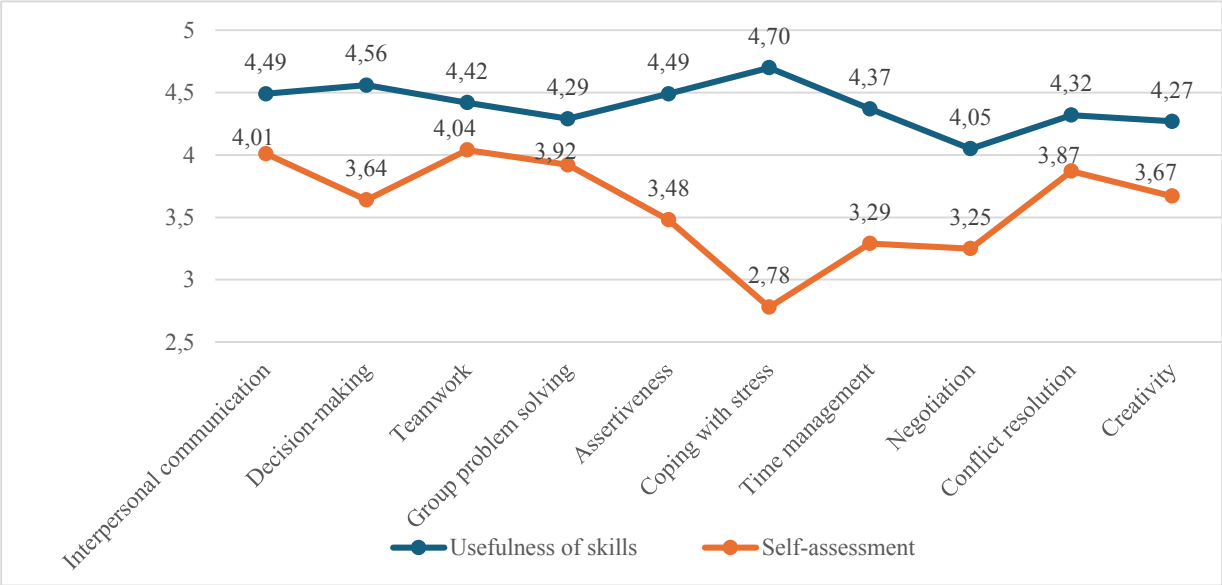


Figure 3. Competency gap – the discrepancy between the labour market usefulness of individual soft skills and the respondents' self-assessment of these skills.

Source: Own elaboration.

Figure 3 illustrates the competency gap, i.e., discrepancies between behavioural competencies desired in the labour market and students' self-assessments. The largest gap – almost two rating points (1.92) – was observed in coping with stress. For the next competencies, time management and assertiveness, the discrepancy was about one point (1.08 and 1.01, respectively). The smallest competency gaps were found in group problem solving (0.37), teamwork (0.38), conflict resolution (0.45), and interpersonal communication (0.48).

Thus, these are the behavioural competencies that, according to self-assessment, surveyed students possess best (Fig. 2).

In subsequent questions, respondents were asked to indicate where – at work, in personal life, or during their studies – these soft skills are most needed (Table 5). They were also asked to indicate the most effective ways to develop these competencies during their studies (Table 6) as well as the key benefits resulting from this process (Table 7).

Table 5.
Assessment of the usefulness of the soft skills examined in different areas

Areas of use	Average usefulness rating
In personal life	4,31
In professional life	4,59
During studies	4,16

Source: Own elaboration.

Table 6.
Respondents' answers regarding their preferred form of classes aimed at improving soft skills

Forms of courses	Response frequency (%)
Classes	63
Lectures	12
Lectures and classes	7
There is no need for such classes	7
Difficult to say	12

Source: Own elaboration.

Table 7.
Benefits expected by respondents from participating in courses developing students' behavioural competencies

Possible benefits for students	Average assessment of benefits
Knowledge about soft skills	3,93
Awareness of the importance of soft skills	3,98
Guidance for developing one's own soft skills	4,35
Ability to build interpersonal relationships	4,27
Increased self-awareness	4,37
Increased competencies	4,47

Source: Own elaboration.

Respondents' answers indicate that behavioural competencies are most needed in professional work (4.59), followed by personal life (4.31), and least needed during studies (4.16) (Table 5).

The majority (63%) consider classes to be the most effective form of courses for developing these competencies. However, 12% of respondents have no definite opinion on the subject, and another 7% regard improving their skills unnecessary (Table 6).

The greatest benefits indicated by respondents from courses developing behavioural competencies were: improvement of these competencies (4.47), increased self-awareness regarding these competencies (4.37), guidance for their development (4.35), and the ability to build interpersonal relationships (4.27) (Table 7).

5. Discussion and conclusions

In implementing the first research objective – identifying which soft skills are most desired in the labour market (by employers) – it was found that the lists of these competencies presented in the scientific literature and in reports for business practitioners differ from each other (Table 2 and 3). The selection of competencies within a specific organisation depends on its characteristics (goals and tasks), the sector in which it operates, its size (SMEs vs. corporations) (cf. Dyrla-Mularczyk, Pluciński, Borowiec, 2018), as well as situational context (including the economic climate) (Jelonek et al., 2022). The most desired competencies in the labour market also change with the evolving environment, especially technological development (Absolwent idealny, 2012; Szelągowska-Rudzka, Mackiewicz, Spodarczyk, 2024; infuture.institute AGH Report, 2024; Strojny et al., 2021).

Among the research agency and HR consulting reports analysed in the article, the most frequently listed behavioural competency is creativity (the ability to generate new solutions) (5 occurrences). The next most common are: people management (group/talent dynamics) (4) and leadership (2); problem solving (4) and decision-making (4); cooperation/teamwork (3) as well as emotional intelligence (2) and empathy (2). Some competencies, such as psychological resilience, engagement, dealing with uncertainty, and persuasion, appear only once in these lists (Table 2).

Among examples of competencies desired by employers and cited in scientific publications, creativity is also most frequently indicated (6 times), as are teamwork (5) or working in multicultural/international environments (3). Following in frequency are: communication skills, negotiation, problem solving, decision-making, analytical skills, customer orientation (4 times each); as well as responsibility, flexibility, and information management (3 times each). Competencies such as people management, tolerance for workforce diversity, entrepreneurship, emotional intelligence, ability to work under time pressure, innovation management, process management, empathy, and the ability to use professional knowledge in practice, appear only in one listing (Table 3).

Thus, employers most need creative graduates (Dyrla-Mularczyk, Pluciński, Borowiec, 2018). Individuals able to respond quickly to changing internal and external conditions, propose, and implement new solutions in organisations that are suited to those circumstances. They can foster innovation, which is particularly important for building the organisation's competitive advantage in the market (Igielski, 2018; Wodecka-Hyjek, Tyrańska, 2021; Tyrańska et al., 2021; Bergman Engineering Report, 2021/2025).

Other frequently indicated and therefore important soft skills for university graduates include: teamwork, problem-solving and decision-making abilities (Galanti et al., 2023), communication, negotiation, people management (group dynamics), customer orientation, analytical skills, and responsibility. The synergy effect – added value derived through

collaboration among different specialists – is key for organisational development, Industry 4.0, and Industry 5.0. Effective adaptation of modern technology requires cooperation between employees in various positions, as well as collaboration between human (employees) and non-human (algorithms, devices) enterprise members (Dębkowska, 2022; Piwowar-Sulej et al., 2025; Czekaj, Tyrańska, Ziębicki, 2022; infuture.institute AGH Report, 2024).

'The key success factor for a modern organisation is not technology itself, but people who can use that technology effectively' (Wodecka-Hyjek, Tyrańska, p. 62). Therefore, employees need to learn and continuously develop their soft skills throughout their lives (infuture.institute AGH Report, 2024). They need to build mutual partnership relations, trust, teamwork, and positive interactions with clients. Thanks to behavioural competencies, they will be able to share their knowledge and innovative ideas, create organisational knowledge, core organisational competencies, and the organisation's value and competitive advantage in the environment (Szelągowska-Rudzka, Mackiewicz, Spodarczyk, 2024; Dyrla-Mularczyk, Pluciński, Borowiec, 2018). With soft skills, they will utilize professional knowledge, modern digital technology, and artificial intelligence more effectively (Igielski, 2018; Ziębicki, Walczak, 2024).

In fostering intra-organisational cooperation, other important soft skills include coping in multicultural and international environments (which are highly dynamic and require flexibility), relationship building and influencing others, assertiveness, psychological resilience (coping with stress), skilful use of information and time, process management, project management, innovation management, and leadership.

Czekaj, Tyrańska, and Ziębicki (2022, p. 254), using the example of graduates of economic (business) universities, conclude that in the 21st century 'employees mainly need soft skills, particularly the ability to organise their own work, communication skills, diligence, meticulousness, ability to work in a team, independence, ability to work under time pressure, engagement, and availability.'

Behavioural competencies are universal (Kraśniewska, Dybaś-Stronkowska, 2019). All employees in various organisational roles require them: economists, engineers (Jagodziński, 2013; Dyrla-Mularczyk, Pluciński, Borowiec, 2018; Bašková, Struková, 2017; infuture. institute AGH Report, 2024), IT professionals, accountants, or auditors (Fastnacht, 2006, pp. 110, 113). Their development will allow graduates to adapt more effectively to an increasingly dynamic and demanding labour market in the future (Kraśniewska, Dybaś-Stronkowska, 2019).

The second theoretical objective of the study was to identify whether university graduates possess the soft skills desired in the labour market and at what level. It was found that, between employers' expectations for these competencies and the level of mastery by young people entering the labour market, a competency gap exists. Graduates possess the studied competencies, but at an insufficient level (Bankier.pl, 2022; Dębkowska et al., 2022; Budnikowski et al., 2012; Bašková, Struková, 2017; Ziębicki, Walczak, 2024).

Tyrańska et al. (2021, pp. 5-6) identified ‘deficiencies in the academic education system, which fails to provide graduates with the necessary soft skills and digital competencies to enable them to quickly adapt to the work environment’, as one of the main reasons for the competency gap globally. Other reasons include:

- rapid technological changes,
- insufficient opportunities for internships or industry training, which would allow new (and current) employees to develop and acquire indispensable skills for their sector already during their education.

Empirical research (the third objective of the study) conducted by the authors among a purposefully selected group of full-time students at the Faculty of Management and Quality Science at Gdynia Maritime University, confirms the existence of a competency gap. The results show that the respondents, most of whom (77%) already have some professional experience, understand the significance of soft skills at work (Table 5; UEK, 2024). At the same time, they are aware that their soft skills do not meet labour market expectations (Table 4, Fig. 3). This is notable, as this faculty had already introduced (Szelągowska-Rudzka, 2018) courses directly dedicated to improving soft skills. Respondents participated in two of these courses: interpersonal communication and creative thinking techniques, delivered as elective lectures. A third course is stress management. Additionally, interpersonal training – delivered as both lectures and classes – forms part of two specialisations (managerial economics and marketing and commerce), focusing mainly on the comprehensive development of behavioural competencies (mainly individual and social). Perhaps if all these courses were mandatory for students of the Faculty of Management and Quality Science, graduates’ soft skills would more closely align with employers’ expectations. The same recommendation applies to the faculty’s second cycle (master’s) programs, which include courses on team building, managerial coaching, and team management and leadership. The first two are elective lectures; the last is offered as a lecture and classes for students of only one specialisation.

The soft skills that surveyed students rated as their strongest are: teamwork, interpersonal communication, group problem-solving, and conflict resolution (Fig. 2). These are also practiced in other courses included in their study program, where students complete team tasks and joint projects. They must cooperate, communicate effectively, solve emerging challenges, and later present their work results to the entire group. This means they actively exercise soft skills.

Interestingly, creativity – a competency especially valued by employers and at the same time, scarce (Jelonek et al., 2019) – was considered one of the least important by respondents. Others in this group include negotiation, assertiveness, and group problem-solving (Fig. 1). On the other hand, coping with stress is regarded as most important but also as the least well-mastered skill (Table 4). Students experience stress during their studies and lack effective coping strategies. To overcome this, as students emphasize (Table 6), exercises should allow them to recognize their reactions in challenging, real-life-like situations; discuss and look for

practical coping methods. Therefore, more classes should be provided on stress management and other soft skills.

Overall, the research conducted in both the theoretical and empirical sections clearly demonstrates how important it is for the labour market (employers), for students of all fields, and for today's knowledge-based economy (Szelągowska-Rudzka, Spodarczyk, 2018) to ensure that universities offer courses facilitating the development of soft skills. Universities play a crucial role in this (Nakhleh, Hanini, 2022) and should strengthen their efforts (Strojny et al., 2021). The authors recommend:

- Place greater emphasis on the development of soft competencies within other courses included in study programmes (Jelonek et al., 2019).
- Consider the introduction of a compulsory course/courses aimed at developing soft competencies across all fields of study (not only in economics), preferably in the form of classes or workshops.

  This action may be preceded by the university's application for participation in projects dedicated to the development of future graduates' competencies and financed, for example, by the National Centre for Research and Development (NCBR). After the completion of such a project, tested solutions ready for implementation at the university will remain (Jelonek et al., 2012, pp. 6, 102-107).
- The popularisation of various activating teaching methods at universities, including, in addition to commonly used teamwork and case studies, role-playing, drama, discussions, brainstorming, demonstrations, and project work (Fastnacht, 2006). This is also associated with the development of the teaching competencies of academic staff (Jelonek et al., 2019, p. 54).
- Creating opportunities for students to participate in additional projects and initiatives organized especially for them by university (Kraśniewska, Dybaś-Stronkowska, 2019).
- Supporting and encouraging students to engage in science clubs, student government, and student associations.

The last two actions are especially useful for developing creativity (Studiuj, UEK, 2024).

Higher education institutions must actively develop educational offerings that match the needs and expectations of today's economy, which requires labour market monitoring and the modification of programs and fields of study (Tyrańska et al., 2021). They should be adapted to rapidly changing organisational, sectoral, and environmental competency requirements (Jelonek et al., 2022). The benefits of soft skills development were recognized by students participating in the study (Table 7), who indicated, above all, growth in these competencies, awareness of their usefulness, and the need to improve them due to the constant change in the external environment.

For the development of students' (graduates') not-cognitive competencies, it is also important that university administrators and higher education policymakers are aware of the existing competency gap (Strojny et al., 2021). This entails understanding that employers'

expectations regarding graduates' soft competencies differ from students' and universities' perceptions. For example, Dyrla-Mularczyk et al. (2018, p. 219) note that "soft skills necessary for civil engineering professionals are not included at all in the curriculum for that major, and management-related courses – helpful for developing soft skills – constitute no more than 9% of total course hours throughout the program".

On the other hand, the infuture.institute (2024) report prepared for the AGH University of Science and Technology in Kraków emphasized the need to redefine the role of the engineer of the future. Such an engineer should be a "technological humanist", combining knowledge from the natural sciences, engineering, humanities, ethics, environmental and social changes, among others. This requires educational changes — specifically, the integration of knowledge from traditional engineering disciplines with knowledge from the social sciences and humanities. Examples of other universities implementing initiatives to develop students' soft competencies and demonstrating good practices in this area were presented by Strojny et al. (2021, pp. 19-29).

Similarly, in response to employer demand, technical faculties at Gdynia Maritime University educating engineers for maritime-related enterprises have introduced courses to develop soft skills. For example: managerial skills and teamwork at the Faculty of Electrical Engineering (Degree programs, WE, 2025), and creative thinking techniques, team management at the Faculty of Mechanical Engineering (Degree programs, WM, 2025).

To overcome the competency gap, higher education institutions also require industry partnerships and closer cooperation with employers. "Industry partnerships can provide students with access to real-world professional experience and enable them to apply theoretical knowledge in practical settings" (Alanazi, Benlaria, 2023, p. 5). The most effective way to eliminate graduates' competency gaps is through real – not merely declarative – close collaboration between universities and employers (Kraśniewska, Dybaś-Stronkowska, 2019). In this context, the offering by employers of opportunities to participate in internships, traineeships, and volunteering, which enable the development and practical application of soft competencies (Spadło, 2025). It is also important for universities and employers to communicate their mutual needs and expectations regarding the development of students' (future graduates') behavioural competencies. Both universities and employers should be involved in these activities since developing graduates' soft competencies brings mutual benefit and shared responsibility. Without well-developed behavioural competencies, young graduates' success in the labour market – and consequently the development and competitive position of universities and the Polish economy – may be significantly hindered.

Students themselves are increasingly aware that soft skills are "essential for effective performance in many varied professional roles, and (…) they greatly facilitate reskilling, job changes, and adaptation to new professions and responsibilities" (Fastnacht, 2006, p. 110) at a given or different employer. They are the key to building professional standing in a rapidly changing labour market, both in the near and distant future, including the need to adapt to

continually emerging new professions (Ziębicki, Walczak, 2024). Thus, "a deeper diagnosis carried out by universities is needed to face future challenges (…) those of ten or fifty years ahead" (Kraśniewska, Dybaś-Stronkowska, 2019, pp. 62-63).

Practical implications

Based on studies conducted using both secondary and primary sources, it was found that higher education institutions should place greater emphasis on ensuring that their graduates acquire soft competencies.

This should primarily be achieved through classes and workshops focused on developing these competencies, by employing various activating teaching methods throughout the entire study period, and through close cooperation with employers. Employers, for their part, should also be open to this cooperation.

A limitation of the literature review is the use of secondary sources from various periods and industries, as well as the pilot nature of the empirical study. The empirical survey conclusions pertain to the sample studied students from one faculty at Gdynia Maritime University. Nevertheless, when combined with the findings from the analysis of the literature and external reports for employers, these results point to possible directions for further research.

Theoretical implications. Based on analysis of data from both secondary and primary sources presented in the article, a research gap was identified: there is a lack of in-depth comparative empirical studies conducted in Poland which comprehensively diagnose discrepancies between the soft skills desired by employers (demand side) and the soft skills possessed by graduates employed with specific education programs (supply side). Previous studies, although relatively numerous (Ziębicki, Walczak, 2024), have been conducted either among students (graduates) or exclusively among employers, thus providing only one-sided conclusions. Comprehensive studies, similar to those carried out by Macioł and Minkiewicz (2008), should be conducted over the long term, simultaneously among students/universities and employers (Ziębicki, Walczak, 2024). This would allow ongoing monitoring of the labour market situation and minimize the competency gap in soft skills among Polish university graduates.

The identified research gap points to directions for future research, which should be comprehensive and comparative. For example, they could focus on identifying the needs of employers from various industries as well as those of university students regarding soft skills desired by those industries. This is not an easy task due to rapid and significant changes in the environment, especially technological changes. However, these changes drive shifts in employers' requirements for soft skills, and should be studied so that universities, with support from the economic environment, can continually improve their educational offer. Such comprehensive, comparative research seems to be an effective way to reduce the soft competencies gap among Polish university graduates.

Soft skills are essential for future graduates to adapt quickly to changing labour market conditions and to recognize the benefits of higher education (Budnikowski et al., 2012). As a result, graduates will become better employees, use their professional (hard) skills more effectively, appreciate the university's role in preparing them for the workforce, and value lifelong learning. The university will enhance its reputation and standing in its environment – including among prospective students.

On the basis of the analysis of the literature and external reports, and despite the methodological limitations outlined in the Methods section as well as the pilot nature of the empirical study, preliminary conclusions and recommendations for employers and higher education institutions concerning the development of graduates' soft competencies were formulated. Moreover, possible directions for further research were indicated and a research gap was identified.

6. Summary

The objectives of the study were achieved. The most desirable soft competencies for HEIs graduates, as sought by employers, were identified. Despite differences in the sets of competencies presented in the literature, it can be concluded that the 'ideal graduate', regardless of field of study, should be open to learning and development, active and engaged at work, adaptable, able to work in a team, communicate effectively, act ethically, be responsible and flexible. They should be able to set priorities, organise their work, and manage their time efficiently.

In general, university graduates possess these competencies, though not always at the level expected by the labour market. These competencies should be tailored to the specific organisation, industry, and environmental situation in which the organisation operates. This conclusion is supported by empirical research conducted among a purposefully selected group of Faculty of Management and Quality Sciences at the Gdynia Maritime University students. Although the study is of a pilot nature, it complements the description of the situation on the Polish labour market based on secondary sources, which does not differ from that observed in the global labour market.

The practical implications of this research indicate that universities should do more to ensure that their graduates acquire soft skills. To this end, dedicated courses (in the form of classes and workshops), the use of various activating teaching methods in general – including those aimed at developing behavioural competencies in other courses within the study programme – as well as more intensive cooperation with employers may prove useful. Effective cooperation between the demand side (employers) and the supply side (universities and their

students) regarding graduates' soft skills can contribute to the improvement of university curricula and the situation on the Polish labour market.

From a theoretical perspective, a research gap was identified: there is a lack of in-depth, comparative empirical studies in Poland that comprehensively diagnose discrepancies between soft skills desired by employers (demand side) and those possessed by graduates of certain educational programs (supply side).

It was determined that universities should conduct systematic, comprehensive scientific research to identify (anticipate) changes in the labour market regarding graduates' soft competencies and suggest ways of improving them in both academic and organizational practice. To fulfil this role, such studies should be carried out simultaneously among employers and among the universities from which their employees graduated.

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DIGITAL TRANSFORMATION OF ENTERPRISES IN THE OPINION OF MANAGERS

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Purpose: The purpose of the study is to examine whether the implementation success of IT systems in enterprises is associated with (1) changes in the company's overall strategy undertaken during IT implementation, (2) management involvement in the implementation process, and (3) the existence of a formal written IT or process management strategy. The research specifically seeks to determine which of these strategic and organizational factors differentiates managers' satisfaction with IT implementation outcomes.
Design/methodology/approach: The study adopts an exploratory research design combining a systematic literature review with an empirical CAWI survey. Primary data were collected at the end of 2024 from 11 enterprises associated with the Kielce Technology Park. The questionnaire measured managers' perceptions of IT implementation outcomes and organizational conditions. Statistical analysis included the Mann–Whitney U test to assess the impact of management involvement and Student's t-tests to examine differences in satisfaction levels related to written IT strategies and strategic changes undertaken during IT implementation.
Findings: The results show a statistically significant relationship between management involvement and satisfaction with IT implementation outcomes (Mann-Whitney $U = 12.5$; $p < 0.01$). Furthermore, a statistically significant difference was identified between enterprises that modified their overall strategy during IT implementation and those that did not, with higher satisfaction regarding achieved objectives observed in the former group ($t >$ critical value at $\alpha = 0.05$). In contrast, the presence of a written IT or process management strategy did not produce statistically significant differences in satisfaction levels. These findings indicate that strategic adaptability and active managerial engagement, rather than formal strategic documentation alone, are key determinants of perceived IT implementation success.
Research limitations/implications: If research is reported on in the paper, this section must be completed and should include suggestions for future research and any identified limitations in the research process.
Practical implications: The study demonstrates that enterprises implementing IT systems should prioritize active top-management involvement and treat IT implementation as a catalyst for strategic adjustment rather than as a purely technical project executed within fixed strategic assumptions. For practitioners, the results suggest that formal IT strategies should be complemented by mechanisms enabling ongoing strategic review and adaptation during implementation. Such an approach may reduce implementation failures and increase

satisfaction with achieved outcomes, particularly in organizations undergoing digital transformation under conditions of uncertainty.
Originality/value: The originality of the paper lies in demonstrating—based on empirical data from Polish enterprises—that strategic change during IT implementation is more strongly associated with satisfaction with achieved implementation objectives than the mere existence of a written IT strategy. The study contributes to the digital transformation literature by shifting the emphasis from static strategic formalization toward strategic adaptability as a managerial capability relevant in technology-driven change. The paper is addressed to scholars investigating digital transformation determinants and IT project success factors, and to managers responsible for IT implementation who require evidence-based guidance on how to reduce failure risk and increase perceived project success.
Keywords: IT system, strategy, success factors, ERP.
Category of the paper: Research paper.

1. Introduction

An effective evaluation framework and methodology for assessing enterprise informatization are essential to guide the implementation and development of corporate information systems. With the rapid advancement of Information Technology (IT), businesses are gaining significant benefits across multiple operational areas, as technology has become a vital component for integrating processes and data within organizations. Enterprises employ information systems to gather, process, and transform data into valuable information that supports decision-making and overall business performance. Digital transformation currently represents one of the key processes determining the competitiveness and efficiency of economic entities, fundamentally reshaping the paradigms of how organizations operate in the modern economy. Digitalization processes are transforming not only the technological aspects of enterprises but also their organizational structures, business models, and relationships with stakeholders. As Pieriegud (Pieriegud, 2016, pp. 11-15) points out, digital transformation signifies a shift in the existing operational model of an enterprise or an entire sector using cutting-edge digital technologies, particularly those based on data analytics, artificial intelligence and cloud computing.

The most common mistakes observed during IT implementations:

- Lack of governance and accountability. No designated process owners, unclear rules for model usage, and insufficient content quality control.
- Overly rapid scaling. Implementation carried out without validating data, costs, or workflow impact.
- Lack of a coherent communication strategy.
- Absence of success metrics. Focus on outcomes rather than KPIs (time, quality, cost, conversions).

- Mismatch between tools and team competencies. Advanced solutions introduced without the necessary operational skills.
- Lack of education and onboarding. Employees were not adequately prepared to work with the new system.

In the Polish context, digital transformation gains particular importance considering the challenges posed by rising labour costs, competitive pressure from foreign entities, and evolving consumer expectations. As indicated by a Deloitte report, Polish enterprises that have successfully implemented digitalization strategies recorded an average 23% increase in productivity and an 18% reduction in operational costs (Deloitte, 2021, pp. 12-18).

Digital transformation constitutes a fundamental process redefining contemporary enterprise management. Its significance extends far beyond technological aspects, encompassing a comprehensive shift in business models, organizational structures, and ways of interacting with customers. Companies that effectively implement digitalization strategies gain a significant competitive advantage by increasing operational efficiency, better understanding customer needs, and adapting more quickly to changing market conditions.

Managers and IT experts employed in Polish enterprises perceive their organizations as innovative and consistently implementing advanced information technologies in response to business needs, competitive pressures, and market trends. The analysis of the study results clearly indicates a high level of advancement among Polish companies in terms of IT solutions that foster innovation and enhance competitive advantage.

Security and business continuity issues are placed unequivocally at the forefront. As many as 91% of companies adopt innovations in cybersecurity and infrastructure monitoring (SOC) to ensure organizational resilience to contemporary threats, while simultaneously continuing to digitalize further business processes.

Up to 92% of entities representing the financial sector currently use cloud computing resources. Across the economy, the saturation with cloud technologies—regardless of the model (IaaS, PaaS, SaaS)—averages 65% in industry and 54% in healthcare. At the same time, companies are not inclined to abandon their own IT infrastructure. As many as 89% of surveyed firms still maintain their internal IT resources, with this percentage reaching 100% in the financial sector (Barometr Cyfrowej Transformacji Polskiego Biznesu, 2025-2026, p. 5).

The article addresses the following research hypotheses:

H1: Enterprises that introduce strategic changes in response to digital transformation report higher levels of satisfaction with IT implementation outcomes than enterprises without such changes.

H2: The identification and formalization of business processes positively influence the effectiveness of IT system implementation.

H3: Organizational and situational determinants significantly differentiate the perceived success of IT implementation projects.

By testing these hypotheses, the study aims to extend existing knowledge on the strategic and organizational factors that condition digital transformation success. Given the limited empirical evidence focused on Polish enterprises, the findings are intended to enrich the literature with context-specific insights while remaining relevant to broader international discussions.

Digital transformation has emerged as a central research theme in management and information systems literature, reflecting the growing role of digital technologies in reshaping enterprise strategies, structures, and competitive dynamics. Contemporary research increasingly emphasizes that digital transformation extends beyond the implementation of advanced IT solutions and constitutes a strategic and organizational process that fundamentally alters how firms create value (Bharadwaj et al., 2013; Vial, 2019). In this perspective, digital technologies are not merely operational tools but strategic resources whose effectiveness depends on alignment with business objectives, managerial capabilities, and organizational readiness.

A substantial body of literature highlights the importance of strategy–IT alignment as a determinant of successful digital initiatives. Early contributions in the field of information systems management demonstrated that misalignment between IT investments and corporate strategy often leads to suboptimal outcomes and implementation failures (Kisielnicki, Sroka, 2001; Markus, Tanis, 2000). More recent studies extend this view by arguing that in environments characterized by rapid technological change, alignment should be understood as a dynamic capability rather than a static state (Matt et al., 2015; Hess et al., 2016). From this standpoint, digital transformation strategies require continuous adaptation as organizations learn from implementation experiences and respond to emerging challenges.

The strategic dimension of digital transformation is closely linked to leadership and managerial involvement. Empirical and conceptual studies consistently indicate that top management commitment plays a decisive role in shaping digital transformation outcomes by providing direction, legitimizing change, and resolving organizational conflicts arising during implementation (Kane et al., 2015; Teece, 2018). Inadequate governance, lack of accountability, and insufficient managerial engagement have been identified as recurrent causes of failure in ERP and enterprise system projects (Lech, 2007; Somers, Nelson, 2004). These findings support the view that digital transformation success depends not only on technological choices but also on leadership-driven coordination of strategic, structural, and cultural change.

The evaluation of IT implementation outcomes has been extensively addressed in the information systems literature through models of IS success. Among these, the DeLone and McLean Information Systems Success Model remains one of the most influential frameworks for assessing the effectiveness of IT systems (DeLone, McLean, 2003). The model conceptualizes success as a multidimensional construct encompassing system quality, information quality, service quality, system use, user satisfaction, and net benefits. Subsequent studies have refined and empirically validated the model, emphasizing the central role of user

satisfaction and perceived benefits as meaningful indicators of implementation success, particularly in organizational contexts where objective performance metrics may be difficult to isolate (Petter et al., 2008; William, Tjhin, 2021). This approach is particularly relevant for research focusing on managerial perceptions of IT outcomes, as satisfaction reflects the extent to which systems meet organizational expectations and strategic objectives.

2. Research Methodology

The first element of the adopted methodology is a systematic literature review aimed at identifying the theoretical foundations of digital transformation and the current state of knowledge in this field. The review covers publications from 2010-2023, with particular emphasis on works published in the last five years, which makes it possible to capture the latest trends and concepts. The process of selecting literature was conducted in accordance with the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which ensures transparency and methodological rigor of the research procedure.

Although the review was not intended as a meta-analysis, PRISMA guidelines were applied as a structured framework for managing the review process and documenting inclusion and exclusion decisions.

The review procedure consisted of four main stages: identification, screening, eligibility assessment, and inclusion.

In the identification stage, a comprehensive search was conducted in the following scientific databases: *Web of Science, Scopus, EBSCO Business Source Complete,* and *BazEkon*. The search covered publications from 2010 to 2023, with particular emphasis on works published in the last five years to capture the most recent developments in digital transformation research. The key search terms included: *digital transformation, enterprise digitalization, digital management, Industry 4.0, digital innovation, digital competencies,* and *digital leadership*. Both Polish and English-language publications were considered.

During the screening stage, duplicated records were removed, and titles and abstracts were examined to assess their relevance to the research objective. Publications that did not address enterprise-level digital transformation, IT systems implementation, or strategic and organizational determinants were excluded at this stage.

In the eligibility assessment stage, full-text versions of the remaining publications were reviewed in detail. Inclusion criteria comprised: (1) relevance to digital transformation or IT systems implementation in enterprises, (2) a clear conceptual or empirical contribution, and (3) alignment with management, information systems, or organizational studies. Exclusion criteria included purely technical studies without managerial implications, publications lacking methodological transparency, and sources not directly related to enterprise contexts.

The final inclusion stage resulted in a corpus of 10 publications, consisting of 3 peer-reviewed scientific articles, 5 academic monographs, and 2 industry reports. The selected sources represented both Polish and international research perspectives, enabling comparative interpretation and contextualization of digital transformation determinants specific to Polish enterprises.

The PRISMA-based procedure ensured that the literature review was conducted in a systematic and replicable manner, minimized selection bias, and provided a transparent foundation for the development of research hypotheses and the interpretation of empirical findings. The outcomes of the review supported the operationalization of key constructs, including strategic alignment, management involvement, and process formalization, which were subsequently examined in the empirical part of the study.

The key search terms used in the process included: digital transformation, enterprise digitalization, digital management, Industry 4.0, digital innovation, digital competencies, and digital leadership. The literature review was oriented toward achieving the following partial objectives: operationalizing the concept of digital transformation, identifying the main models and frameworks of transformation, analysing success factors and barriers in the digitalization process, and determining the impact of digital solutions on enterprise competitiveness.

The study was conducted using the CAWI method (Computer-Assisted Web Interview) on a sample of 11 respondents representing various organizational levels. A stratified sampling procedure was applied, considering the employment structure within the enterprise.

The survey questionnaire consisted of 16 questions grouped into the following thematic areas:

1. Perception of digital transformation processes in the enterprise.
2. Assessment of the impact of digitalization on work efficiency and job satisfaction.
3. Identification of barriers and challenges associated with the implementation of digital solutions.
4. Evaluation of employees' digital competencies and training needs.

In constructing the questionnaire, both closed-ended questions (Likert scales, ordinal scales) and open-ended questions were used, which made it possible to obtain in-depth qualitative information.

For research purposes, a set of quantifiable variables was developed to characterize the situational and organizational conditions determining the effectiveness of IT system implementation. The study focused particularly on the identification of business processes that form the basis for IT integration and automation. During the research procedure, the actual determinants affecting successful IT implementation were distinguished from potential factors by examining how process identification shaped system adoption outcomes.

The determinants of effective IT systems adoption were identified based on questionnaire responses from companies associated with the Kielce Technology Park (as of the end of 2024). Respondents were allowed to select one or more predefined options or to provide descriptive

answers, which enabled a nuanced interpretation of organizational conditions shaping digital transformation outcomes.

Qualitative data obtained from open-ended questions in the CAWI survey were analysed using a thematic content analysis approach. The analysis followed an iterative procedure aimed at identifying recurring patterns, meanings, and explanatory categories related to IT system implementation and digital transformation outcomes.

In the first step, all open-ended responses were reviewed to achieve data familiarization. Subsequently, initial codes were assigned to text segments reflecting key issues raised by respondents, such as management involvement, strategic adaptation, process-related challenges, user readiness, and perceived benefits or barriers of IT implementation. Coding was conducted manually due to the limited volume of qualitative material, which enabled close interpretative engagement with the data.

In the next stage, the codes were grouped into higher-order thematic categories corresponding to the study's analytical framework and research hypotheses. Attention was paid to themes that complemented or explained quantitative findings, especially those related to strategic change during implementation and managerial support. Finally, the identified themes were interpreted in conjunction with quantitative results to provide contextual explanations for observed statistical relationships.

This qualitative analysis served a supporting and explanatory role, enhancing the interpretation of survey results rather than generating independent theory. The integration of qualitative insights with quantitative findings strengthened the internal validity of the study by enabling triangulation of data sources and perspectives.

3. Conditions for IT systems Implementation

Introducing IT system helps address several critical challenges facing modern enterprises:

- Lack of standardized methods for assessing process maturity and identifying risks affecting IT implementation and business performance.
- Limited tools for evaluating the consistency between real task execution and model-based workflow representations.
- Need for standardized, adaptable processes to simplify enterprise application requirements and reduce system complexity.
- The necessity for managerial guidance on implementing business process foundations that foster agility and reduce operating costs (Lech, 2007).

Implementing IT system is an investment requiring thorough planning from the outset. Key Performance Indicators (KPIs) should be selected based on a detailed analysis of business requirements before choosing a consultant. The appropriate KPIs depend on factors such as:

- company size,
- industry sector,
- short-term business strategy,
- current operational challenges (Kisielnicki, Sroka, 2001).

The evaluation theory used is the Information Systems (IS) Success Model developed by William H. DeLone and Ephraim R. McLean. The IS Success Model consists of several variables: Systems Quality, Information Quality, Service Quality, User Satisfaction, System use and Intention to use, and Net Benefits. These variables are interrelated and have a dependence on measuring the success of information systems. The working model IS Success framework has been considered the most influential model for assessing information. There are other models such as the Technology Acceptance Model (TAM), Diffusion of Innovation Theory (DOI), Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), Model of PC Utilization (MPCU), Unified Theory of Acceptance and Use of Technology (UTAUT).

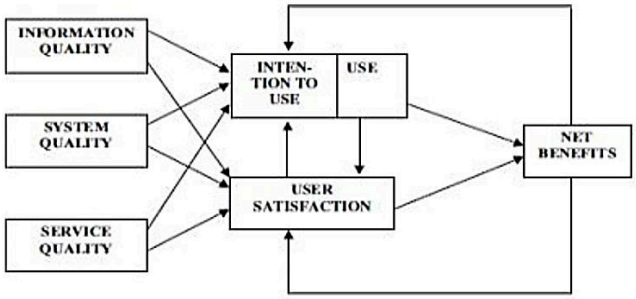


Figure 1. Information Systems (IS) Success Model.

Source: William, Tjhin, 2021, p. 2.

The success variable measured using the IS Success Model:

- System Quality. The system quality variable is a desired characteristic of an IS. System quality variables focus on aspects of usability, ease of use, system flexibility, system reliability, and ease of learning, as well as intuitiveness, sophistication, flexibility, and system response time.
- Information Quality. The information quality variable is the desired output characteristic in IS. Information that the system can generate is relevant, easy to understand, accurate, concise, complete, fast, and usable.
- Service Quality. The service quality success variable represents the quality of support users receive from the IS department and IT support personnel. For example, training, helpdesk, and so on.
- System use and intention to use. The success variable of intention to use IS represents its users' use the degree and way IS. Measuring IS use is a broad concept that can be considered from several perspectives. In that case, using IS voluntarily and the actual use of an IS an appropriate measure of success.

- User satisfaction. The success variable of user satisfaction is the level of user satisfaction when using IS. The user satisfaction variable is considered as one of the most important variables for IS success.
- Net benefits. The success variable of net benefits is the extent to which IS contributes to the success of individuals, groups, organizations, or various stakeholders. This variable summarizes the separate dimensions of individual impact, and organizational impact and additional IS impact measures from other researchers such as workgroup impact and social impact into a single success dimension. The choice of what impact to measure depends on the system being evaluated, the study's objectives, and the level of analysis.

4. Research Results

Primary data were collected at the end of 2024 from enterprises within the Kielce Technology Park. The target group comprised individuals responsible for IT system implementation—project managers, IT heads, or other designated staff. Using random sampling, responses were obtained from 11 companies.

The applied random selection method resulted in responses from 11 entities. This result raises concerns about the representativeness of the research. This error resulted both from the limited size of the surveyed population and from the reluctant cooperation of a large group of surveyed companies.

Due to the limitations resulting from the adopted sampling method, it was not possible to apply the subjective estimation and extrapolation method. Among the available secondary sources, there were no data useful to analyze the issues constituting the essence of the described research, those related to the corporate strategy.

The small sample size and limited cooperation among firms raised concerns about representativeness. Consequently, subjective estimation and extrapolation methods could not be applied, and relevant secondary data were unavailable. Given these limitations, the study was classified as exploratory research, aiming primarily to identify issues. The initial hypotheses proposed that:

- IT system implementation depends on the company’s strategy.
- The level of IT systems utilization perceived by management is generally unsatisfactory.

Table 1.
Relationship between Management Commitment and Satisfaction with Process Management

Satisfaction level	Management Commitment: Yes	Management Commitment: No
1	0	3
2	0	1
3	0	2
4	1	0
5	4	0
Average	4.1	2.5
Standard deviation	0.6	1.4

Source: Own study based on research.

The relationship between management involvement and the level of satisfaction with the IT system implementation was verified using the Mann–Whitney U test. The analysis revealed that organizations where management actively participated in the IT project reported significantly higher satisfaction levels ($p < 0.01$). The calculated U statistic amounted to 12.5, confirming a strong relationship between managerial engagement and perceived project success.

Table 2 illustrates the relationship between the existence of a formal process management strategy and satisfaction with IT system implementation outcomes. The analysis was based on qualitative indicators rather than quantitative performance measures (e.g., ROI). Results indicate no statistically significant difference in satisfaction between companies that had a written IT strategy and those that did not.

However, organizations that adapted or modified their overall business strategy during IT implementation demonstrated a noticeable increase in satisfaction with achieved results. This finding highlights the importance of strategic flexibility—especially since structural or procedural changes often disturb existing power relations and may trigger competency conflicts within the organization.

Table 2.
Strategic factors and satisfaction level with IT system project implementation

Factor	Written IT Strategy		Changes in Company Strategy Resulting from IT Implementation	
	Yes	No	Yes	No
Satisfaction with implementation	2.9	2.7	3.5	2.4
Satisfaction with achieved objectives	3.4	2.4	4.2	2.5

Source: Own study based on research.

To assess the statistical significance of the obtained results, a Student's t-test for the difference between two means was conducted. The analysis assumed 7 degrees of freedom and a significance level of $\alpha = 0.05$. The results are summarized in Table 3.

Table 3.
Significance of mean differences

Satisfaction Dimension	Assumption	Factor	Group	Mean Score	t Statistic	Critical Value
Satisfaction with implementation	Equal variance	Written strategy	Yes	2.9	0.364	2.3646
			No	2.7		
		Changes to strategy	Yes	3.5	1.350	2.3646
			No	2.4		
	Unequal variance	Written strategy	Yes	2.9	0.345	2.3646
			No	2.7		
		Changes to strategy	Yes	3.5	1.354	2.3646
			No	2.4		
Satisfaction with achieved objectives	Equal variance	Written strategy	Yes	3.4	2.001	2.3646
			No	2.4		
		Changes to strategy	Yes	4.2	2.930	2.3646
			No	2.5		
	Unequal variance	Written strategy	Yes	3.4	1.922	2.3646
			No	2.4		
		Changes to strategy	Yes	4.2	4.129	2.3646
			No	2.5		

Source: Own study based on research.

The empirical results of the study allow for the formulation of specific managerial recommendations that go beyond general statements and are directly grounded in observed patterns. In particular, the confirmed relationships between management involvement, strategic adaptability, and satisfaction with IT implementation outcomes, combined with the identified perception–behaviour gap, indicate that digital transformation requires targeted, behaviour-sensitive managerial interventions.

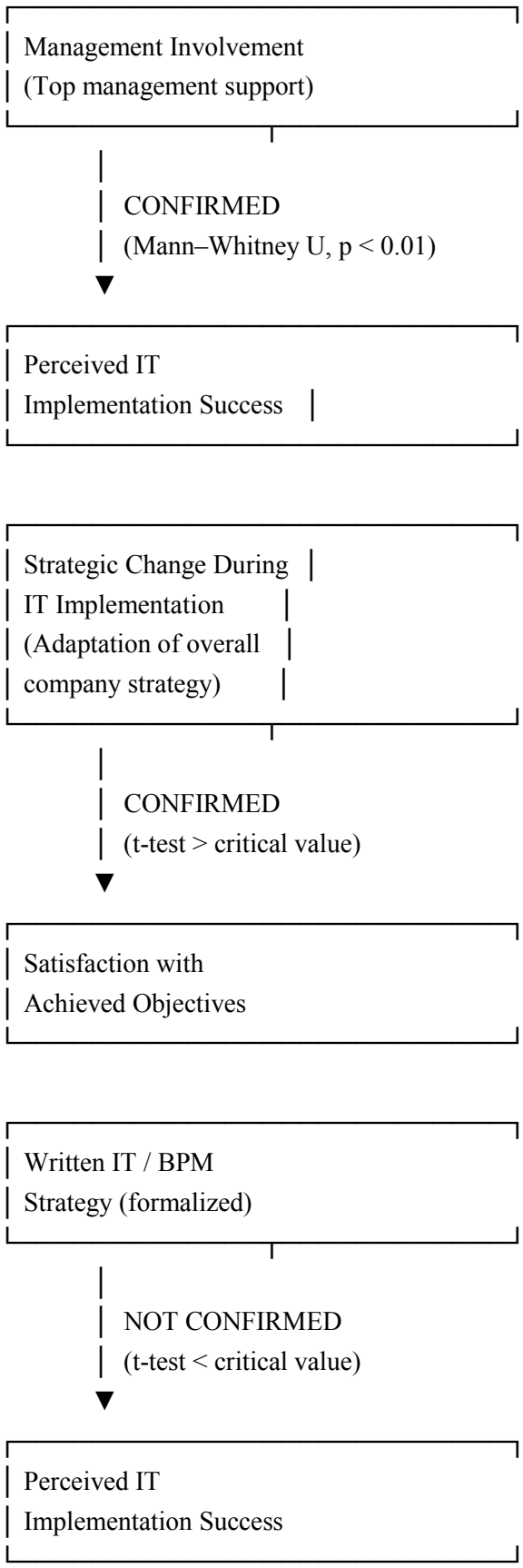


Figure 1. Conceptual model.

Source: own preparation.

First, the strong relationship between management involvement and satisfaction with IT implementation outcomes suggests that organizations should institutionalize visible leadership engagement throughout the implementation lifecycle. This may include assigning executive sponsors with clearly defined accountability for IT projects, introducing regular management reviews focused not only on technical milestones but also on user behaviour and process compliance, and communicating explicitly how IT systems support strategic objectives. Such practices can reduce the discrepancy between declared satisfaction and actual system use by reinforcing the importance of disciplined behaviour.

Second, the finding that strategic change during implementation, rather than the mere existence of a written IT strategy, significantly improves satisfaction with achieved objectives implies that organizations should implement formal mechanisms for strategic recalibration. In practice, this can take the form of scheduled strategy checkpoints during IT implementation, where assumptions about processes, roles, and expected benefits are reassessed. These checkpoints should explicitly address behavioural indicators, such as the extent to which employees use advanced system functionalities or revert to informal workarounds.

Third, the observed perception–behaviour gap highlights the need for differentiated behavioural interventions rather than uniform training or communication programs. Empirical patterns suggest that satisfaction with IT systems may coexist with risky or inefficient practices, particularly in areas related to security monitoring, process compliance, and system exploitation. For example, targeted reminders and dashboards encouraging more frequent transaction monitoring and anomaly checking may be particularly effective among user groups that express high confidence but demonstrate lower behavioural vigilance. Conversely, reinforcing and formalizing the use of advanced security methods, such as multi-factor authentication or role-based access controls, among users already inclined toward cautious behaviour can help institutionalize good practices and prevent regression over time.

Fourth, process identification and formalization—although not statistically significant as a standalone factor—emerged as a necessary enabling condition for effective IT use. Managers should therefore link BPM initiatives more explicitly to everyday behaviour by embedding process controls directly into IT systems, reducing the scope for bypassing formal workflows. This may involve limiting manual overrides, integrating automated alerts for non-compliant actions, and aligning performance metrics with actual system use rather than declared adoption.

Finally, the study suggests that evaluating IT implementation success solely through satisfaction surveys is insufficient. Organizations should complement perceptual measures with behavioural and usage indicators, such as system log analysis, frequency of use of advanced functionalities, or compliance with security and process standards. This combined evaluation approach can help managers detect early warning signals of a perception–behaviour gap and intervene before it undermines the long-term benefits of digital transformation.

Overall, these recommendations emphasize that the applied value of digital transformation lies not only in technology deployment, but in actively shaping user behaviour through leadership, strategic adaptability, and targeted interventions. By aligning managerial actions with empirically observed patterns, organizations can increase the likelihood that IT implementation translates into sustained operational and strategic benefits.

Recommendation 1: Institutionalize visible top-management involvement throughout IT implementation. Table 1 shows a statistically significant difference in satisfaction levels between enterprises with active management involvement and those without (Mann-Whitney $U = 12.5$; $p < 0.01$). Organizations with managerial engagement reported markedly higher average satisfaction (4.1 vs. 2.5). Enterprises should appoint executive sponsors for IT projects, ensure regular leadership reviews of implementation progress, and communicate management accountability for system adoption. This recommendation directly follows from the confirmed relationship between management involvement and perceived IT success.

Recommendation 2: Treat IT implementation as a trigger for strategic adjustment rather than execution of a fixed plan. Tables 2 and 3 demonstrate that enterprises which introduced changes to their overall strategy during IT implementation achieved significantly higher satisfaction with accomplished objectives (mean 4.2 vs. 2.5; t-statistic exceeding the critical value at $\alpha = 0.05$). No such effect was observed for the mere existence of a written IT strategy. Organizations should introduce formal strategy review checkpoints during IT implementation, allowing goals, priorities, and processes to be revised in response to implementation experience. This recommendation is grounded in the empirically confirmed superiority of strategic adaptability over static strategic formalization.

Recommendation 3: Do not rely solely on written IT/BPM strategies as indicators of implementation success. Statistical tests showed no significant differences in satisfaction between enterprises with and without a written IT or BPM strategy. In both equal and unequal variance assumptions, t-values remained below the critical threshold. While written strategies remain useful as coordination tools, managers should avoid treating them as guarantees of success. Instead, strategic documents should be complemented by active governance, leadership involvement, and adaptive decision-making mechanisms.

Recommendation 4: Address the perception–behaviour gap through targeted behavioural interventions. Despite high declared satisfaction with IT systems, qualitative data revealed inconsistent behaviours, indicating a perception–behaviour gap. The strongest empirical drivers of satisfaction—management involvement and strategic change—suggest that behavioural alignment requires leadership-driven reinforcement. Targeting users who express high confidence but show limited vigilance (e.g., reminders for frequent transaction monitoring). Reinforcing advanced security practices among users already inclined toward cautious behaviour (e.g., consistent use of multi-factor authentication). Digital transformation programs should include differentiated behavioural nudges, monitoring tools, and reinforcement mechanisms rather than uniform training programs.

Recommendation 5: Integrate behavioural and usage indicators into IT success evaluation frameworks. The differentiation of satisfaction outcomes by organizational and situational determinants confirms that perceived success varies systematically across enterprises. Satisfaction alone does not fully capture implementation effectiveness. Managers should complement satisfaction surveys with behavioural metrics such as system usage logs, frequency of advanced feature use, and compliance with defined workflows. This approach aligns evaluation practices with empirically observed determinants of success.

Table 4.
Summary Mapping

Recommendation	Hypothesis	Table(s)	Status
Management involvement	H1	Table 1	✔ Confirmed
Strategic change during implementation	H1	Tables 2–3	✔ Confirmed
Written IT/BPM strategy alone	H2	Tables 2–3	✖ Not confirmed
Address perception–behaviour gap	H1, H3	Tables 1–3	✔ Supported
Behavioural metrics in evaluation	H3	Tables 1–3	✔ Supported

Source: Own study based on research.

5. Discussion

The primary contribution of this study lies in empirically demonstrating the significance of strategic change as a determinant of satisfaction with IT system implementation outcomes in enterprises undergoing digital transformation. While prior research has widely acknowledged the importance of IT alignment with business strategy, the present findings add nuance by showing that it is not the mere existence of a written IT or process management strategy that matters, but rather the organization's willingness to adapt and modify its overall strategic orientation during the implementation process. This distinction represents a novel contribution, particularly in the context of Polish enterprises, where empirical evidence on strategic flexibility in digital transformation remains limited. Previous studies have emphasized that digital transformation should be treated as a holistic organizational change rather than a purely technological upgrade (Pieriegud, 2016; Deloitte, 2021). The literature consistently points to strategy–IT alignment as a success factor in ERP and other integrated system implementations (Kisielnicki, Sroka, 2001; Lech, 2007). What was already known is that inadequate governance, weak managerial involvement, and insufficient process formalization often lead to implementation failures. However, existing studies frequently focus on formal strategic documents or predefined frameworks as indicators of maturity. In contrast, the present research suggests that adaptive strategic behaviour during implementation plays a more decisive role in shaping perceived success than static strategic formalization.

The results obtained in this study are partially consistent with earlier findings reported in the literature. Like prior research based on the Information Systems Success Model (DeLone, McLean), user satisfaction and perceived benefits were confirmed as central indicators of IT implementation success (William, Tjhin, 2021). Moreover, the strong relationship identified between management involvement and satisfaction with IT outcomes aligns with earlier observations that leadership commitment is a critical success factor in digital projects (Lech, 2007; PARP, 2022). At the same time, the lack of statistically significant differences between companies with and without a written IT strategy contrasts with some normative models that treat formal strategic documentation as a prerequisite for success. This discrepancy suggests that in dynamic digital environments, flexibility and responsiveness may outweigh formal planning.

A particularly important conclusion emerging from the analysis is that strategic change acts as a mediating mechanism between IT implementation and satisfaction with achieved objectives. Organizations that adjusted their overall strategy during implementation reported significantly higher satisfaction levels, even when other structural factors remained unchanged. This finding supports the view that digital transformation disrupts existing power relations, competencies, and workflows, requiring iterative strategic recalibration rather than rigid adherence to predefined plans. Such observations are consistent with broader studies on Industry 4.0 and digital innovation, which emphasize learning, experimentation, and organizational agility as key transformation capabilities (Deloitte, 2021; Polcom, 2025).

Regarding the formulated hypotheses, the empirical results provide partial but meaningful confirmation. Hypothesis H1 was supported, as enterprises introducing strategic changes in response to digital transformation reported significantly higher satisfaction with IT implementation outcomes. Hypothesis H2 received indirect support: although the existence of a written process or IT strategy alone did not differentiate satisfaction levels, process identification and managerial engagement were shown to be essential conditions enabling effective system adoption. Hypothesis H3 was also confirmed, as organizational and situational determinants—particularly management commitment and strategic adaptability—clearly differentiated perceived implementation success.

Despite these contributions, the study has limitations that should be acknowledged. The small sample size and exploratory nature of the research restrict the generalizability of the findings. The focus on enterprises associated with the Kielce Technology Park further narrows the empirical scope, although it provides valuable insight into a specific innovation-oriented ecosystem. Consequently, the results should be interpreted as indicative rather than conclusive. Nevertheless, exploratory studies play an important role in identifying patterns and generating hypotheses for further investigation (Churchill, 2002).

Future research should aim to validate these findings using larger and more diverse samples, enabling the application of advanced statistical techniques and cross-sectoral comparisons. Longitudinal studies would be particularly valuable in examining how strategic adjustments

evolve throughout different stages of IT implementation and how they affect long-term organizational performance. Additionally, integrating objective performance indicators, such as productivity gains or cost reductions, with perceptual measures of satisfaction would strengthen the explanatory power of future analyses.

6. Conclusion

The results of the survey conducted among enterprises operating within the Kielce Technology Park (n = 11) indicate that managerial and strategic factors differentiate satisfaction with IT implementation outcomes. Two empirical patterns are particularly clear. First, the Mann–Whitney U test confirmed that organizations with active management involvement in the IT project reported significantly higher satisfaction levels than those without such involvement ($p < 0.01$). Second—and most importantly—the Student's t-test demonstrated a statistically significant difference in satisfaction with achieved objectives between enterprises that introduced changes to their overall strategy because of IT implementation and those that did not (t values exceeding the critical threshold under both equal and unequal variance assumptions). In contrast, the existence of a written IT strategy did not yield statistically significant differences in satisfaction, suggesting that formal documentation alone is not sufficient to increase perceived implementation success.

These findings provide new knowledge by indicating that what drives positive evaluations of IT implementation is not only alignment with a pre-existing plan, but also the organization's capacity to adapt strategy during implementation, i.e., to reconfigure priorities, governance, and operating logic in response to implementation challenges. This result extends earlier observations that digital transformation is a comprehensive organizational change rather than a technological upgrade (Pieriegud, 2016) and is consistent with evidence that successful digitalization requires leadership commitment and adaptive capabilities (Deloitte, 2021; PARP, 2022). The lesson learned from the study is that strategic flexibility should be treated as a success factor: IT implementation disrupts processes, roles, and power structures, and therefore organizations that modify strategy during implementation may be better positioned to absorb those disruptions and translate technology into perceived benefits.

From a theoretical perspective, the results support approaches to IT success that emphasize user satisfaction and perceived benefits as meaningful outcome variables (William, Tjhin, 2021) and suggest that "strategy" should be conceptualized not only as a static document, but as an adaptive mechanism interacting with implementation dynamics. From a practical perspective, the results imply that managers should prioritize: (1) visible top-management engagement and accountability structures; (2) process identification as the foundation for integration and automation; and (3) structured strategic review points during implementation,

where business goals and operating assumptions are adjusted rather than treated as fixed. Such an approach can reduce the risk of implementation failure and increase satisfaction with achieved objectives, which is particularly important in the Polish context where enterprises face strong cost pressure and rising demands for digital competitiveness (Deloitte, 2021; Polcom, 2025, Kowalewski, Weresa, 2020).

One of the clearest empirical findings emerging from the presented data is the existence of a perception–behaviour gap in the context of IT system implementation and digital transformation. While managers generally expressed high levels of satisfaction with implemented IT solutions and perceived their organizations as digitally mature and well prepared, qualitative responses and selected survey indicators revealed inconsistencies between these positive perceptions and actual organizational practices.

This gap is particularly visible in areas related to process discipline, user behaviour, and everyday system use. Respondents frequently declared confidence in the effectiveness, security, and usability of implemented systems, yet simultaneously reported behaviours and practices that contradict these assessments, such as incomplete process formalization, ad hoc workarounds, limited exploitation of system functionalities, or reliance on informal routines outside the system. These findings suggest that subjective satisfaction and declared readiness do not necessarily translate into consistent, system-aligned behaviour at the operational level.

The observed perception–behaviour gap can be interpreted through the lens of the Information Systems Success Model, which distinguishes between user satisfaction, system use, and net benefits (DeLone, McLean, 2003). The results indicate that high satisfaction does not automatically imply intensive or correct system use, nor does it guarantee the realization of full organizational benefits. This divergence is consistent with prior research showing that users may report positive attitudes toward IT systems while continuing to apply familiar practices that limit the transformative potential of digital solutions (Petter et al., 2008; Vial, 2019).

From a managerial perspective, the presence of this gap highlights the risk of overestimating digital maturity based solely on declarative indicators. Organizations may prematurely conclude that digital transformation objectives have been achieved, while underlying behavioural patterns remain unchanged. This finding reinforces the importance of combining perceptual measures with behavioural and process-oriented indicators when evaluating IT implementation outcomes. It also underscores the need for ongoing training, monitoring, and reinforcement mechanisms that align everyday practices with strategic and technological intentions.

In theoretical terms, the perception–behaviour gap supports arguments that digital transformation is a continuous learning process rather than a one-time implementation event. The gap further explains why strategic change and managerial involvement—both empirically confirmed in this study—are critical for sustaining behavioural alignment over time. Without active leadership and adaptive governance, positive perceptions of IT systems may

coexist with practices that undermine their effective use and limit the realization of expected benefits.

At the same time, the study's limitations—particularly the small sample size and reliance on perceptual indicators—mean that conclusions should be interpreted as exploratory. Nevertheless, the identified patterns are sufficiently consistent to justify further research. Future studies should verify the observed relationships on larger samples, incorporate objective performance indicators, and test whether strategic adaptability remains significant when controlling for sectoral and organizational differences. In this way, the findings of the present study can be further used to build evidence-based models of digital transformation success factors in Polish enterprises and to develop managerial guidance supporting more effective and sustainable IT implementation.

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THE RELATIONSHIP BETWEEN ESG SCORES, RISK, AND BANK PERFORMANCE: A NARRATIVE LITERATURE REVIEW

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Purpose: The aim of this article is to identify and assess the relationship between a bank's ESG score and its risk and performance.
Design/methodology/approach: The study utilized a narrative literature review. Articles were searched in the Web of Science database.
Findings: Most of the reviewed studies show that engaging with ESG issues in the banking sector not only helps mitigate negative environmental and social impacts but also positively influences banks' risk-taking behavior. The relationship between ESG scores and bank performance is ambiguous.
Research limitations/implications: Articles used in the review were obtained from only one database.
Practical implications: The results of this study may have significant implications for banks and regulators. For banks, understanding the relationship between ESG scores, risk, and performance can be useful in further improving their ESG strategies, non-financial reporting processes, monitoring ESG risk exposure, and promoting sustainability initiatives. For regulators, evidence that ESG scores are crucial to the business success of financial institutions can provide a basis for developing regulations that will facilitate banks' implementation of sustainable practices and transparent ESG reporting.
Originality/value: The review synthesized existing research, identified existing research gaps, and suggested directions for further research. This article is intended for ESG researchers, banks, investors, and regulators.
Keywords: ESG, banks, bank performance, bank risk, narrative literature review.
Category of the paper: Literature review.

1. Introduction

The rationale for selecting the topic of this study is the special role assigned to banks in supporting sustainable development. Banks are themselves the subject of investment and simultaneously determine the allocation of resources in the economy by selecting investments, entities, and activities that merit financing (Beck et al., 2010). If they choose to finance the green transformation (Kalfaoglou, Faidon, 2021), they can significantly contribute to solving

environmental and social problems, increasing social well-being (Olteanu (Burcă) et al., 2023), and building a more sustainable and inclusive global economy. Government enforcement through regulatory bodies is driving banks to prioritize ESG (Environmental, Social, and Governance) as a value driving performance improvement (Nathania, Ekawati, 2024; Guo et al., 2025; Boudawara et al., 2023). Customer and investor pressure on financial institutions is also growing. Today's customers expect banks to take action to mitigate and adapt to climate change, protect ecosystems, and transition to a circular economy (Birindelli et al., 2022; Yu et al., 2022). Investors apply ESG criteria when selecting their investment portfolios. They are more likely to engage with banks that implement corporate social responsibility (CSR) policies that promote improved management transparency and build social awareness. Self-regulation also plays a significant role in promoting ESG in the banking sector. They are perceived as a credible signal of responsible banking practices (Manos et al., 2024).

Banks' activities in the area of environmental, social, and corporate governance are often associated with the ability to reduce systemic risk, improve financial performance, financial stability, create shareholder value, and generate reputational benefits. A key question is whether, how, and why bank sustainability translates into the benefits listed above.

This article provides an overview of existing research on the relationship between banks' ESG activities and risk and performance. The research question is formulated as follows: What is the relationship between ESG scores and bank risk and performance? To address this issue, a narrative review approach was employed. The review synthesized existing research, identified existing research gaps, and identified directions for further research.

2. Theoretical Background

Banks' interest in ESG issues is underpinned by legal regulations and the benefits that implementing sustainable development principles can bring. A noticeable increase in banks' interest in sustainable development occurred following the establishment of the Sustainable Development Goals (Agenda 2030) in 2015 and the signing of the Paris Climate Agreement (UN, 2015) by international financial organizations, states, and central banks that same year. Institutions such as the European Commission (EC), the European Parliament (EP), the European Banking Authority (EBA), and the European Central Bank (ECB) are involved in the legislative process shaping sustainable finance in the European Union. In March 2018, the European Commission adopted the Sustainable Finance Action Plan (European Commission, 2018). The plan outlines a comprehensive strategy aimed at linking finance with sustainable development. The implementation of sustainable development principles in banking operations in European Union countries is stimulated by regulations such as the 2019 Regulation on Sustainability-Related Disclosures in the Financial Services Sector (SFDR

Regulation (EU) 2019/2088), the 2019 European Green Deal, the EU Taxonomy (Regulation (EU) 2020/852), the Corporate Sustainability Reporting Directive and its complementary ESRS standards (CSRD Directive - (EU) 2022/2464), and the CSDDD Directive of 4 May 2024 on Corporate Due Diligence for Sustainable Development, which requires companies to counteract the negative impacts of their activities on the environment, human rights, workers' rights, and social rights (EC/2022/0071).

Initially, research on sustainable development in the banking sector focused on social responsibility. It primarily analyzed the correlation between banks' financial performance and the integration of social responsibility principles into management processes and systems. These studies have led to divergent conclusions. Simpsons and Kohers (2002) found a strong positive correlation between the introduction of social responsibility practices and banks' financial performance. However, Esteban-Sánchez et al.'s (2017) study, conducted between 2005 and 2010 on a sample of 154 banks from 22 countries that had implemented social responsibility principles, found no positive relationship between the adoption of these principles and banks' financial performance. Over time, researchers have broadened their scope of research to encompass all three pillars of ESG, i.e., environmental (e.g., environmental impact, resource consumption, biodiversity impact, and waste management), social (e.g., community and supplier impact, working conditions, and other social impacts), and corporate governance (e.g., organizational transparency, relationships with shareholders and management, executive compensation, and board diversity) (Clément et al., 2022).

The relationship between board diversity and ESG performance has been raised in the work of many researchers. It turns out that board size, the ratio of women and the ratio of independent directors on the board are positively and significantly associated with environmental and social governance performance (Gurol, Lagasio, 2023). There is a positive relationship between cultural and gender diversity of boards and ESG performance, but their combined effect is negative (Paolone et al., 2024). The positive impact of women on boards on ESG performance appears only when there are at least three women on the board. The social pillar of ESG is particularly sensitive to the proportion of women on the board (Menicucci, Paolucci, 2023, 2024). Studies show that board size and independence and the existence of a CSR/sustainability committee positively influence banks' ESG performance, while there is no significant relationship between the average age of board members and ESG performance. Other studies (Remo-Diez et al., 2025) analyzed the combined effect of board member characteristics (specific skills, seniority, gender diversity and (connections) and the CEO's power (formal and informal) to achieve a high ESG score. It has been noted that regardless of the CEO's formal power, banks need an informally influential CEO or board members with important advisory competencies to support managers in decision-making.

Soana (2011), Matuszak and Różańska (2017) found no significant relationship between ESG and bank financial performance at the country level. However, Wu and Shen (2013), who examined the relationship for 162 banks in 22 countries, Cornett, Erhemjamts, and Tehranian (2016), who studied American banks, and Akdogan, Selimoglu, and Turkcan (2020) for Turkey, found a positive relationship. Miralles-Quirós et al. (2019) found a positive correlation between banks' Tobin's Q index and the adoption of ESG principles. At the same time, they found a negative correlation between the adoption of these principles. principles and creating shareholder value.

The ambiguity described above between the integration of ESG issues into banks' operational practices and their performance prompted a narrative literature review.

3. Methodological Approach and Results

The narrative review method was used in the literature search. Narrative reviews, also known as non-systematic narrative reviews (Oxman et al., 1994), are comprehensive narrative syntheses of previously published information. This type of literature review presents the author's research findings in a condensed form, typically summarizing the content of each article. Some researchers (Helewa, Walker, 2000) suggest that a proper narrative review should include a critical assessment of each included study. However, Day (1998), DePoy and Gitlin (1993) argue that this is not necessary.

Narrative review is a flexible and widely used method of knowledge synthesis that allows for the interpretation and critical analysis of existing research in a given field, taking into account the historical and organizational context (Sukhera, 2022a; Ahmad, 2025; Sukhera, 2022b; Greenhalgh et al., 2018). Unlike systematic reviews, there are no universally accepted guidelines for conducting a narrative review. However, it is recommended to clearly define the purpose, scope, search strategy, and rationale for literature selection (Ferrari, 2015; Green et al., 2006; Baethge et al., 2019). An example procedure is presented in Figure 1.

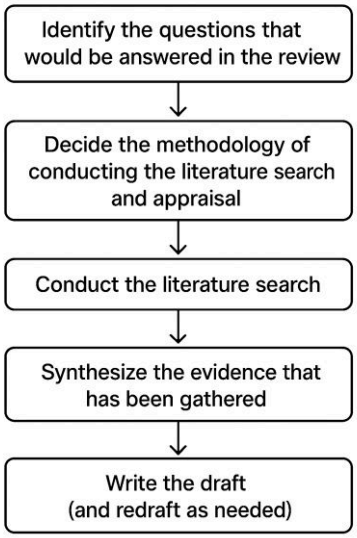


Figure 1. Steps of writing a narrative review.

Source: (Siddharth, Gayatri, 2021).

The purpose of the review conducted for this study was to identify and assess the relationship between ESG scores and banks' risk and performance. The following research questions were formulated:

Q1: What is the relationship between a bank's ESG score and risk?

Q2: What is the relationship between a bank's ESG score and operational, financial, and market performance?

The Web of Science research database was selected for the study. The search was conducted based on the following keywords: "ESG AND financial performance" AND banks, "ESG disclosure" AND "banking sector", "sustainable finance" AND "bank performance", "ESG rating" AND profitability, "non-financial performance" AND banks, and "CSR in banking" AND performance.

The search was limited to peer-reviewed scientific publications resulting from empirical research (quantitative and qualitative) published in English between 2016 and the first half of 2025. The document types analyzed were: Article, Review Article, and Proceeding Paper. The search was based on papers from fields such as Business Finance, Environmental Studies, Business, Management, and Economics. Exclusion criteria included articles not related to the banking sector, non-empirical works (e.g., essays, commentaries without data), and articles without an explicit description of the relationship between ESG and bank risk and/or performance. The search yielded 89 papers.

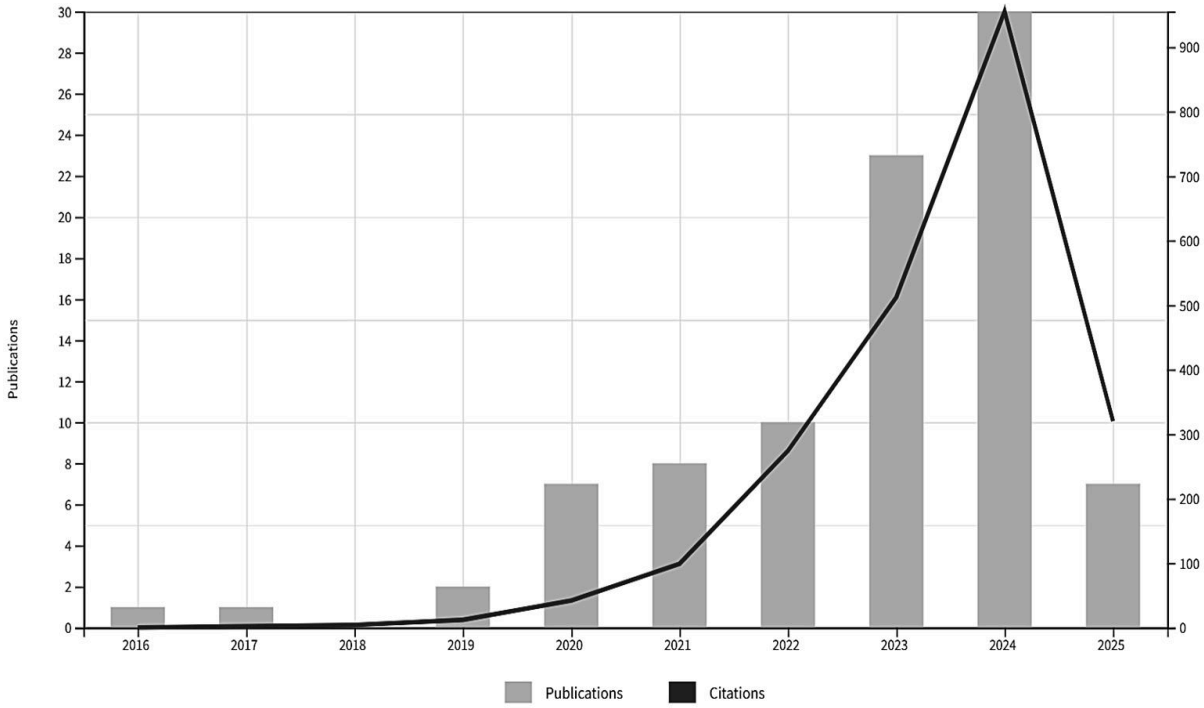


Figure 2. Number of publications and citations on ESG and bank risk and/or performance, 2016–H1 2025.

Source: own study.

Figure 2 shows the number of publications and their citations in the analyzed years. The majority of the generated documents were published in 2024 (30 articles) and 2023 (23 articles). After a detailed analysis of abstracts and the removal of irrelevant items, 40 publications were accepted for final analysis.

Based on a preliminary content analysis of the 40 publications, the publications were classified into two main research streams: bank ESG score and risk, and bank ESG score and its performance (operational, financial, market).

3.1. Bank ESG Score and Risk

The majority of the analyzed articles indicate a positive relationship between banks' ESG scores and the risks they take. Banks with higher ESG scores are perceived by the market as less risky, therefore, it can be concluded that ESG factors mitigate risk. Studies (Horobet et al., 2025; Manta et al., 2025; Porzio, Battaglia, 2024). There is a correlation between a country's cultural characteristics and the ESG risk assessment of banks registered in that jurisdiction, as well as between ESG risk and credit risk. Niedziółka et al.'s (2023) study of 330 banks from 50 countries found that the region with the highest ESG risk attributed to banks was Arab countries, while the regions with the lowest ESG risk were Western European and Nordic countries. ESG risk is linked to the credit risk reflected in an external credit rating, as evidenced by the fact that a one-unit improvement in a credit rating reduces the chance of a bank being classified as high or medium ESG risk by approximately 25% compared to being classified as low ESG risk. Aevoae et al. (2023), using a dynamic panel model (the sample consisted

of 367 public banks from 47 countries from 2007 to 2020), demonstrated the positive impact of the combined ESG score and the corporate governance pillar on reducing overall systemic risk. Gangwani and Kashiramka (2024) reached similar conclusions by examining 178 commercial banks listed on stock exchanges in 20 of the largest emerging market (EME) economies from 2015 to 2021. They found that higher ESG scores were associated with lower default risk, leverage, and liquidity.

The impact of the ESG pillar scores on banks' risk profiles varies across bank types (Palmieri et al., 2024). Research on a sample of 639 EU banks from 2013 to 2022 shows that commercial banks can reduce the risk of insolvency by improving their performance in the environmental pillar, while investment banks can reduce their performance in the area of corporate governance. Basar et al.'s (2025) research, conducted on a sample of 117 banks from 29 less developed countries from 2015 to 2022, indicates a bidirectional relationship between ESG and the Z-score risk indicator. This applies to both private and state-owned banks. Banks with fewer ESG controversies take less risk (Galletta, Mazzù, 2022). This suggests the need to integrate social, corporate governance, and environmental risks into banks' risk management.

Banks' ESG activities influence lending during financial crises. Analyzing the ESG ratings of European banks from 2002 to 2020, Danisman and Tarazi (2022) found that banks with higher ESG commitments reduce lending less during crises than banks with lower ESG commitments. Their study showed that during crises, banks with high ESG ratings are less exposed to credit risk, asset value risk, and profitability risk. Some studies do not support a clearly positive relationship between ESG performance, banks' social responsibility, and risk taking. Hojer and Mataigne (2024) examined the impact of ESG performance on European banks' risk appetite using panel data from 2005 to 2022. They observed an inverted U-shaped relationship between ESG and risk and a direct negative effect of CSR on risk density. Korzeb et al.'s (2025) research indicates a positive impact of ESG activities on bank insolvency risk; however, this relationship shifts to a negative one depending on the specific pillars of the bank's sustainability policy. Banks facing ESG controversies are exposed to increased risk, and corporate governance plays a key role in moderating these effects. Strong corporate governance structures, characterized by board diversity and independence, mitigate the financial risks associated with ESG controversies, while weak governance amplifies these risks (Del Sarto, 2025).

Di Tommaso and Thornton (2020), analyzing the impact of European banks' environmental, social, and governance indicators on their risk appetite and market value, found that high ESG ratings are associated with a moderate decrease in risk appetite, and their impact depends on board characteristics. These results are consistent with the stakeholder theory of ESG activities. High ESG ratings are also associated with a decline in bank value, consistent with the ESG overinvestment theory, which posits that limited resources are drawn away from investments. This decline in bank value occurs despite the positive indirect effect of ESG scores

on bank value through their impact on risk levels. Therefore, there is a trade-off between reducing banks' risk appetite and financial system stability on the one hand, and bank value on the other. Trinh et al. (2023), using a sample of 244 banks listed on 52 stock markets, examined the impact of corporate social responsibility on bank risk exposure during stable and turbulent times. Their study found no significant evidence that CSR intensity protects banks from extreme risk ex ante or during the global financial crisis of 2007-2009. However, investors appear to be more tolerant and lenient towards banks with stronger CSR after an economic recession, reducing the likelihood of extreme stock devaluation. Researchers have observed that banks with higher social capital and trust resulting from conducting socially responsible activities experienced lower idiosyncratic and systemic extreme risks during the COVID-19 pandemic in 2020.

To meet the increasing number of regulations, both hard and soft, banks must incorporate ESG factors into their compliance processes. Implementing ESG practices can reduce the risk of non-compliance[1] through its impact on reputation. A study by Mure et al. (2021) shows that ESG scores and the likelihood of sanctions are positively correlated. This relationship is statistically significant. Receiving financial penalties damages banks' reputations and forces them to improve their image by adopting ESG practices. According to the researchers, integrating ESG criteria is important not only for sustainable development but also for correcting unfair practices.

3.2. ESG Score and Bank Performance (Operational, Financial, Market)

Many studies indicate that pro-environmental, pro-social, and governance activities not only benefit the planet but can also positively impact banks' financial performance (Prorokowski, 2016; Porzio, Battaglia, 2024; Brogi, Lagasio, 2019; Afzal et al., 2024; Gangwani, Kashiramka, 2024), build reputation, and strengthen competitive advantage (Sain, Kashiramka, 2024). In particular, implementing a cybersecurity policy, as an element of corporate governance, improves banks' financial stability and compliance, thus increasing the bank's operational resilience (Bruno et al., 2024). ESG factors play a key role in banking performance, even in a period of rising interest rates (Sun et al., 2024). An analysis of the impact of ESG on the financial performance of Islamic banks in the GCC[2] countries from 2010 to 2021 showed that the social component of ESG positively affects performance indicators, the governance pillar affects ROE, and the environmental factor correlates positively with Tobin’s Q (Alghafes et al., 2024). Nathania and Ekawati (2024) reached similar conclusions when examining the impact of ESG performance on bank performance in five countries of the Association of Southeast Asian Nations (ASEAN): Indonesia, Malaysia, Singapore, Thailand, and the Philippines. Their study showed that ESG performance has a significant positive impact on banks’ financial performance, measured by return on assets (ROA), return on equity (ROE), and price-to-book value (PBV). The positive impact of ESG performance on bank performance is stronger for state-owned banks than for private banks. Shaddady and Alnori (2024), analyzing

the impact of Saudi banks' ESG policies on their performance, demonstrated that ESG activities play a significant role in increasing bank efficiency. Banks' ESG policies have sustained their performance during the decline in oil prices and the COVID-19 pandemic.

Effective corporate governance of financial institutions is crucial for the stability of the financial system and the prevention of financial crises. According to the study by Komath et al. (2023) (a sample of 242 banks from 43 countries) found a positive and statistically significant relationship between CSR strategy performance and bank market value, as well as between governance performance and bank market value. Furthermore, there was a statistically significant relationship between corporate governance controversy performance and bank market value.

Tasnia et al. (2021) examined CSR on the stock price volatility of 37 US banks from 2013 to 2017. The researchers found a significant and positive relationship between CSR and stock price volatility. Shareholders of US banks do not accept an excessive focus on CSR due to the additional investment costs associated with CSR implementation. Sustainable practices contribute not only to the growth of tangible assets and profitability but also to intangible assets (Lapinskaitė et al., 2025).

ESG practices positively impact the stability of financial institutions. Chiaramonte et al. (2021), analyzing the performance of European banks operating in 21 countries between 2005 and 2017, found that the overall ESG assessment, including its three pillars, reduces bank fragility. Tutar et al. (2025) reached similar conclusions when analyzing the relationship between the financial stability of banks in Turkey, assessed using the CAMELS framework, and ESG scores. The results indicate a statistically significant relationship between CAMELS indicators and ESG scores. Banks with higher CAMELS[3] scores achieved better ESG scores, although this relationship was not linear. Comparative studies of "conventional" and Islamic banks showed that the environmental pillar is particularly important in conventional banking, while in Islamic banking, stability is positively correlated with the social pillar (Sendi et al., 2024).

ESG practices appear to influence the costs of debt financing in the banking sector. Agnese and Giacomini (2023), using a dataset of 19,106 fixed-rate senior bonds issued by 63 EU banks between 2006 and 2021, found that the cost of issuance was lower for banks with higher ESG ratings. These results were not due to the issuer's environmental credentials, but rather to high corporate governance standards and ESG reporting and transparency practices.

Some studies indicate an ambiguous relationship between ESG and bank performance. La Torre et al. (2021), using data from European banks listed in the STOXX Europe 600 between 2008 and 2019, examined the relationship between environmental, social, and governance (ESGP) performance and corporate financial performance (CFP). They considered various dimensions of financial performance – both accounting-based (ROA and ROE) and market-based (capitalization to book value, Tobin's Q). The results of his

study show a positive and statistically significant relationship between ESGP and VBM (Value-Based Metrics) represented by EVA Spread, and no relationship with accounting-based performance. Surprisingly, the study found a negative and very weak relationship between both dependent variables chosen to represent a bank's market performance and ESGP. According to the study's authors, the main factor "forcing" banks to adopt a sustainable business model is the actions of banking supervisors.

El Khoury et al. (2021) analyzed the impact of ESG on bank performance in the Middle East, North Africa, and Turkey (MENAT) region. Their sample included 46 publicly listed banks from 2007 to 2019. Their results indicate a nonlinear relationship between ESG and bank financial performance, with ESG investments yielding benefits up to a certain inflection point. The governance pillar exhibits a concave relationship with accounting performance, while the environmental pillar exhibits a convex relationship with market returns. Hojer and Mataigne's (2024) study of European banks covering the period 2005-2022 confirmed a U-shaped relationship between ESG and financial performance. No relationship was found between CSR initiatives and the financial performance of European banks. Furthermore, research (Jaiwani, Gopalkrishnan, 2025) conducted among Indian banks revealed that the impact of ESG on financial performance varies depending on ownership structure. In private banks, the impact of ESG on financial performance is negative but positively impacts efficiency, while in state-owned banks, environmental performance is positively correlated with return on equity and asset quality. The ambiguous impact of ESG performance on bank performance is also indicated by Bui et al. (2024). Their study aimed to assess the impact of ESG on the financial performance of 24 Vietnamese commercial banks in terms of return on assets (ROA), return on equity (ROE), and net interest margin (NIM). The study showed a positive impact of ESG policies and individual environmental (E) and corporate governance (G) disclosures on banks' financial performance. In particular, E and G have the greatest impact on ROE. However, no statistically significant relationship between social disclosure and financial performance was found. Horobet et al. (2025) obtained different results. Analyzing data from 61 European banks, they found that better environmental and social performance leads to higher ROE, while higher governance scores reduce ROE.

The aim of Halim et al. (2024) study was to examine whether sustainability reporting leads to better performance and creates value for investors in emerging markets. Analyzing data from 32 banks in Bangladesh, the authors concluded that environmental, social, and governance indicators reduce both bank profitability and value. Their study also revealed a lack of correlation between environmental and corporate governance disclosures and bank performance (ROE).

The empirical findings of Buallay et al. (2020) indicate a significant positive impact of ESG on performance and economic benefits for shareholders. However, the relationship between ESG disclosures varies across entities. The authors find that social performance plays a negative role in determining bank profitability and value. Furthermore, the authors provide evidence supporting the influence of bank- and country-specific factors on bank performance.

4. Conclusions

The aim of the review conducted for this study was to identify and assess the relationship between ESG performance and bank risk and performance. The following research questions were sought:

Q1: What is the relationship between a bank's ESG performance and risk?

Q2: What is the relationship between a bank's ESG performance and operational, financial, and market performance?

The review shows that existing research on banks' engagement in ESG activities and the relationship between ESG performance and risk and performance is fragmented, based on various methods and indicators. Typically, it is unidirectional, i.e., authors focus on the impact of banks' ESG on risk and performance, and less frequently identify factors influencing banks' ESG.

Various types of banks (private/state, commercial/investment) are explored in various regions of the world (EU member states, GCC, MENAT, ASEAN). Most studies have been limited to a selected geographic area – there is relatively little comparative research between different regions. The advantage of European banks in implementing sustainable development principles over banks in other regions is emphasized (Niedziółka et al., 2023; Basar et al., 2025). The region with the highest ESG risk attributed to banks is Arab countries, while the regions with the lowest ESG risk are Western European and Nordic countries. The actions of banking supervisors are considered the main factor "forcing" banks to adopt a sustainable business model (La Torre et al., 2021).

In answering the research questions, it should be noted that:

– *Firstly (Q1),* most of the analyzed studies show that engagement with ESG issues in the banking sector not only helps reduce negative environmental and social impacts but also positively influences the risk they take. Banks with higher ESG scores are perceived by the market as less risky, which supports the notion that ESG factors mitigate risk (Horobet et al., 2025; Manta et al., 2025; Porzio, Battaglia, 2024; Aevoae et al., 2023; Gangwani, Kashiramka, 2024). The impact of individual ESG pillars on risk varies across different types of banks (Palmieri et al., 2024). Commercial banks can reduce default risk by improving their performance in the environmental pillar, while investment banks can do so in the area of corporate governance. Banks' ESG activities influence lending during financial crises (Danisman, Tarazi, 2022). During crises, banks with high ESG ratings are less exposed to credit risk, asset value risk, and profitability risk.

  There are also studies that do not clearly confirm a positive relationship between ESG performance and risk (Hojer, Mataigne, 2024; Korzeb et al., 2025; Del Sarto, 2025; Di Tommaso, Thornton, 2020; Trinh et al., 2023). Researchers have found that high

ESG ratings are associated with a moderate decrease in risk appetite, and their impact depends on factors such as management board characteristics.

- *Secondly (Q2)*, the relationship between ESG scores and bank performance is ambiguous. Many studies indicate that pro-environmental, pro-social, and governance activities positively impact banks' financial performance (Prorokowski, 2016; Porzio, Battaglia, 2024; Brogi, Lagasio, 2019; Afzal et al., 2024; Gangwani, Kashiramka, 2024; Agnese, Giacomini, 2023), reputation, and competitive advantage (Sain, Kashiramka, 2024). A significant and positive relationship has been found between CSR and stock price volatility (Tasnia et al., 2021). It has also been noted that sustainable practices contribute not only to the growth of tangible assets and profitability but also to the intangible value of banks (Lapinskaitė et al., 2025). The studies by Bui et al. (2024), Buallay et al. (2020) and Horobet et al. (2025) show that the impact of each of the three ESG pillars on bank financial performance varies.

Reasons for these varied research results can be traced to measurement issues. Mostly it is unknown if the underlying score measures input, output, outcome or impact. One reason can be that not every question behind each data point in ESG databases is transparent for scholars (Drempetic et al., 2020). Dobrik et al. (2023) examined the relationship between company size and sustainability ratings using Refinitiv (now LSEG) ESG, E, G, and S scores. The researchers noted that there is a size bias in Refinitiv's E, G, and S scores. A one unit increase in company size corresponds to an increase in the ESG (E) score of around 5.8 (6.7) compared with previous 3.5 (4) in Drempetic et al. (2020). For G and S it is 3.7 and 6.3, respectively. To remedy the size error problem, researchers recommend that users of this database apply a correction factor that takes into account the presence of size error. Bruno et al. (2024) note that banks have considerable discretion in classifying their investments as "sustainable", which makes ESG scores somewhat imprecise. Liang and Renneboog (2017) demonstrate that CSR ratings and legal regulations in the organization's country of origin are strongly correlated. In particular, companies from common law countries exhibit lower levels of CSR than companies from civil law countries.

The findings in this study could have significant implications for banks and policymakers. For banks, understanding the impact of ESG on risk and performance could prove useful in further improving their ESG strategies, non-financial reporting processes, monitoring ESG risk exposures, and promoting sustainable development initiatives. For policymakers, evidence that ESG performance is crucial to financial institutions' business success could inform regulations that facilitate banks' implementation of sustainable practices and transparent ESG reporting. Therefore, further research could focus on national institutional frameworks governing banks' ESG activities. There is also a need for comparative studies, for example between the European Union and other regions of the world, as well as the use of data analysis methods such as multilevel modeling.

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Footnotes

[1] The risk of non-compliance - the risk of legal or regulatory sanctions, financial losses or loss of reputation that a bank may incur as a result of non-compliance with all applicable laws, regulations, codes of conduct and standards of good practice", and therefore as a combination of reputational and financial elements (Basel Committee on Banking Supervision, 2003).

[2] GCC - Gulf Cooperation Council is composed of six member states: Saudi Arabia, Bahrain, Qatar, Kuwait, Oman and the United Arab Emirates.

[3] CAMELS is an international rating system for financial institutions such as banks and credit unions, based on six key factors: Capital adequacy, Asset quality, Management, Earnings, Liquidity and Sensitivity to market risk.

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ATTITUDES OF HOUSEHOLDS AS ENTITIES INVESTING IN GREEN INFRASTRUCTURE COMPONENTS

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Purpose: The study focused on two distinct research areas: the first focused on the attitudes of households as investors in green infrastructure components. The second focused on understanding the attitudes of households as citizens—recipients of green infrastructure provided by local government units. The study had three main objectives. The first was to assess household knowledge and attitudes regarding "green" investments. The second objective was to identify barriers and expectations regarding forms of support for "green" investments undertaken by households. The third objective involved understanding household attitudes towards "green" investments undertaken by local government units.
Design/methodology/approach: The research was conducted using a survey questionnaire. Data were collected using the CAWI method. The survey consisted of 60 questions. The target group of participants were representatives of households residing in Poland. The research sample was N = 1000. The survey was anonymous.
Findings: The conducted research enabled the formulation of conclusions supporting the process of designing policy instruments and tools for "green" investments that are appropriate to the needs expressed by households.
The study also provided conclusions regarding household preferences for "green" investments provided by local government units.
Research limitations/implications: The research results presented in this article are geographically limited to Poland, and subjectively limited to households. Furthermore, the presentation of results is subject-specifically limited to one component of "green" investments: photovoltaics.
Practical implications: Gathering knowledge about the attitudes of households towards "green" investments will contribute to supporting decision-making processes at the national level and at the level of cities and municipalities, including the GZM Metropolis, for a more effective implementation of the energy transformation of the country and regions.
Social implications: Identifying household attitudes toward "green" investments will enable the adaptation of policy instruments and tools at the national and regional levels to the expressed expectations. Furthermore, the research findings will allow for the identification of household expectations regarding "green" investments provided by local government units.
Originality/value: The development of knowledge regarding the attitudes of households towards "green" investments (private and public) will make it possible to fill the cognitive gap in the above-mentioned research area, and will also contribute to the economics of climate change by diagnosing the existing state of affairs, expanding knowledge and identifying new research directions.

Keywords: green investments, sustainable development, green infrastructure, photovoltaic panels.
Category of the paper: research paper.

1. Introduction

Climate change is a priority for European Union institutions, EU Member States, and individual regions. The European Green Deal, launched in 2019, has prompted further action at the EU level to achieve the goal of achieving climate neutrality by 2050. (Communication from the Commission, 2019). In this respect, one of the key elements of the European Green Deal is the European Climate Law, which was adopted in 2021. (Regulation EU 2021/1119, 2021). These provisions are intended to help achieve the overall goal of climate neutrality by 2050, as well as implement a new target of reducing net greenhouse gas emissions in the EU by at least 55% by 2030 compared to 1990 levels. Furthermore, in 2024, the European Commission recommended an additional intermediate climate target of reducing net GHG emissions by 90% by 2040 compared to 1990 levels. In turn, in the field of energy from renewable sources, the agreement on the revised Renewable Energy Directive sets a binding EU target of at least 42.5% share of renewable energy in final energy consumption by 2030. (Directive EU, 2023/2413, 2023). The revised target assumes doubling the share of energy from renewable sources in the EU energy mix in relation to previously formulated targets in this area.

Referring the above to the structure of electricity generation in Poland in 2023, the share of energy generated by hard coal and lignite-fired power plants dominates, accounting for over 60% of the country's electricity production. (Energy 2024, 2024). According to the same source, the share of photovoltaic installations in energy production is approximately 7% of Poland's overall energy mix (excluding thermal energy production). This situation poses a significant challenge for both the government and local government authorities, as well as the Metropolis GZM.

At the national level, the main documents shaping the adopted energy strategy are the "Poland's Energy Policy until 2040" (Polityka Energetyczna Polski Do Roku 2040, 2021), which will be updated due to changes in the political and economic situation. The second document defining the country's energy transformation is the "National Energy and Climate Plan for 2021-2030" (Krajowy Plan w Dziedzinie Energii i Klimatu na lata 2021-2030, 2019) with two amendments from 2024 (Projekt Krajowego Planu, luty 2024; Projekt Krajowego Planu, październik 2024).

Transferring further considerations to the functioning of the Upper Silesian-Zagłębie Metropolis (GZM), as stated in the Diagnosis of the State of GZM, "GZM faces the challenge of carrying out a just transformation, including energy transformation, requiring social, economic and technological changes, as well as replacing high-emission industries and energy

sources with clean energy technologies" (Opracowanie Strategii Rozwoju Górnośląsko-Zagłębiowskiej Metropolii, 2022, p. 250), which requires huge investment outlays.

In the Development Strategy of the Upper Silesian-Zagłębie Metropolis for 2022-2027, with a perspective until 2035, among the development challenges 1 are indicated within the objectives of priority A, in particular: A.1. Development and management of blue-green infrastructure and A.2. Energy transformation and improvement of air quality (Strategia Rozwoju GZM na lata 2022-2027, 2022).

In turn, in the Development Strategy of the Silesian Voivodeship "Śląskie 2030" - Green Silesia within the framework of Strategic Objective A, it was decided: The Silesian Voivodeship as a region of responsible economic transformation (Strategia Rozwoju Województwa Śląskiego, 2020).

According to the provisions of the Regional Innovation Strategy of the Silesian Voivodeship 2030 - the Silesian Voivodeship "(...) faces the challenge of carrying out the process of economic transformation from an energy- and resource-intensive economy, based on traditional fossil fuels, towards a sustainable, low-emission, closed-loop economy" (Regionalna Strategia Innowacji Województwa Śląskiego 2030, 2021).

Implementing the energy transformation process in line with the adopted assumptions requires large-scale investment and the involvement of the widest possible range of investors.

Given the above, it is justified to assess household attitudes towards private and public "green" investments to enable their involvement in financing the transformation process, as well as to identify their expectations of the state and local government units in this regard.

In the literature, the issue of investors' attitudes towards "green" investments, as well as barriers and expectations, has been the subject of research both in foreign literature (Zeru, Guta, 2021; Sun et al., 2018; Palm, 2018) and domestic literature (Juszczyk et al., 2022; Dąbrowska et al., 2021; Stanisławska, 2023).

However, a literature review led to the conclusion that there is a lack of comprehensive research conducted on a representative national sample regarding the knowledge and attitudes of households towards investing in photovoltaic installations in Poland. The research conducted allowed us to understand the knowledge and attitudes of Polish households towards investing in photovoltaics, as well as to identify the main barriers and expectations of households related to investing in photovoltaics. These results expand this knowledge and provide a basis for formulating proposals for forms of support for "green" investments tailored to household needs.

This article formulates three research objectives. The first is to assess household knowledge and attitudes toward "green" investments. The second is to identify barriers and expectations regarding forms of support for "green" investments undertaken by households. The third objective involves understanding household attitudes toward "green" investments undertaken by local government units.

Achieving these goals can contribute to shaping instruments supporting "green" investments and policy tools in this area at the national and regional levels, in a manner that is adequate to the expectations expressed by households, thus increasing households' willingness to invest in "green" infrastructure components. Furthermore, the research results will allow for the identification of household expectations regarding "green" investments provided by local government units.

For the purposes of the study, the following research questions were formulated:

1. What is the attitude of households towards investing in photovoltaics?
2. What is the knowledge of households about investing in photovoltaics?
3. What are the main barriers to households investing in photovoltaics?
4. What are household expectations regarding the forms of support for investing in photovoltaic installations?
5. Do households support local governments investing in photovoltaics?

The research was conducted using the CAWI method. A 60-question survey questionnaire was designed for the study. Representatives of households residing in Poland were selected as the survey respondents (the research sample included 1000 household representatives).

2. Literature review

Energy transformation is one of the greatest challenges facing Poland's economy today. This is due to the ambitious climate policy goals being developed by the EU. The importance of this issue is underscored by the fact that the economy relies heavily on conventional energy sources. According to McKinsey & Company, electricity demand is projected to increase 2.4 times in 2050 compared to 2020 levels (Engel, Purta, Speelman et al., 2020). Additionally, the problem is exacerbated by difficulties related to the implementation of investment projects in the field of climate-resilient infrastructure (Mrozowska et al., 2021). As emphasized in the literature, large-scale investments are necessary to enable the energy transformation and adaptation to the EU goals (Kundzewicz, Matczak, 2012). The CAKE report presents scenarios relating to the way of implementing Poland's energy transformation in the perspective outlined by the EU, which at the same time meet the EU requirements regarding the share of renewable energy sources in the energy mix in 2050 (Tatarewicz, Lewarski, Skwierz et al., 2022). According to a report by McKinsey & Company, solar energy could account for approximately 13% of the total electricity supply in 2050 (Engel, Purta, Speelman et al., 2020). Ensuring the achievement of EU climate goals will require the implementation of renewable energy projects, such as onshore and offshore wind energy, and prosumer photovoltaics. In terms of photovoltaic investments, it will be necessary to engage both public and private sector entities, including households, in financing photovoltaic installations.

In the literature on the subject, the issue of investing in photovoltaics is considered in various contexts: economic, environmental, social (Mauleón, 2017). Numerous studies address issues related to willingness to pay for photovoltaic installations – WTP (Bragolusi, D'Alpaos, 2021; Skordoulis et al., 2020; Lee et al., 2018; Ugulu, Aigbavboa, 2019). A key issue is shaping policy to support renewable energy markets, particularly photovoltaic investments. The authors point out that political stability is a key aspect supporting this type of investment (Assereto, Byrne, 2020). In many studies, the authors review the state of development of photovoltaic investments, including a review of experiences in the field of government interventions, as well as their comparison on an international scale (Huo, Zhang, 2012; Moosavian et al., 2013). Some authors emphasize that investments in household photovoltaics can make a significant contribution to decarbonization. Research results indicate the need to reduce political uncertainty regarding incentive programs for these investments (Petrovich, 2021; Zhang et al., 2025).

In foreign literature, the issues of investors' knowledge and attitudes towards "green" investments have been the subject of research undertaken by many authors (Zeru, Guta, 2021; Sun et al., 2018; Palm, 2018). In Poland, research was conducted on selected aspects of the behavior and attitudes of Polish investors towards photovoltaic installations (Dąbrowska et al., 2021; Stanisławska, 2023). Gręboszc-Krawczyk et al. examined factors influencing consumer behavior towards green energy (Gręboszc-Krawczyk et al., 2021). Research on factors shaping investment intentions in prosumer PV technology was conducted by Mularczyk et al. (Mularczyk et al., 2022), as well as Wicki et al. (Wicki et al., 2022). Igliński et al., in turn, examined the potential, prospects, and development of photovoltaic installations (Igliński et al., 2022).

In the context of barriers and investor expectations regarding forms of support for "green" investments, research was conducted by, among others, Rataj et al. (Rataj et al., 2021). The results of these studies provided proposals for shaping selected aspects of energy policy at the EU, national, and regional levels. Barriers to implementing investments in renewable energy sources, using the examples of Poland and Finland, were the subject of research by Juszczyk et al. (Juszczyk et al., 2022). Wardal et al., in turn, presented the results of research on barriers to the development of green energy in Germany, Italy, Spain, and Poland (Wardal et al., 2024). Research on the main determinants of the development of the broadly understood photovoltaic industry in Poland is presented by Błaszczyk et al. (Błaszczyk et al., 2024).

A review of the literature leads to the conclusion that there is a lack of comprehensive research conducted on a representative national sample regarding the knowledge and attitudes of households towards investing in photovoltaic installations in Poland. According to our findings, there is also a lack of nationwide research on the barriers and expectations of households as investors in photovoltaic installations. The literature study also leads to the conclusion that there is a lack of research presenting household attitudes towards investing in photovoltaic installations by local government units.

Taking into account the diagnosed research gaps, in this article the attention was focused on aspects related to the knowledge and attitudes of households towards “green” investments in which they act as investors and as recipients of “green” investments provided by local government units, as well as on the diagnosis of barriers and expectations of households towards the forms of support for “green” investments in Poland.

The research results are intended to contribute to a better understanding of the needs that will enable policy to be adapted to the expectations of households, and thus contribute to a more effective implementation of the energy transformation process in Poland.

3. Methods

The research results presented in this article were carried out as part of the ECOnomics4ClimateIII project. This project encompasses several research topics in Area 2 closely linked to the goals outlined in the GZM Development Strategy, the Metropolitan Strategic Action Program, and the Regional Innovation Strategy of the Silesian Voivodeship 2030. The goals of this project are also aligned with the UN Sustainable Development Goals, particularly Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action). The research topic under which this article was written is titled: "Household Attitudes Toward Green Investments". The main goal of the research task is to diagnose household attitudes and preferences toward green investments in two fundamental contexts: households acting as investors and as recipients of green investments.

This article formulates three main research objectives. The first is to assess household knowledge and attitudes regarding "green" investments. The second is to identify barriers and expectations regarding forms of support for "green" investments undertaken by households. The final objective involves understanding household attitudes toward "green" investments undertaken by local government units.

A survey questionnaire was designed to conduct the study. This questionnaire consisted of 60 questions, mostly closed-ended and scaled using a Likert scale. Research material was collected using the CAWI method. Representatives of households residing in Poland were selected as the survey respondents. To ensure the study's representativeness, a sample of 1000 households was used. The study was conducted in 2025.

The study was designed to take into account the representativeness of the sample for the GZM Metropolis and Poland, as well as the gender and age of the respondents.

The survey was anonymous. The questionnaire was divided into six sections, including questions regarding:

- values guiding respondents,
- utilitarian issues,

- deontological issues,
- direct variables of the VBN model,
- propensity to invest in "green" infrastructure,
- benefits, knowledge, trust, energy independence, and household behavior as consumers and citizens.

This article presents only selected conclusions from the conducted research.

The collection and preparation of the data was financed, among others, by the Metropolitan Fund for the Support of Science.

This article is limited to presenting general results in selected aspects. Future in-depth research is planned based on the collected data, applying Stern's theory of Value-Belief-Norm (VBN). The VBN theory is based on a causal chain explaining the willingness to engage in specific behaviors in the context of environmental issues (Stern et al., 1999).

4. Results

The following section presents the research results. The focus is on the first strand of research, which addresses household investors' preferences for one of the components of "green" infrastructure: photovoltaic installations.

The primary goal was to determine whether respondents were investing in photovoltaic installations. The results are presented in Figure 1.

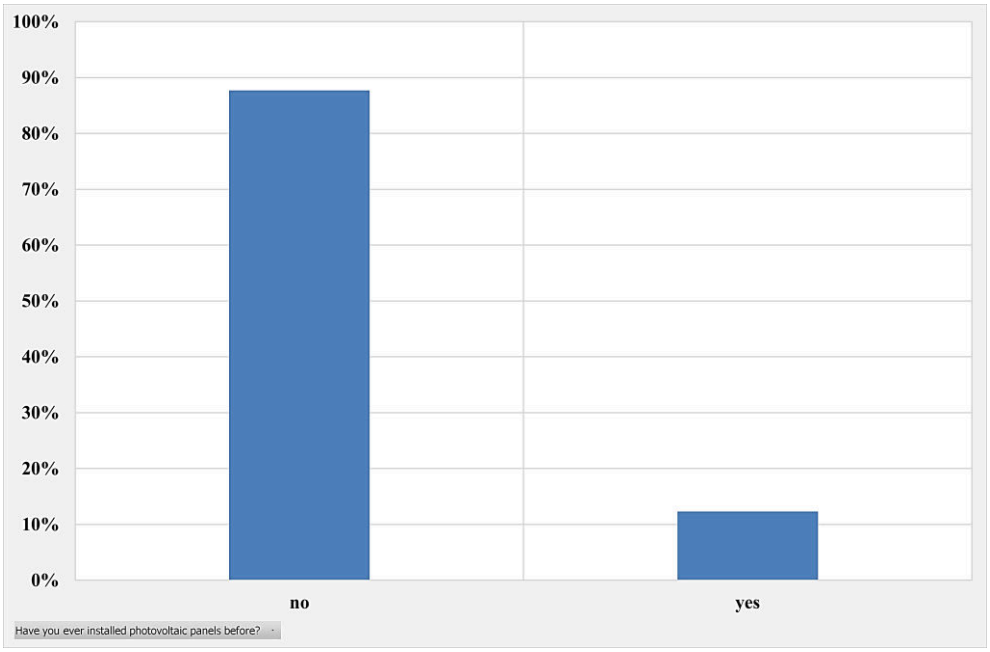


Figure 1. Investment activity of households in photovoltaic installations.

Source: Own study.

The survey results indicate that the vast majority of surveyed households have not invested in photovoltaics. Less than 10% of respondents declared that they had installed photovoltaic panels.

The next question asked respondents to what extent they were willing to invest in photovoltaics, and if they already had photovoltaic panels, whether they were willing to invest again, for example, by increasing the surface area or power. Figure 2 presents the results.

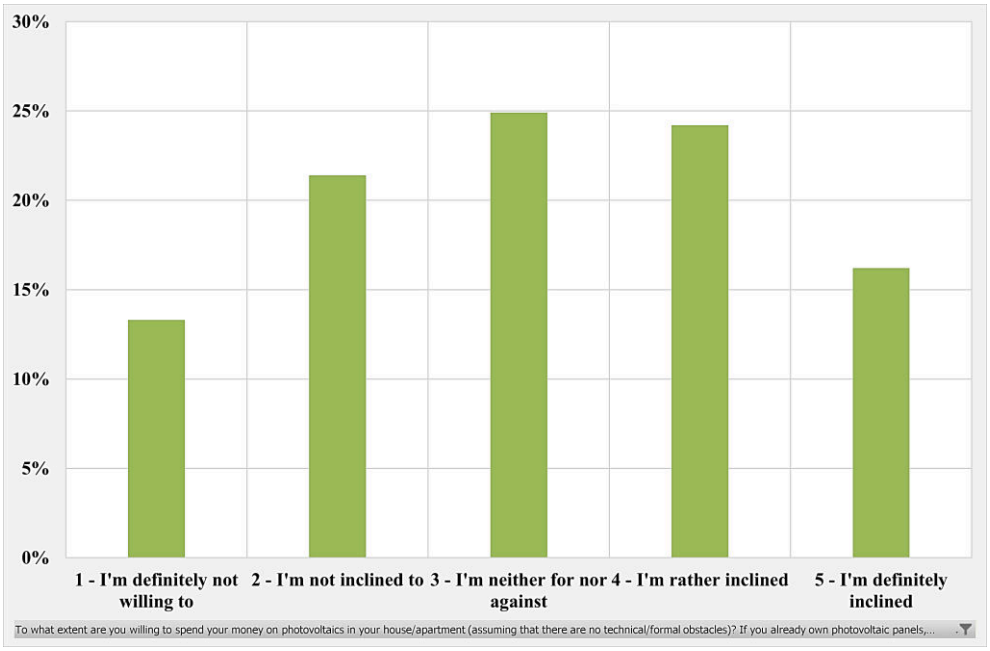


Figure 2. Household willingness to invest in photovoltaic panels.

Source: Own study.

The results are mixed. Approximately 40% of respondents are willing to invest in photovoltaics (responses 4 and 5). Conversely, approximately 35% are not willing to make this type of investment (responses 1 and 2).

The next goal of the survey was to determine households' self-assessment of their knowledge regarding the technical aspects of investing in photovoltaics, such as panel types, technical requirements, and installation efficiency. The results are presented in Figure 3.

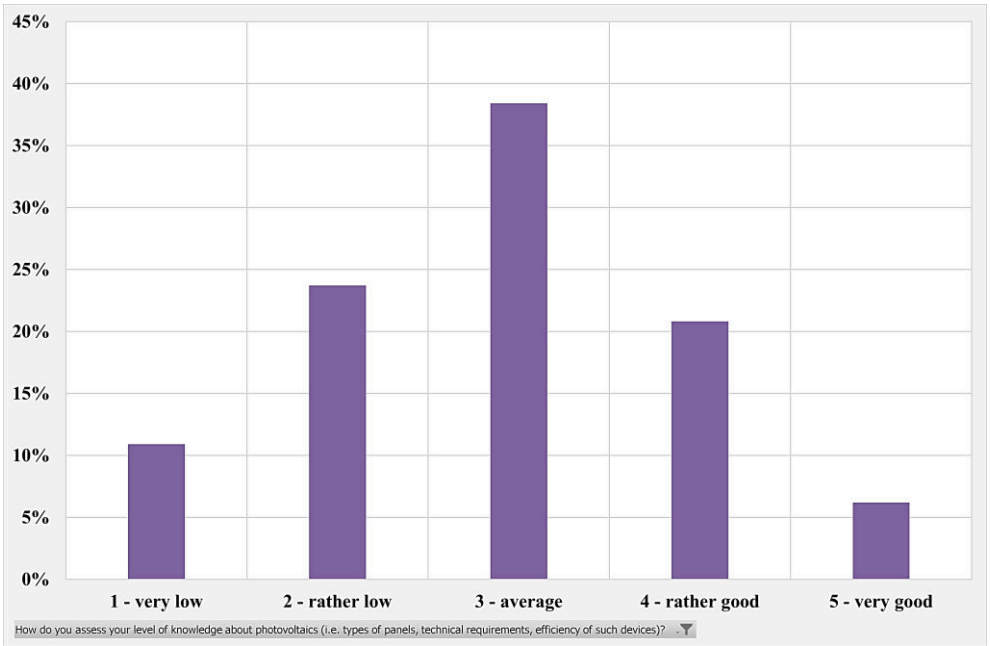


Figure 3. Assessment of the level of knowledge of households about the technical aspects of investing in photovoltaics.

Source: Own study.

The research results indicate differences in the level of knowledge regarding the technical aspects of household photovoltaics, however, it can be stated that respondents most often declared having average knowledge (38.4% of respondents), while approximately 27% of respondents stated that they had very good or rather good knowledge in this field.

In turn, household opinions on the financial efficiency of photovoltaic installations are illustrated in Figure 4.

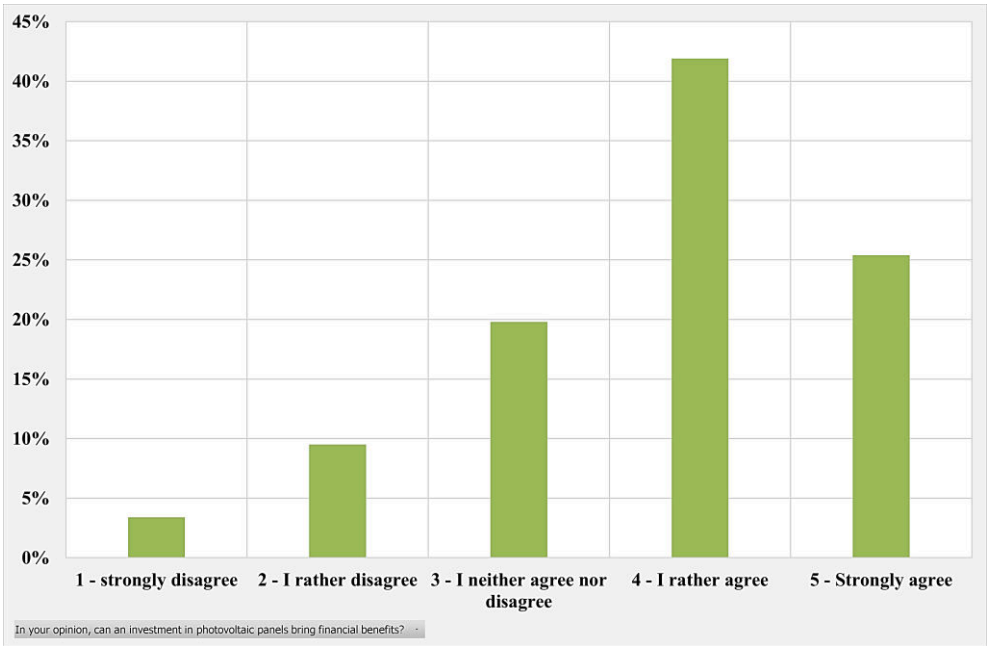


Figure 4. Household opinions on the financial effectiveness of investing in photovoltaics.

Source: Own study.

The vast majority of respondents, approximately 67.3% in total (responses 4 and 5), indicated that they consider investing in photovoltaics to be financially efficient.

Respondents were also asked to express their opinion on the environmental benefits of investing in photovoltaics. The responses are presented in Figure 5.

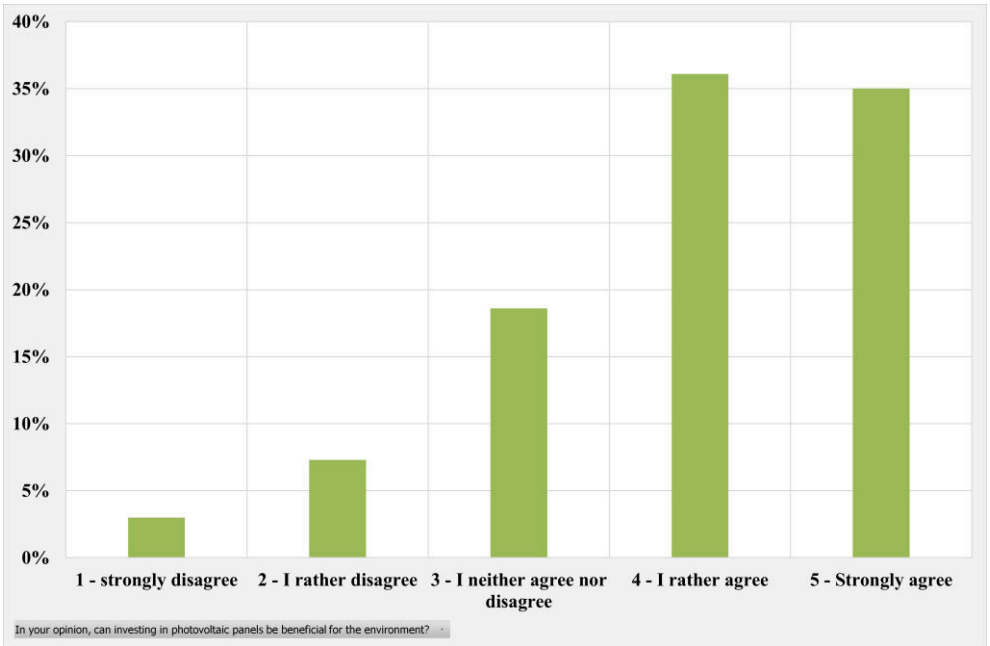


Figure 5. Respondents' opinions on the environmental benefits of installing photovoltaic panels. Source: Own study.

The vast majority of household representatives express the opinion that photovoltaics contributes to generating positive externalities for the natural environment (answers 4 and 5).

The survey also identified respondents' views on the impact of household investments in photovoltaic installations on achieving energy independence. The results are illustrated in Figure 6.

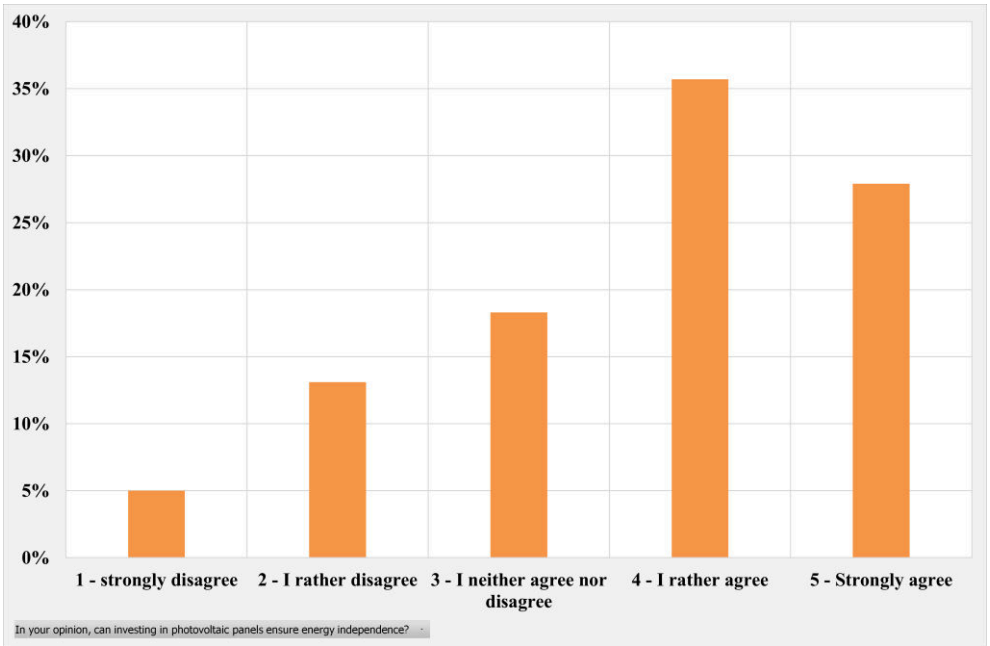


Figure 6. Household opinions on the impact of investing in photovoltaic panels on achieving energy independence.

Source: Own study.

The vast majority of respondents – approximately 63.6% – expressed the belief that investing in photovoltaics has a positive impact on achieving energy independence (answers 4 and 5).

The study then aimed to identify the main barriers to household investment in photovoltaics. Figure 7 illustrates the responses.

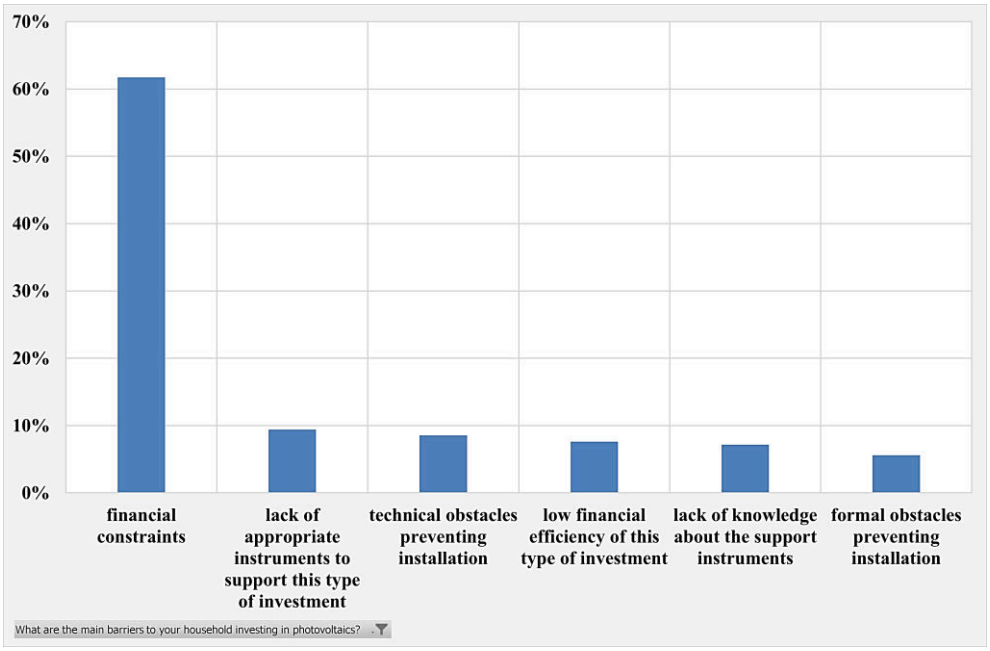


Figure 7. Main barriers to household investment in photovoltaic installations.

Source: Own study.

The main obstacle to investing in photovoltaics cited by households is financial barriers (over 60% of respondents). Approximately 10% of respondents indicated a lack of adequate instruments supporting investment in photovoltaics. Approximately 8% of respondents reported a lack of knowledge about existing instruments supporting this type of investment.

The aim of the study was to determine household expectations regarding the forms of support for investing in photovoltaic installations. These expectations are presented in Figure 8.

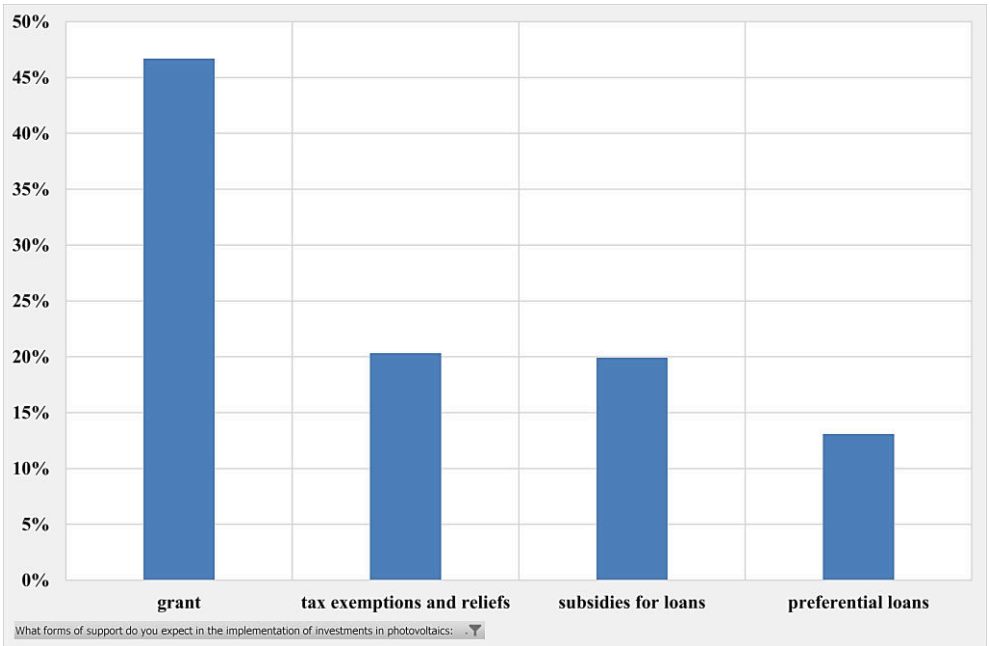


Figure 8. Household expectations regarding forms of support for investments in photovoltaic panels. Source: Own study.

The most desirable form of support for household investments in photovoltaic panels is grants. This was the response of nearly half of the survey respondents.

The study further aimed to determine how households assess their level of knowledge about programs supporting photovoltaic investments offered by the state and local governments. Figure 9 presents the results.

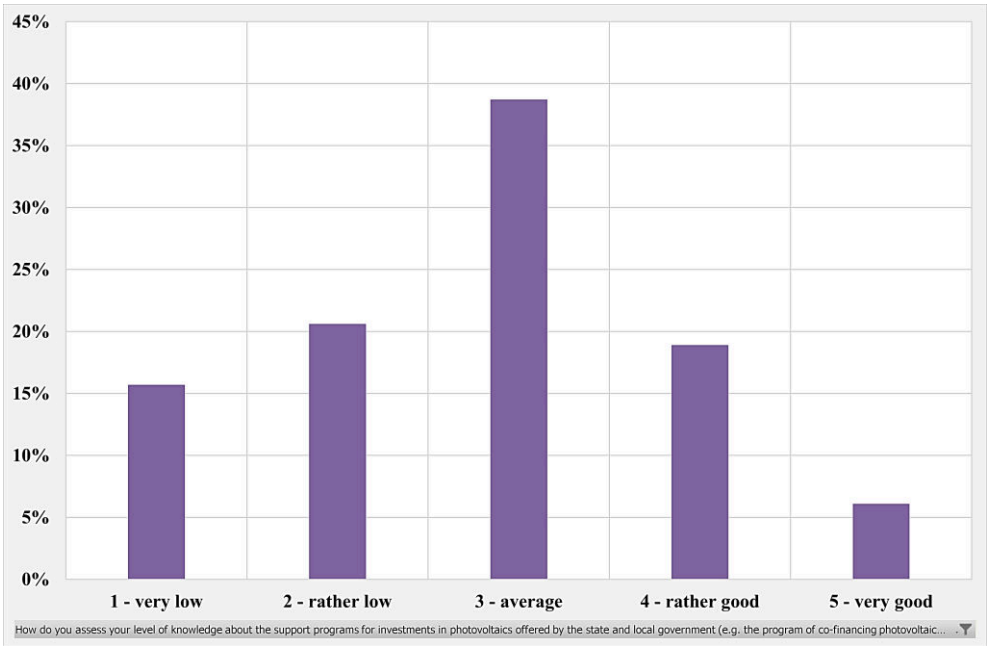


Figure 9. Household knowledge about programs supporting investments in photovoltaic panels.
Source: Own study.

As the survey results indicate, households' knowledge of photovoltaic investment support programs varies. Over 35% of respondents considered their knowledge on this topic to be very low or rather low.

The second research strand aimed to understand the preferences of households participating in photovoltaic investments made by local government units. Figure 10 presents the results regarding households' level of support for local government investments in photovoltaic installations.

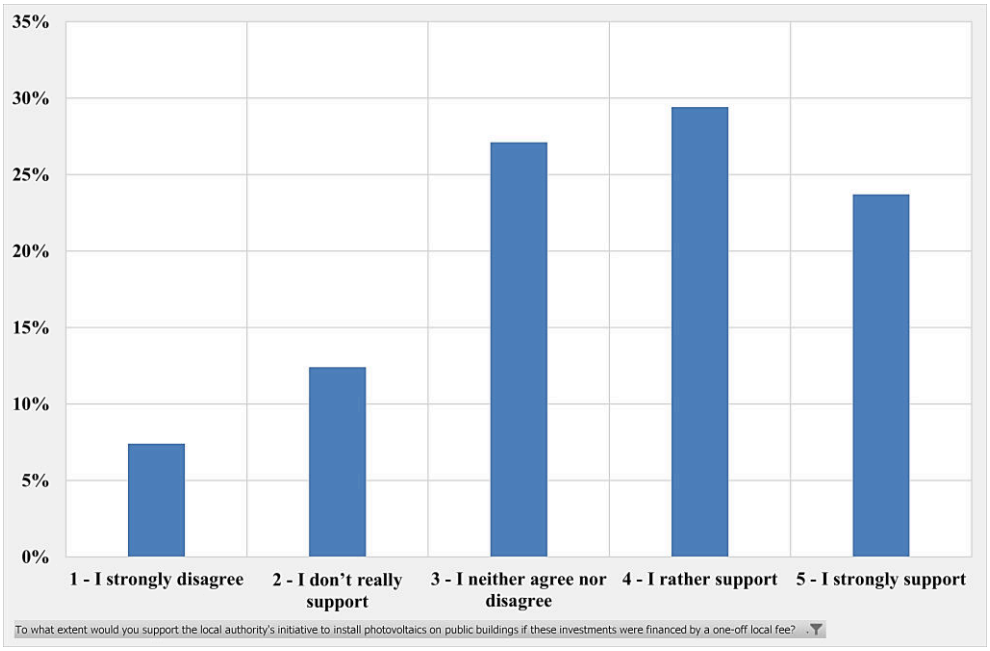


Figure 10. Degree of support for local government investments in photovoltaics by households.
Source: Own study.

According to the survey, over half of respondents support local government investment in photovoltaics (responses 4 and 5), while approximately 20% do not support this type of initiative (responses 1 and 2).

Respondents were asked about their opinions on the main barriers preventing local governments from investing in photovoltaics. Figure 11 presents the responses.

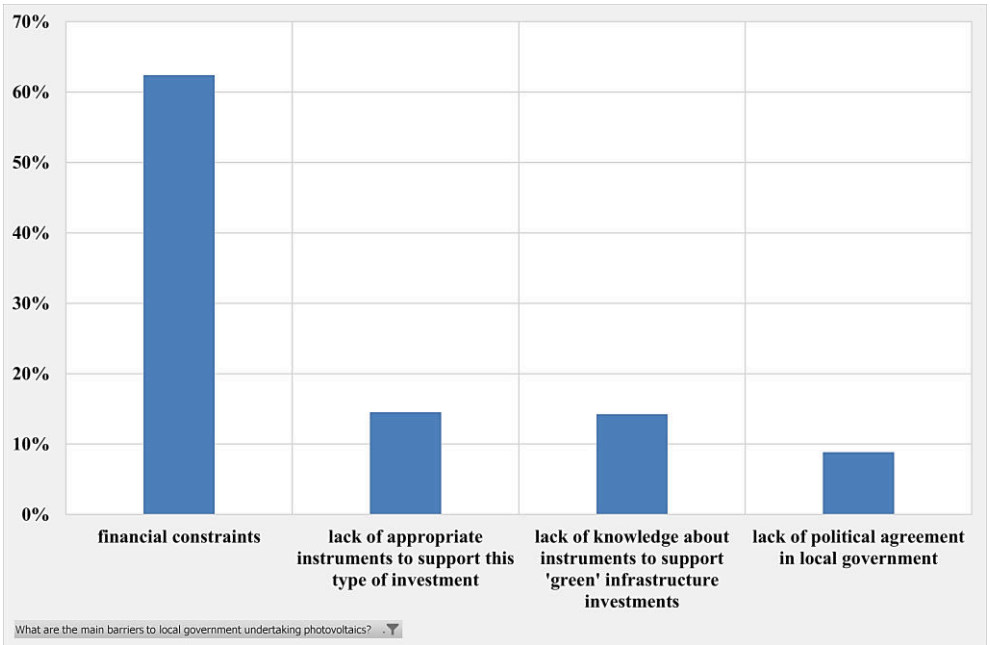


Figure 11. Main barriers to investing in photovoltaic installations by local government units in the opinion of households.

Source: Own study.

The results indicate that, in the opinion of respondents, the main barrier to investing in photovoltaics by local government units is financial constraints. Households expressed the same opinion regarding the barriers to investing in photovoltaic panels by households, as shown in Figure 7.

5. Discussion

In the first area, nationwide research enabled a diagnosis of household attitudes and knowledge regarding one of the components of "green" investments, namely photovoltaic installations. It was found that the vast majority of households had not invested in photovoltaics (approximately 90%) – as of 2025. Considering the literature on the subject, these results complement the current state of knowledge. These aspects were the subject of research by, among others, Igliński et al. (Igliński et al., 2022), who examined the situation of the photovoltaic sector in Poland and globally, although these studies addressed all types of prosumers. Rataj et al., in turn, indicate that Poland is a leader in the growth dynamics of the

photovoltaic market (Rataj et al., 2021). The results of our own research indicate significant potential for the photovoltaic market in Poland and the potential for greater household involvement in energy production, and thus greater involvement in the country's energy transformation process. The study aimed to provide insight into households' willingness to invest (including reinvestment) in photovoltaics nationwide. The results indicate a scattering of respondents' responses, with approximately 40% of households declaring a willingness to undertake this type of investment. Stanisławska conducted research in this area, limiting the scope of her research to owners of single-family homes located in the Lower Silesian Voivodeship (Stanisławska, 2023). Both studies indicate that the willingness to invest is limited and constrained by various barriers. Foreign studies also point to differences in the willingness to invest in photovoltaics and varying degrees of acceptance for this type of investment (Gava Gastaldo, et al., 2019).

The nationwide survey also aimed to address household knowledge of selected aspects of investing in photovoltaics, including technical aspects, financial efficiency, environmental benefits, and the impact of this type of investment on achieving energy independence. Filling the identified research gap in these areas may allow for a better understanding of the investor profile and the adaptation of national-level actions aimed at increasing household involvement in the energy transition. These issues are addressed in the international literature by Gava Gastaldo et al. (Gava Gastaldo et al., 2019). The issue of knowledge and availability of information about photovoltaics was also the subject of research by Sommerfeldt et al. in Sweden (Sommerfeldt et al., 2022). In Poland, research is limited to identifying the factors determining investment in photovoltaics (Wicki et al., 2022; Błaszczyk, 2024). The results of the conducted research indicate knowledge deficits regarding the technical aspects of investing in photovoltaics. In this regard, it is necessary to advocate for informational activities. The vast majority of surveyed households declare knowledge about the financial efficiency of photovoltaic panels, their environmental benefits, and their impact on achieving energy independence.

Another area of research identified the main barriers to household investment in photovoltaics. Financial constraints were identified as the primary barrier to investment in Poland. In other areas, households reported that these barriers included the lack of adequate instruments supporting investment in photovoltaics and a lack of knowledge in this area. Other comparative studies conducted in Poland and Finland point to inflexible, ineffective, and excessive regulatory frameworks, limited financing options, and insufficient public awareness as the main barriers hindering the widespread adoption of this type of investment (Juszczyk et al., 2022). Similar comparative studies were conducted by Wardal et al. in Germany, Italy, Spain, and Poland, where they identified many specific barriers in addition to economic ones (Wardal et al., 2024). A new finding in the results of own research was that households primarily perceive financial constraints as the main barrier. This issue should be taken into account in shaping support for photovoltaic investments.

The study also aimed to determine household expectations regarding forms of support for investments in photovoltaic installations. The study results indicate that subsidies are the most desirable form of support. In other respects, households expect tax exemptions and loan subsidies. Research conducted by Stanisławska (Stanisławska, 2023) indicates certain similarities in the expected forms of support, demonstrating the need to develop more effective support mechanisms, including those related to financial accessibility and the perceived profitability of photovoltaic investments. As the author of the study states, policy interventions should take these factors into account to support the implementation of green energy, especially in low-income households. A limitation of the cited research results is that they were conducted for a sample of single-family homeowners in the Lower Silesian Voivodeship. The special role of tools in shaping economic conditions, particularly investor subsidies, is demonstrated by research conducted in the Visegrad Group countries (Kułyk et al., 2023). It's worth mentioning that our own research also provided insight into household knowledge of programs supporting investments in photovoltaic panels. A new finding from the study is that over 35% of respondents have a low level of knowledge on this topic. This situation requires action to promote awareness of forms of support for "green" investments. Considering this observation leads to the conclusion that, in addition to the identified need to adapt financial support for photovoltaic investments, there is also a need to improve communication regarding existing instruments supporting "green" household investments.

The final area of research focused on household support for photovoltaic investments undertaken by local government units. The study's findings filled a previously identified research gap related to understanding the level of support for this type of investment and the barriers to investment by local government units. A new finding from the study is that the majority of households support this type of investment, citing financial constraints as the main barrier to investment. Therefore, it is recommended that action be taken at the government level to improve the policy framework for energy transition in local government units.

Summary

Implementing the climate transition requires numerous actions at the European Union and Member State levels. For Poland, this process represents one of its greatest contemporary challenges, particularly given the current conditions and the economy's reliance on conventional energy sources. This issue is the subject of numerous scientific studies and reports. Implementing the EU's climate policy objectives by 2050 requires numerous investment projects in renewable energy sources, including photovoltaic installations. It is becoming essential to engage both public sector entities and the private sector, including households, in financing photovoltaic installations. In this context, it is important to learn about the knowledge

and preferences of households acting as investors and recipients of "green" investments, as well as to diagnose the barriers and expectations of households in order to develop appropriate institutional solutions to support initiatives in the field of investment in photovoltaic panels.

This paper presents selected results from a nationwide study conducted in 2025. A key limitation of the study was its reliance on household respondents. The research findings presented in this article constitute a preliminary exploration of the problem. Future implementation of the VBN model is planned. The results of this study provide information that can be used to develop new institutions supporting photovoltaic investments, and also contribute to filling a identified research gap.

The research results indicate, firstly, that household investment activity in photovoltaic installations remains relatively low, therefore, it is necessary to create new instruments to promote this type of investment project. In this context, it is worth emphasizing that the conducted research provides new knowledge on the relatively high level of household willingness to invest in photovoltaics, as well as positive opinions regarding the financial effectiveness of investing in photovoltaics and their positive impact on achieving energy independence. A diagnosis of household attitudes toward investing in photovoltaics supports the need to implement new systemic solutions to support households' involvement in the energy transition process. The results indicate a lack of knowledge among Polish households regarding the technical aspects of investing in photovoltaics and programs supporting such investments. In this regard, the research indicates the need for informational activities and improved communication, which could contribute to increased interest in such investments.

The research also showed that the main barrier to investing in photovoltaic installations by households is financial, which is why it is necessary to review the policy regarding the forms of support for this type of investment projects.

The research indicates that households consider subsidies to be the most desirable form of support for photovoltaic investments. The study indicates that households primarily expect the creation of instruments that influence the financial efficiency of this type of investment. Therefore, it is necessary to propose a review of existing financial support instruments to stimulate household investment activity, and these actions should be accompanied by parallel efforts to disseminate information about investment support programs. The research findings can support the development of new investment support instruments to meet the identified needs of households while simultaneously highlighting identified communication issues.

Households acting as recipients (users) of investments in photovoltaic installations provided by local government units express a positive opinion on the merits of such investments and simultaneously indicate that, in their opinion, the main barrier to implementing such investment projects by local government units is financial constraints. In this regard, the conducted research leads to the conclusion that it is also becoming necessary for local government units to develop financial support instruments for photovoltaic investments.

In summary, the results of this study provide valuable insights for researchers studying energy transition and the economics of climate change, as well as practical managerial and regulatory implications for addressing the challenges associated with the energy transition process.

Future research should apply the VBN model to further refine the findings. Furthermore, research should explore the causes of perceived insufficient financial support and determine the roles of various forms of support. Furthermore, research with a subjective perspective should be extended to include enterprises in the future.

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SELF-MANAGEMENT AS A STRATEGIC COMPETENCE OF A MANAGER IN A MARKET ECONOMY

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Purpose: The article provides an interdisciplinary narrative review of research on the self-management competences of modern managers—integrating psychological, managerial, and economic-financial perspectives—and explains how these competences shape decision-making, risk management, and organisational outcomes.
Methodology: A narrative literature review was conducted on self-management and related constructs, including cognitive processes, self-awareness, emotional intelligence, time management, self-esteem, and mental health. The findings were synthesised into a competence-based framework relevant to managers operating in contemporary organisations.
Results: The review indicates that key components of managerial self-management—awareness of cognitive and emotional processes, metacognition, rational self-regulation over time, emotional intelligence, self-esteem, and mental/physical well-being—can be treated as elements of human and psychological capital. These resources influence decision quality, susceptibility to behavioural errors, risk perception and risk-taking, and the stability of organisational economic and financial results (Becker, 1964; Kahneman, Tversky, 1979; Luthans, Broad, 2022).
Implications and recommendations: Managers should treat self-management as an investment in their human and psychological capital and use systematic practices that develop self-awareness, emotion regulation, time-oriented self-regulation, and recovery. Organisations seeking sustainable results should implement development programmes and HR solutions that strengthen managerial self-management and well-being (World Health Organization, 2022).
Originality/value: The article integrates dispersed findings from psychology, management, and economics/finance into a coherent interpretative framework linking managerial self-management to decision-making and risk management mechanisms (Goldfarb et al., 2012; Cristofaro, 2020).
Keywords: self-management; managerial competences; cognitive processes; emotional intelligence; stress management; time management; risk management; human capital.
Category of the paper: Research paper/Literature review.

1. Introduction

Rapid technological development, including the diffusion of artificial intelligence, increases the cognitive and emotional demands placed on managers. In this context, self-management—understood as the ability to regulate one's attention, thinking, emotions, energy, and values—becomes a strategic competence underpinning both personal effectiveness and organisational performance (Chopra, 2021).

From a business perspective, the ability to deal with risk is inherent in entrepreneurial and managerial work (Grontkowska, Klepacki, 2002). We argue that risk-related competence is inseparable from self-management, because risk perception and risk-taking depend not only on information and tools, but also on cognitive framing, emotional reactivity, and recovery under pressure (Kahneman, Tversky, 1979; Cristofaro, 2020; Cristofaro et al., 2022). This framing is consistent with the idea of "intellectual entrepreneurship", in which the manager's internal resources become a major driver of strategic and economic outcomes (Wyrzykowska, 2012).

In economics and management, competences are interpreted as capital. Human capital theory stresses that skills and knowledge translate into productivity and performance (Becker, 1964). More recent approaches highlight psychological resources as a factor supporting functioning in VUCA environments and buffering the mental-health costs of sustained uncertainty (Luthans, Broad, 2022; Youssef Morgan, 2024). Thus, managerial self-management can be conceptualised as a form of human and psychological capital that affects decision quality, risk management, and organisational results.

2. Literature Review

Managers with high cognitive proficiency typically maintain a level of awareness that enables them to function effectively in their surrounding environment. The concept of consciousness is complex and has not yet been fully explained by science. In psychology, consciousness has been described as brain activity that generates mental representations of the world and ongoing thoughts; a key component of this process is attention—the mechanism by which one element of experience is brought to the foreground while other elements remain in the background (Nęcka et al., 2020; Zimbardo, 2010; Zimbardo, Gerrig, 2018). Attention therefore acts as a selective filter that prioritizes information considered relevant to current goals and actions, while inhibiting stimuli that are irrelevant.

These authors also emphasize that consciousness, as a function of the mind, makes it possible to connect current reality with imagination. For example, when hungry, people can mentally represent food using working memory; similarly, managers can simulate the

consequences of their decisions (e.g., investment choices or financial calculations). Awareness can both narrow and broaden the scope of attention; it integrates perception with memory, emotion, and motivation, allowing individuals to construct mental models of the world that can be manipulated in thought (Zimbardo, 2010). In cognitive psychology, consciousness is often conceptualized as the outcome of selective attention—an information-selection system that prevents cognitive overload, integrates ongoing experience with memory, emotion, and motivation, and yields working models of reality (Baars, 1997; Budson et al., 2022; Dehaene, 2014; Marchetti, 2018; Nęcka et al., 2020). Zimbardo (2010) further describes consciousness as a process that isolates one element of experience from others and subjects it to conscious analysis and interpretation.

Managerial behaviour can be viewed as an expression of this awareness: it reflects how limited attention is allocated and which mental models of organizational reality are constructed. From the attention-based view of the firm, Ocasio (1997) argues that organizational behaviour largely reflects which signals—both external and internal—capture decision-makers' attention. Faced with an abundance of stimuli, managers admit only a subset of issues (e.g., problems, people, projects) into focal awareness, which in practice shapes action priorities and resource allocation.

Because consciousness integrates current impressions with memory, emotion, and motivation to form working models of the world (Nęcka et al., 2020; Zimbardo et al., 2010), managerial behaviour in decision-making situations can be interpreted as the enactment of specific "mental models" of the organization, the market, and other actors. Research on managerial cognition indicates that such simplified models—patterns and beliefs about "how business works"—strongly shape strategic choices and performance differences across firms, because they filter information and privilege certain interpretations as "obvious" (Gary, Wood, 2011; Weick, 1995).

Because consciousness integrates emotion as well as cognition, leadership style, responses to stress, and communication with employees depend in part on how managers notice and interpret their own affective states and motivations (Cristofaro, 2020; Cristofaro et al., 2022). In short, the mechanisms of consciousness—attentional selection, mental modelling, and affective integration—shape what information managers notice, how they interpret organizational situations, and which decisions they ultimately make.

Branden (2008) argues that conscious living involves an intentional effort to become aware—so far as possible—of what is relevant to one's actions, goals, and values, and to act in accordance with that knowledge. The level of consciousness therefore influences how individuals perceive (inevitably in a subjective manner) their environment, their roles within it, and the options they consider available. The same holds for modern managers, who must remain aware of the environment and emerging opportunities if they are to pursue organizational goals effectively.

In psychological terms, intelligence is commonly understood as the ability to comprehend situations and generate adequate, purposeful responses, whereas intellect is sometimes associated with the mind (reason) as a general capacity to learn about the world and perform mental operations (Tokarski, 1979). Given the nature of managerial work, managers benefit from proficiency in higher-order cognitive operations such as analysis, synthesis, comparison, abstraction, generalization, classification, and inference. An appropriate state of consciousness supports the effective use of intelligence and the performance of managerial roles and functions.

Contemporary management scholarship echoes Branden's proposition that conscious living involves intentionally directing attention, thought, and action toward one's goals and values. In management research, this idea is developed most explicitly within the concept of self-leadership. Neck and Houghton (2006) define self-leadership as a process through which individuals consciously and intentionally influence themselves to guide their behaviour and motivation at work. This includes, among other strategies, deliberate goal setting, self-observation, self-reward, and corrective self-feedback. Put differently, employees may operate on "autopilot" or actively increase their level of awareness in relation to tasks, goals, and organizational values.

Furtner et al. (2015) show that self-leadership strategies are largely voluntary: they rely on intentional effort rather than solely on automatic self-regulation. Individuals with higher levels of self-leadership are more likely to monitor their thoughts and emotions, confront reality, and modify their behaviours in ways consistent with long-term goals. In this sense, self-leadership can be interpreted as a structured approach to what Branden (2008) describes as the decision to actively "use" one's consciousness rather than to weaken it.

Branden's idea of conscious living also corresponds to the concept of mindful leadership. Reviews of leadership-development interventions based on mindfulness and self-leadership training indicate that leaders who practice mindfulness tend to exhibit greater self-awareness, better emotion regulation, and stronger alignment between declared values and actual behaviour (Tenschert et al., 2025). Mindful leadership assumes the maintenance of intentional, non-judgmental attention to oneself, others, and the organizational situation—translating the aspiration to become aware of what is relevant for action and values into the domain of managerial work.

Related themes appear in the concept of authentic leadership. Eriksen (2009) emphasizes that authentic leaders must first reflectively recognize and articulate their values and beliefs before entering situations characterized by pressure and conflicting expectations. Without such prior work on self-awareness, leaders may become more susceptible to conformity and to adopting dominant views even when these conflict with their personal value system.

A complementary perspective is provided by goal-setting theory, which highlights the causal role of conscious intentions in shaping workplace behaviour. Locke and Latham (2002) argue that behaviour is strongly influenced by consciously adopted goals that are specific and challenging—goals that focus attention, mobilize effort, and support persistence. Subsequent

research further shows that work motivation is shaped by the conscious formulation of measurable, ambitious goals, their acceptance by employees, and systematic monitoring of progress (Gkizani, Galanakis, 2022; Harkin et al., 2016; Locke, Latham, 2002). From this perspective, management by objectives (MBO) can be understood as an organizational extension of these mechanisms: it relies on jointly formulating goals, communicating them, establishing checkpoints, and periodically reviewing outcomes, thereby making focal awareness a central axis of organizational action (Islami et al., 2018).

Taken together, the literature suggests that managers should be able to perform complex mental operations, consciously direct attention, reflect on their own thinking and emotions, and set and monitor goals. An appropriate state of consciousness supports the full use of intelligence, knowledge, skills, and personality resources and, consequently, the effective performance of managerial roles and functions. Managers with well-developed awareness and intelligence, supported by self-management competences, are better prepared to manage organizational resources—including human resources. However, to manage others effectively, managers must first learn to manage themselves.

3. Methods

The article adopts a narrative literature review approach. Research on self-management and adjacent constructs (cognitive functioning, self-awareness, emotional intelligence, time-oriented self-regulation, self-esteem, stress, recovery, and mental health at work) was synthesised into an integrative framework of managerial self-management competences.

The review was guided by eight research questions addressing: (1) cognitive abilities and self-awareness; (2) balance across core life domains; (3) imagination and future visualisation; (4) emotional intelligence; (5) emotion and stress regulation; (6) time-oriented self-regulation; (7) self-esteem and values; and (8) mental health principles and routines. To guide the review, the following research questions were formulated:

RQ1. How does the literature conceptualise the relationship between cognitive abilities, self-awareness (apperception), and the self-management of one's thoughts, and how are these factors linked to managerial effectiveness and decision-making?

RQ2. How does the literature address balance across the physical, intellectual, emotional, and spiritual domains, and what significance is attributed to this balance for the self-management of modern managers?

RQ3. What role do imagination and future visualisation play—according to the literature—in developing managerial visions, goal setting, and problem solving?

RQ4. How is managerial emotional intelligence defined and operationalised in the literature, and which components are considered essential for effectively managing oneself and others?

RQ5. What strategies for managing emotions and stress are described in the literature, and how are these strategies associated with relationship quality, leadership, and work effectiveness?

RQ6. How does the literature describe the importance of time management (self-management in time) for managerial effectiveness, and which mechanisms and barriers (e.g., procrastination) are most frequently identified?

RQ7. What role does self-esteem play in models of managerial self-management, and which factors are identified in the literature as strengthening or weakening self-esteem?

RQ8. Which mental health principles and lifestyle practices are discussed in the literature as conditions for sustaining managerial self-management in a dynamically changing organisational environment?

4. Results

For the purposes of this review, self-management refers to planning, organising, and controlling one's projects in line with decisions, priorities, and motivations, ensuring purposeful, effective, and timely implementation.

The synthesis suggests eight interrelated competence domains: (1) cognitive abilities, self-awareness, and thought management; (2) balance across physical, intellectual, emotional, and spiritual domains; (3) imagination and future visualisation; (4) emotional intelligence; (5) managing emotions and stress; (6) time-oriented self-regulation; (7) self-esteem and values-based regulation; and (8) compliance with mental health principles and recovery routines.

Cognitive ability supports learning, complex information processing, and problem solving—capabilities central to managerial work under uncertainty. Meta-analytic evidence links cognitive ability to job performance in complex roles (Nye et al., 2022). However, the literature consistently indicates that performance and decision quality also depend on self-awareness: the ability to recognise one's motives, biases, habitual patterns, and impact on others (London et al., 2023; Da Fonseca et al., 2022). This dimension is particularly relevant in risk contexts where judgement is shaped by framing and affect (Kahneman, Tversky, 1979; Cristofaro, 2020).

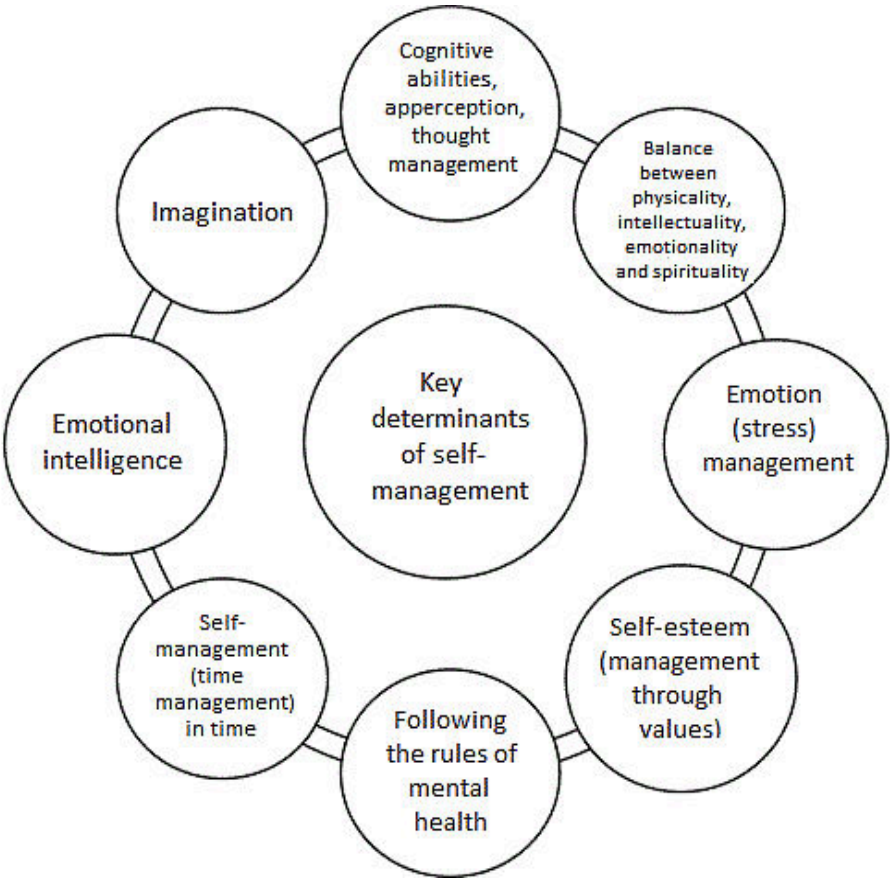


Figure 1. Key factors determining self-management competences.

Source: own study.

A key mechanism that links cognition and self-awareness is metacognition—monitoring and regulating one's own thinking. Research suggests that metacognitive capacity is associated with more deliberate decision styles and can be strengthened through training, improving decision quality in complex tasks (Basu, Dixit, 2022; Batha, Carroll, 2007; Thagard, 2017). In sum, cognitive ability provides analytical capacity, self-awareness supports calibration and feedback use, and metacognition enables deliberate correction of automatic cognitive patterns.

A recurring conclusion across managerial and leadership literatures is that sustained effectiveness depends on balancing and replenishing core personal resources. Holistic approaches conceptualise managers as systems of interconnected resources (mind, emotions, body, and values/meaning) that require awareness and deliberate management (Gut et al., 2008). From a performance standpoint, the shift from "time management" to energy management emphasises that high performance depends on cycles of effort and renewal (Loehr, Schwartz, 2003).

Values and meaning processes are often treated as the "spiritual" domain: they provide direction and intrinsic motivation and support coherent leadership behaviour (Covey, 2004; Fry, 2003). In practice, balance across domains is presented as a condition for resilience, stable judgement, and sustained leadership effectiveness under pressure (Gut et al., 2008; Loehr, Schwartz, 2003).

Imagination connects knowledge to action by enabling managers to construct plausible futures, translate aspirations into plans, and explore options under uncertainty. Research on mental simulation shows that rehearsing the process of goal attainment (steps, obstacles, coping strategies) supports planning, anticipatory coping, and self-regulation (Taylor et al., 1998; Baumeister et al., 2016). Work on episodic future thinking highlights that imagining future situations is central to evaluating consequences and guiding action (Schacter et al., 2017).

In strategy and organisational change, imagination supports future-oriented narratives and scenario construction that help organisations move beyond reactive adaptation (Rindova, Martins, 2022; Thompson, Byrne, 2022). Empirical work also links future thinking to innovative behaviour and to managerial capability to act under uncertainty (Eisenbart et al., 2023; Pettit et al., 2023). Thus, imagination functions as a competence supporting vision, disciplined execution, and creative problem solving.

Emotional intelligence (EI) is discussed both as an ability and as a competence set relevant to recognising, understanding, using, and regulating emotions. Within the ability model, EI is conceptualised as reasoning about emotions and using emotions to facilitate thinking (Mayer et al., 2016). Mixed approaches emphasise EI as a cluster of emotional and social competences supporting leadership effectiveness (Goleman, 1999; Kozyra, 2015).

In organisational research, EI is measured using performance-based tests and self-report measures such as the Wong and Law Emotional Intelligence Scale (Wong, Law, 2002), with evidence supporting its use in managerial samples (Acosta-Prado et al., 2022). Meta-analytic findings indicate that EI is meaningfully related to job performance, beyond cognitive intelligence and personality (O'Boyle et al., 2011). Reviews further suggest that leader EI is associated with relationship quality, trust, and team outcomes (Coronado-Maldonado, Benítez-Márquez, 2023). In managerial practice, EI supports self-awareness and self-regulation under pressure and enables adaptive interpersonal behaviors.

Emotion regulation is a practical mechanism through which managers maintain decision quality and relationship functioning under stress. Evidence suggests that leaders' emotion regulation tendencies relate to leadership performance and the quality of responses in demanding situations (Torrence, Connelly, 2019). Mindfulness-based approaches are linked to lower exhaustion and higher job satisfaction partly through healthier emotion regulation at work (Hülsheger et al., 2013), and leadership-focused reviews suggest that mindfulness practice supports self-awareness and intentional responding (Doornich, Lynch, 2024; Tenschert et al., 2025).

A second line of evidence emphasises recovery. Meta-analytic results show that detachment, relaxation, mastery, and control over non-work time are associated with better well-being and effectiveness (Bennett et al., 2018). Recovery frameworks used in occupational research also emphasise systematic replenishment as a condition for sustained functioning under load (Virtanen et al., 2019). In leader–member relations, emotion regulation is also interpersonal: leaders' emotion management shapes relationship quality and follower outcomes

(Little et al., 2016; Haver et al., 2013). Practically, this implies that stress management is not auxiliary but foundational for stable leadership behaviour and performance.

The reviewed literature increasingly treats time management as self-regulation in time rather than calendar mechanics. Bubrowiecki (2012) captures this perspective by arguing that effective time management begins with managing oneself. A meta-analysis suggests that time management is positively associated with performance and well-being and negatively associated with distress (Aeon et al., 2021). In managerial contexts, time-oriented self-regulation supports prioritisation, sustained effort, and reduced overload, which indirectly benefits decision quality and resource efficiency.

Self-esteem functions as a core resource for self-regulation, learning from setbacks, and responsible decision-making. Contemporary research revisits the benefits and limits of high self-esteem and highlights the importance of stability and realism (Orth, Robins, 2022). Evidence also indicates that self-esteem can develop over time and is shaped by work experiences and feedback loops (Krauss, Orth, 2022; Lin et al., 2022). Interventions can strengthen self-esteem, although effects typically require sustained work on beliefs and behavioural patterns (Niveau et al., 2021).

Within values-based approaches, self-esteem is linked to authentic, responsible self-regulation rather than short-term image protection (Branden, 2008, 2014). Experimental evidence suggests that self-evaluations may shape managerial decision patterns, including the tendency toward self-serving interpretations (Cristofaro, Giardino, 2020). Reviews also highlight that self-compassion supports healthier self-evaluations and well-being (Muris, Otgaar, 2023). Accordingly, self-esteem can be treated as a stabilising resource supporting autonomy, persistence, and constructive coping in managerial roles (Sivanathan, Pettit, 2010).

Recent research increasingly frames mental health as an economic and organisational issue: poor well-being is associated with errors, absenteeism, turnover, and productivity losses, while protective organisational practices support sustainable performance (Hampel, Ucieklak-Jeż, 2023; Hampel, Ucieklak-Jeż, Bem, Hajduova, 2023; Khalid, Syed, 2024). The WHO Guidelines on Mental Health at Work emphasise combining organisational interventions (e.g., workload design, flexible arrangements), managerial training, and support for individual strategies (World Health Organization, 2022).

Reviews of leader well-being further indicate that formal leaders face specific well-being risks and may require both personal resources and organisational support to avoid chronic overload and burnout (Oc, 2024). In this light, maintaining self-management capacity requires stable routines of recovery and realistic self-regulation practices that protect attention, emotional stability, and learning capacity (Luthans, Broad, 2022; Youssef Morgan, 2024). At the organisational level, such practices contribute to the stability of decision-making and reduce “human costs” that can translate into economic and financial risk.

5. Discussion And Conclusions

This article synthesises research that helps clarify why the ability to manage oneself is increasingly important for contemporary managers. In light of current findings on self-leadership, it can be concluded that in a dynamically developing market economy—characterised by increasing environmental volatility, intensifying competition, and heightened exposure to economic and financial risk—self-management constitutes one of the leader's key "basic" competences. Meta-analyses indicate that self-leadership is strongly associated with employee performance, engagement, satisfaction, and creativity (Harari, Williams, Castro, Brant, 2021; Tenschert, Furtner, Peters, 2025). These variables are also treated in economic research as important determinants of productivity, innovation, and organisational financial performance.

Managers, as conscious agents, must assume responsibility for their own development in order to realise life and career goals. This also implies the intentional development and maintenance of one's human and psychological capital, which—although not directly recognised in financial statements—co-determines an individual's capacity to create value for the company. Contemporary reviews on the development of self-awareness highlight that the ability to see oneself realistically, understand one's motives, and influence one's environment is a developmental process that can be supported through reflection, feedback, and intentional personal development practices (London, Sessa, Shelley, 2023).

Self-management, however, is not easy—especially when managers face everyday life demands alongside the pressures of formal leadership roles. In organisational practice, managers often work under uncertainty, continuous change, and resource constraints while striving to achieve organisational goals. In economic and financial terms, this implies making decisions under risk, optimising resource allocation, and balancing short-term performance with long-term organisational sustainability. More recent reviews of leaders' well-being show that leadership comes not only with responsibility but also with a tangible health "cost": formal leaders may be particularly vulnerable to overload, burnout, and mental health problems if they lack sufficient personal resources and organisational support (Oc, 2024; Rudolph, Murphy, Zacher, 2020). From an economic perspective, reduced managerial well-being may translate into lower decision quality, higher costs related to turnover, absenteeism, and errors, and—ultimately—worse financial performance.

Naturally, multiple factors shape an individual's ability to self-manage, and managers enter their roles with different levels of personal, social, and material resources. Nevertheless, research on core self-evaluations and self-esteem indicates that self-esteem, agency, and emotional stability can develop across the lifespan and support better work functioning, higher performance, and stronger psychological resilience (Krauss, Orth, 2022; Orth, Robins, 2022; Cristofaro, Giardino, 2020). This resonates with Brian Tracy's statement that "you are

your most valuable capital" (Tracy, 2011). Contemporary research adds that this is capital in which one can—and should—invest deliberately, because such investment pays off at both the individual level (career and income) and the organisational level (economic and financial results and stakeholder value).

On the basis of the literature review and the proposed model, the following extended practical conclusions can be formulated.

First, self-management is a transversal competence that conditions the effective use of other managerial competences. Recent meta-analyses show that self-leadership—understood as the capacity to set goals, monitor one's behaviour, apply cognitive strategies, and self-motivate—is significantly and relatively strongly associated with work performance, self-efficacy, engagement, creativity, and proactive behaviour (Harari et al., 2021; Tenschert et al., 2025). In practice, "leading from the inside" becomes the axis supporting decision competence as well as relationship building and strategy execution. From an economics and finance perspective, self-management can therefore be treated as a meta-competence that determines whether professional knowledge, emotional intelligence, and management tools are actually translated into economic value creation, productivity gains, and fewer costly decision errors.

Second, the development of self-awareness, emotional intelligence, time management skills, and care for mental and physical health represents the basic improvement agenda for the modern manager. Literature reviews indicate that self-awareness—understood as a clear self-view and awareness of one's impact on others—is a fundamental condition for leadership development because it enables the correction of behavioural patterns and the conscious shaping of leadership style (London et al., 2023). Hybrid reviews of emotional intelligence and leadership research show that leaders' emotional competences (self-awareness, self-regulation, empathy, and relational skills) are systematically linked to relationship quality in teams, trust, and work outcomes (Coronado Maldonado, Benítez Márquez, 2023). A meta-analysis by Aeon and co-authors (2021) further confirms that effective time management—as a form of self-regulation—improves work performance and well-being while reducing perceived stress (Aeon, Faber, Panaccio, 2021). Research on health and resilience also suggests that practices such as mindfulness, self-compassion, post-work recovery, and intentional lifestyle care are not merely a "nice addition" but a realistic condition for maintaining learning capacity, decision quality, and constructive responses to crises (Lefebvre, Montani, Courcy, 2020; Krauss, Orth, 2022; Muris, Otgaar, 2023). At the microeconomic level, these competences and practices strengthen organisational human and psychological capital, with direct implications for resource efficiency, innovation, and the stability of financial outcomes.

Third, organisations that expect high managerial performance should intentionally support development in these areas—for example through training, coaching, wellbeing programmes, and a culture that facilitates balance. A systematic review of development programmes based on self-leadership and mindfulness suggests that such interventions increase resilience to stress, work performance, leadership satisfaction, and the ability to organise and motivate teams, while

reducing burnout and improving sleep quality (Tenschert et al., 2025; Bonde, Mikkelsen, Overby Fjorback, Juul, 2022). From an economic standpoint, this implies the potential to reduce costs associated with absenteeism, turnover, decision-making errors, and losses of human capital. More recent work on formal leaders' well-being and resilience strategies further indicates that supportive leadership at the top of the hierarchy, a culture that normalises self-care, flexible working arrangements, and psychosocial support systems are crucial at the organisational level (Rudolf et al., 2020). Finally, reviews of self-compassion and resilience practices in the workplace suggest that HR policies and wellbeing programmes that teach leaders to adopt a kinder and more realistic stance toward mistakes and limitations help sustain long-term self-management capacity (Lefebvre et al., 2020; Muris, Otgaar, 2023). In broader terms, this can translate into more stable organisational development and reduced economic and financial risks related to "human costs."

In summary, recent literature confirms that self-management is not a "soft" supplement to classic managerial competences, but their foundation. Competences such as self-leadership, self-awareness, emotional intelligence, time management, and care for mental and physical health are simultaneously an individual developmental task for managers and an organisational responsibility. If organisations expect high effectiveness and sustainable economic and financial outcomes, they should deliberately create conditions that support the development of these competences (Harari et al., 2021; London et al., 2023; Orth, Robins, 2022; Coronado Maldonado, Benítez Márquez, 2023).

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MANAGERIAL DECENTRALIZATION IN THE POST-COMMUNIST WELFARE MODEL. EVIDENCE FROM POLAND

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Purpose: The aim of this article is to diagnose the level of managerial decentralization in the post-communist social welfare regime according to Gøst Esping-Andersen's classification.
Design/methodology/approach: Using the Participatory Action Research method, a diagnosis of managerial decentralization was carried out in all 2573 local government social welfare organizations in Poland (LGSWO). Using formative indicators, a research construct was developed, which was used to diagnose and evaluate management delegation, increasing the powers and responsibilities of LGSWO managers in the Polish social welfare system.
Findings: The diagnosis indicated that the managerial approach to management is based on the decentralization of management through the delegation of responsibility. It is worth noting that the responses varied depending on the age of the managers.
Research limitations/implications: The results of the study indicate the need to extend the research to CEE countries in order to make comparative analyses with other post-communist social welfare models.
Practical implications: Social policy management should be conducted in such a way as to define the true relationship between the decision-making center and decentralized entities. LGSOW managers in CEE countries that have greater autonomy in decision making will be able to respond effectively to dynamic changes in the environment by applying business management methods, techniques, and tools.
Social implications: Managerial decentralization processes are of great importance in improving organizational efficiency and the effectiveness of social services.
Originality/value: The conclusions of this article provide public policy managers with information on the current state of affairs and the need to pursue decentralization processes in response to the changing socioeconomic environment.
Keywords: welfare state, post-communist regime, public management, managerial decentralization, CEE countries.
Category of the paper: Research paper.

1. Introduction

When analyzing managerial decentralization processes in post-communist CEE countries, it is necessary to focus on the problems resulting from the political transformations in these countries and the turbulent socioeconomic environment that generates new social problems. The social welfare system should focus on restoring a sense of dignity to citizens who are unable to cope on their own. Establishing indicators for measuring decentralization is not as big a problem as determining the degree of advancement of this process (Harguindéguy, Cole, Pasquier, 2021, pp. 185-208). From the point of view of implementation in the public sector, decentralization has legal regulations, but its practical implementation is becoming more difficult and requires the involvement of many stakeholder groups (Dick-Sagoe, Goncalves-Adras, 2020, pp. 1-13). As Ch. Polidano points out that managerial decentralization in a broad sense means a change in the entire structure of state ownership when private ownership increases and state involvement in the economy is reduced. In a narrow sense, however, it is the implementation of management techniques and procedures from the private sector to the public sector (Polidano, 1999). When analyzing managerial decentralization in terms of delegating responsibility to LGSWO managers, it is necessary to go beyond a formal and legal analysis (Overman, 2015, pp. 1238-1262). We need to focus on the origins and directions of these processes in public policy management to determine the true relationship between the decision-making center and decentralized entities (Broekstra, 2018). When analyzing the issue of managerial decentralization as the delegation of responsibility to lower levels in public sector organizations, it should be noted that this is one of the instruments directly related to the concept of new public management (NPM) (Laffin, 2016). The main assumption of this concept of public management is an approach to management through the implementation of mechanisms used in business (Van Dooren et al., 2015, pp. 42-58). When dialogue in the implementation of joint initiatives, conditions for change should be created. It is necessary to increase the effectiveness of action and the shared responsibility of public entities, businesses, and citizens in creating new social policy strategies (Kuhlmann, Wyenberg, 2016). Despite the 35-year gap since the beginning of the political transformation, the social welfare system in Poland has many elements of a conservative welfare state slowly moving towards a liberal regime. The analysis of the social welfare system in Poland was carried out in the context of G. Esping-Andersen's classification of social welfare regimes.

2. Decentralization

The phenomenon of decentralization is presented in the literature as a certain characteristic of organizational structures encompassing scientific disciplines such as management and quality sciences or political and administrative sciences. Decentralization is an element of state activity related to the system of exercising power and its territorial division (Azfar et al., 2004). In summary, decentralization should be seen as the transfer of specific public tasks performed by the government administration to other state authorities (Hanson, 2022, pp. 105-128). The concept of decentralization is often used in the following approaches (Smith, 2023): (1) subject, who is affected by decentralization (e.g., the state, administration, organization); (2) object, what is the subject of decentralization (e.g., power, rights, resources); (3) process – how decentralization occurs (horizontal, vertical, apparent, real, progressive, but also limited). Subjective decentralization is the most general in nature (Diaz-Serrano, Rodríguez-Pose, 2012, pp. 179-193). An organization consists of systems with many roots, the most important of which are social character, purposefulness, formalization, and economic component (Morozov, 2016, pp. 275-307). Objective decentralization is used in the context of an organization as a social group with a given level of formalization and specific resources at its disposal (Diaz-Serrano, Rodríguez-Pose, 2015, pp. 411-435). These resources are made up of many elements, integrated into a whole through organizational structures that determine the division of power, coordination, and integration of tasks, as well as the course of work processes and the manner of communication (Savy et al., 2017). Decentralization in a process-based approach means the process of transferring tasks, powers, responsibilities, and resources to local structures. Limits organizational subordination to higher-level entities. Allows independent use of powers and resources (OECD, 2019, pp. 4-19). In management and quality sciences, centralization is defined as the process of systematic maintenance of power and authority by higher-level managers, and decentralization as the process of systematic delegation of power and authority (Odoom, 2016, pp. 21-38; *The Economist*, 2009). The subject of analysis in this article is managerial decentralization understood as the delegation of responsibility to lower levels of management.

2.1. Managerial decentralization

Managerial decentralization, or delegation of responsibility (Polidano, 1999, p. 19), means transferring authority to lower-level managers in organizations and increasing the scope of authority and responsibility of the organization (Henderson, Medeiros, 2021, pp. 139-145). Decentralization understood in this way poses a management challenge because, in addition to delegating authority within the organization, it also encompasses the concept of deconcentration (Thomas, 2013, pp. 786-796). Delegation of public tasks in the context of political decentralization should be distinguished from delegation of public services (Andronic,

Dumitraşcu, 2018, pp. 408-413). In the first case, this means a permanent systemic transfer of responsibility for the performance of specific tasks, while in the second case, the transfer of tasks usually takes place through a tender or competition procedure and is limited in time (Polidano, 1999, pp. 227-239). Territorial decentralization processes can take place top-down through the transfer of powers from central authorities to organizations of the basic administrative division (Smith, 2023). The second option is the division of power between the center and the territorial organizations (Zelek, 2023). This results from the bottom-up integration of independent entities and the creation of joint political institutions (Ferlie et al., 1996, pp. 10-15). Material decentralization involves delegating public administration powers to entities that exercise them independently and autonomously (Zelek, 2025). Managerial decentralization can be defined as a technique for managing a public administration organization that involves expanding the autonomy of lower-level managers. It takes place within the structures of state administration (Smoke, 2015, pp. 97-112). The benefits of managerial decentralization include: rapid response to changes in the environment, stimulation of social participation, rapid decision-making, effective communication, and autonomy of objectives (Polidano, 1999, p. 19). The benefits that may result from the introduction of managerial decentralization mechanisms include, above all, streamlined strategic decision-making and ensuring an appropriate legal framework for public policy. In this process, current and potential comparative advantages should be exploited (Andronic, Dumitraşcu, 2018, pp. 408-413). Managerial decentralization emerged with the so-called first generation of reforms of the public administration of the NPM. Some management methods were transferred from the private sector to the state administration in order to increase its economy, efficiency, and effectiveness (Waldo, 2017, p. 169). The pioneering countries that began reforms in line with the concept of NPM were the countries of the British Commonwealth, led by the United Kingdom and the United States (Svara, 2017, pp. 33-55), followed by the Scandinavian countries (Green, 2002, pp. 271-294). Managerial decentralization was implemented in these countries in all areas of the public sector, from reforms in the management of military and police structures, through education, to healthcare and social assistance (OECD, 2016). One of the most important benefits of social welfare system reforms in western Europe and the United States, according to the NPM concept, is the replacement of administrators with managers (Drakeford, 2000, pp. 18-19).

2.2. European welfare models

The analysis of studies in the field of social policy resulted in the establishment of several classifications presenting various systems of policy implementation in the area of social welfare. A review of the literature shows that the most significant classifications were created by the following. Richard Titmuss (Titmuss, 1974); Norman Furniss and Dorothy Tilton (Furniss, Tilton, 1977); Gøst Esping-Andersen (Esping-Andersen, 1990).

Table 1.
Classifications of Social Welfare Models

Author	Model
R. Titmuss	– Marginal (residual) social policy can only intervene when the private market fails to meet needs. – Motivational (subservient, efficiency oriented) - social policy is treated as an addition to the economy, serving a subservient role. – Institutional-redistributive – social policy is an integral institution within a given society, with universal access to benefits and services based on need.
N. Furniss, D. Tilton	– Positive state – social policy aims to protect capital owners from difficulties associated with market forces and demands for income redistribution. – Social security state – the aim of social policy is to guarantee a minimum income for all citizens. – Welfare state – the aim of social policy is to equalize the living conditions of all citizens.
G. Esping-Andersen	– Liberal regime. – Conservative-corporatist regime. – Mediterranean regime – Social democratic regime. – Post-communist regime.

Source: own study based on: (Titmuss, 1974, pp. 138-147; Furniss, Tilton, 1977, pp. 249; Esping-Andersen, 1990, p. 248; Esping-Andersen, 2007, p. 6).

G. Esping-Andersen's concept remains the most important typology of social policies to this day. His classification of welfare state regimes is treated as a starting point in discussions about social welfare systems in European countries (Table 2).

Table 2.
Regimes of European social welfare models according to G. Esping – Andersen

Regime	Details
liberal (Anglo-Saxon)	– well-functioning market and family support, – marginal role of the state, – the state only steps in when the market does not meet the requirements for ensuring minimum subsistence, – state aid is only provided on a temporary basis, – by definition, most citizens should be able to cope well in the conditions of the market economy, – state interference may have harmful effects leading to decreased work productivity and economic slowdown.
conservative-corporatist regime	– permits the state's interference in the sphere of social policy, – the highest benefits are received by public sector employees.
Mediterranean regime	– elementary welfare state, – institutionalized promise of a modern welfare state, – limited participation of the state in social welfare activities, – very generous benefits for some groups with other groups not secured sufficiently, – shift from corporate solutions to partial universalism, – a special type of relationship between public and nonpublic entities in this sphere, – occurrence of the phenomenon of clientelism, – patronage system in the distribution of cash benefits in some spheres, – weakness of state institutions, – empowerment of political parties as main representatives of social interests.

Cont. table 2.

social-democratic regime	– social problems arise from the "system", – the state is responsible for the situation of citizens and their families, as well as for providing forms of assistance, – questioning the thesis that the private market and family are able to meet all human needs at the level expected from the social point of view, – the highest degree of the state's interference in the social policy sphere, – high level of institutionalization of social rights, – in the model, market criteria do not play any role in access to social welfare, – the state is responsible for the social security of citizens.
post-communist regime	– elements of a conservative welfare state and the liberal concept, – central management, – uniform organizational structure.

Source: own work based on: (Culfaz, 2016; Minas, 2014; Danforth, 2014; Valeyeva et al., 2011; Heath, 2011; Cerami, 2008; Esping-Andersen, 1985, 1990, 1999, 2007; Hoekstra, 2003).

The post-communist regime encompasses the countries of the former eastern bloc, including Poland. It is characterized by typical features of a socialist system. Post-communist countries had to make changes in the areas of state ownership, centrally planned economies, and autocratic governance. During the transition period in the 1990s, private property, a free market, and democratic systems of government were introduced (Cerami, 2008, p. 5). Rapid changes led to a lack of systemic coherence. These countries exhibit certain elements of a conservative welfare state and liberal concepts, but still retain features of the socialist system (Zelek, 2024). In some sectors, central management and a uniform organizational structure still exist (Esping-Andersen, 2007, p. 3). The countries where this regime operates include Bulgaria, the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia and Slovenia.

The article presents the results of original research obtained as part of the ‘Diagnosis of the management of social welfare organizational units’ among all local government social welfare organizations (LGSWO) in Poland. The conclusions obtained in the area of managerial decentralization, which is one of eight research constructs scaled by formative indicators using the Participatory Action Research method (Chevalier, 2019), are presented.

Two research hypotheses were formulated: H1: LGSWOs have mechanisms to transfer power to lower-level managers in management processes. H2: LGSWOs have processes for increasing the scope of authority and responsibility of lower-level organizations. An attempt will be made to answer the following question: Is the managerial approach to management in post-communist social welfare in Poland based on managerial decentralization?

3. Research Methods

The study covered 2,573 LGSWOs in Poland. The study used *Participatory Action Research* (PAR), a research method based on a scientific approach to solving practical organizational problems, with extensive participation of managers (Eden, Huxham, 1996, pp. 526-542; Cornish et al., 2023, pp. 1-14). The basic assumption of the research process was to conduct research 'with people' so that LGSWO managers would become its subjects (Heron, 1996, p. 236). These assumptions focused on conducting a two-stage research process (Brydon-Miller, Kral, Ortiz Aragón, 2020, pp. 103-111). In the first stage, a preliminary version of the research tool was created, which was then made available to selected LGSWOs and experts for verification and refinement (Karlsen, 1991, p. 146). The managers had a real impact on the creation of the research tool by commenting on the proposed statements. In the research process, for each observable variable developed in accordance with the PAR assumptions (each formative indicator, area/instrument), sets of questions/statements were developed to enable the assessment of a given variable (Karlsen, 1991, p. 146) in the form of an *OPS-OpenIndex* electronic form. After collecting the comments, the second stage began, that is, conducting the actual research.

In the second stage, the research tool was consulted with experts and practitioners managing LGSWO. The comments submitted by the experts mainly concern formal and legal issues related to the functioning of the organization, such as decision-making procedures. After consultation and consideration of the comments, the research tool was placed on the Web server www.google.com. An email was sent to 2573 LGSWOs with an invitation to participate in the study, along with a link to an electronic form that was active for 14 days according to the PAR guidelines. All responses were exported to *MS Excel* and then subjected to statistical analysis in *Statistica 13*.

Table 3.
A summary of the collected statistical data

Type of organizational unit social welfare	Total		% of complete form completion
	Sent forms	Full form completions	
LGSWOs	2573	1959	76,1%

Source: own study based on research results.

Multivariate data analysis was used to perform a descriptive analysis of the results (Table 3).

Table 4.
Multidimensional data analysis indicators

Indicator	Parameters
Cronbach's α coefficient	to assess the internal consistency (reliability) of the construct, taking values from 0 to 1 in a two-sided closed range. It was assumed that values greater than 0.6 indicate the reliability of the construct.
Kendall's tau coefficient	takes values from -1 to 1, with the higher the absolute value, the stronger the relationship between the statements under consideration (negative and positive, respectively). A value of zero means no relationship. Only variables for which the test probability p was lower than 0.05, indicating a statistically significant correlation, were considered.
A test probability	lower than 0.05 provided grounds for rejecting the null hypothesis. The strength of the relationship was then checked using the *Cramer V* coefficient. The latter takes values from 0 to 1 from a mutually closed range. The higher its value, the stronger the relationship between the variables.
The *chi-square* independence	test was used to check the relationships between the variables. Before its application, the assumption regarding the minimum numbers in the fields of the table with expected values was checked. The null hypothesis was: *There is no relationship between the studied variables and the alternative hypothesis: there is a relationship between the studied variables*.
The *t test* for independent	samples was used to check the differences between the two means. Assumptions regarding the conformity of the distributions of variables in groups with the normal distribution and the assumptions of homogeneity of variance in the groups were met. A test probability value lower than the significance level (here 0.05) provides grounds for rejecting the null hypothesis (H0: *the means in both groups are the same*) and accepting the alternative hypothesis (H1: *the means in the compared groups differ significantly*).

Source: own study.

The purpose of the study within the construct was to identify the time of decision making, the occurrence of political factors influencing the career advancement process, the manner of task formulation, the possibility of refusing to perform a task and, on the other hand, the increase in employee participation and the reliability of employee evaluation. An attempt was made to determine whether tasks were defined in a transparent manner and whether they were consistent with the qualifications and competencies of managers. The construct measuring managerial decentralization consisted of eight statements, whose numbering was deliberately changed so as not to suggest answers to potential respondents (Table 5).

Table 5.
OPS-Open Index - Managerial decentralization construct

No.	Area of decentralization	Statement
06.	Understandable tasks	The tasks and responsibilities for my position are clearly defined
24.	Clear instructions	I receive clear instructions on how to perform my tasks in the unit
29.	The right to refuse a task	I have the right to refuse to accept a task if it is inconsistent with my qualifications
36.	Implementation of other projects	Anyone who works in the unit, if they want, can take greater responsibility for its fate, e.g. by getting involved in nonstatutory activities, projects, etc.
44.	Informing about decisions	I am quickly informed about the decisions of my direct superiors
52.	Tasks consistent with duties	The work performed corresponds to the scope of tasks assigned to my position
56.	Tasks consistent with qualifications	The tasks assigned to me are consistent with my knowledge and experience
59.	Fair assessment	Employee evaluation is carried out in a fair manner

Source: own study based on research results.

4. Results of the research

The construct is reliable, as confirmed by Cronbach's alpha coefficient of 0.81. The division of the responses of the LGSWO respondents is presented in Table 6. and graphically in Figure 1.

Table 6.
Responses of LGSWOs respondents within the construct of managerial decentralization (in %, N = 1959)

Specification	S. 24	S. 44	S. 36	S. 52	S. 6	S. 56	S. 29	S. 59
I strongly disagree	5	4	6	1	4	7	18	17
I tend to disagree	16	11	9	3	10	11	26	25
I have no opinion	9	25	17	8	4	17	24	22
I tend to agree	47	44	37	49	40	42	23	26
I definitely agree	23	16	31	39	43	24	8	9

S. – means a statement.

Source: own study based on research results.

A summary analysis of the survey results confirmed that managers receive clear instructions on how to perform their tasks within the organization (statement 24). 47% of the respondents agreed with this statement to a moderate extent and another 23% strongly agreed. The respondents expressed the opinion that they are quickly informed about the decisions of their immediate superiors (statement 44), which was moderately confirmed by 44% of the surveyed group, but 25% of them did not express an opinion. 37% of the respondents agreed to moderate extent, and 31% strongly agreed that anyone who works at LGSWOs can assume greater responsibility for its fate if they so wish (statement 36). Similarly, high percentages of affirmative responses were recorded for Statement 52. 39% of the respondents confirmed that the work they perform corresponds to the scope of tasks assigned to their position, and 49% of the respondents agreed with this to a moderate extent.

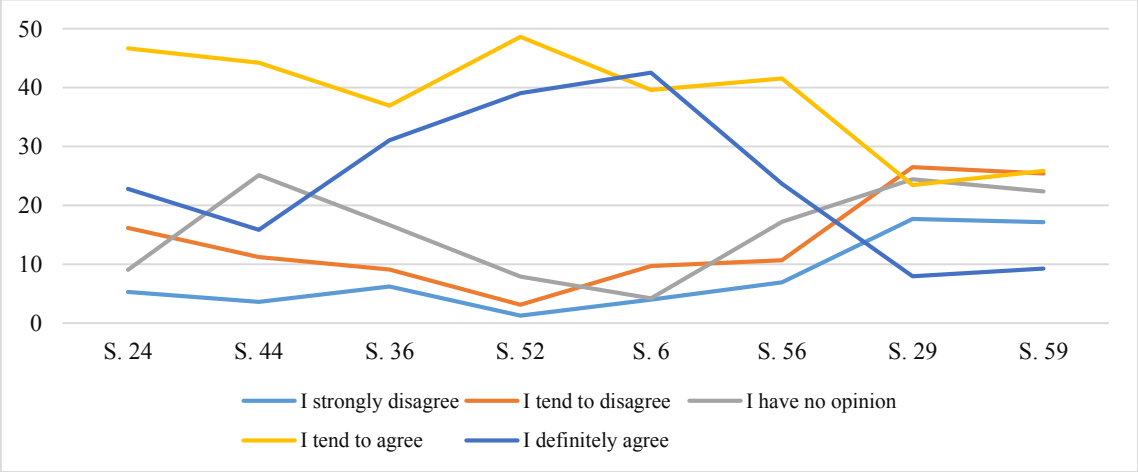


Figure 1. Responses of LGSWOs respondents within the construct of managerial decentralization (in %, N = 1959).

Source: own study based on research results.

The aggregated responses of the respondents indicate that the tasks and responsibilities of their positions are clearly defined (statement 6), with only 14% of the respondents disagreeing. The tasks assigned to them are generally consistent with their knowledge and experience (statement 56), which was moderately confirmed by 42% of the respondents and strongly confirmed by another 24%.

In the case of the last two statements, the responses were varied. It is difficult to determine whether the respondents have the right to refuse a task if it is not in line with their qualifications (statement 29). Twenty-six percent of the respondents did not confirm this relationship, but 23% confirmed this statement to a moderate extent. Twenty-four percent did not have an opinion. The aggregated results of the study indicated that the respondents did not express clear opinions on whether employee evaluations are conducted fairly (statement 59). 25% of the study group had doubts about this and 26% moderately considered the evaluation process fair.

The research construct contained eight statements, so the range of possible results was 8-40. The descriptive statistics obtained for LGSWOs are presented in Table 7.

Table 7.
Descriptive statistics for the construct of managerial decentralization in the LGSWOs sample

N valid	Mean arithm.	Median	Minimum	Maximum	Range	Std. deviation
1959	28,55	29,00	8,00	40,00	32,00	5,82

Source: own study based on research results.

The minimum and maximum responses were the same as the limits of the research construct. The mean and median were similar and amounted to 29.0. The standard deviation was 5.82.

There was a statistically significant ($p < 0.05$), positive, and moderately strong (Kendall's tau coefficient = 0.53) between statements 56 and 36. Managers who confirmed that the tasks assigned to them were consistent with their knowledge and experience also believed that everyone working at LGSWO could take greater responsibility for its results. A moderately positive relationship (Kendall's tau coefficient = 0.45) and statistically significant ($p < 0.05$) relationship was found between statements 24 and 56. This means that respondents who claim to receive clear instructions on how to perform tasks in the organization expressed the opinion that the tasks assigned to them were consistent with their knowledge and experience. A statistically significant ($p < 0.05$), positive and moderately strong (Kendall's tau coefficient = 0.47) correlation was also found for statements 6 and 24. Respondents who claimed that the tasks and responsibilities of their position were clearly defined stated that they received clear instructions on how to perform tasks within the organization.

As a result of applying multi-index formative indicators for the construct of managerial decentralization in LGSWOs, the level of delegation of authority to lower-level managers in organizations (H1) and the increase in the scope of authority and responsibility of LGSWOs (H2) were identified. Therefore, the following research hypotheses should be confirmed:

- in LGSWOs, there are mechanisms for transferring power to lower-level managers in management processes (H1),
- in LGSWOs, there are processes for increasing the scope of authority and responsibility of lower-level organizations (H2).

The answer to the question of whether, in the opinion of LGSWO managers, managerial decentralization is the result of delegating responsibility to lower levels of management should also be affirmative.

5. Discussion

Managers confirmed that they receive clear instructions on how to perform their tasks at LGSWOs and also responded that they are quickly informed about the decisions of their immediate superiors. Accessibility to all people working in the organization and the opportunity to assume greater responsibility for its tasks were rated highly. Similarly, a high percentage of respondents said that the work they do corresponds to the scope of tasks assigned to their position. The answers clearly show that the tasks and responsibilities of their positions are clearly defined and that the tasks assigned to them are generally consistent with their knowledge and experience. The results of the study confirm the slogan of D. Osborne and T. Gaebler (1992): *let managers rule and authorities steer*, *not row*, which defines managerial decentralization. In the study, there was no unanimity among managers about the lack of refusal to perform a task when it did not match their qualifications. It was noted that the employee evaluation process is not entirely fair. Those who agreed that the tasks assigned to them were in line with their knowledge and experience generally also believed that anyone working in the organization could take on more responsibility for the tasks performed if they wanted to. Reiter, R. and Kulhmann, S. (2016), analyzing the problems of decentralization of the French welfare state, points to the excessive expectations of central authorities towards local organizations. These dependencies should be considered in relation to Poland's location among the countries of Central and Eastern Europe (CEE), where, according to G. Esping-Andersen, a post-communist social welfare regime characterized by a conservative approach to management prevails (Esping-Andersen, 2007, pp. 3-6). One of the assumptions of the NPM concept – business-like management (Kickert, 1997, p. 731) – indicates that managerial decentralization should be implemented in a process-oriented manner with the involvement of central authorities at various levels. From the point of view of further research, it seems

interesting to perform a diagnosis of managerial decentralization in a transnational dimension, taking into account the specificity of social welfare systems in CEE countries (Hajnal, Jeziorska, Kovács, 2021, p. 615). Social policy faces new challenges. The profile of social assistance clients is changing. It is not only CEE countries that are looking for new solutions in the area of social welfare systems.

Respondents who stated that they had received clear instructions on how to perform their tasks generally considered that the tasks assigned to them were in line with their knowledge and experience. Managers who felt that the tasks and responsibilities of their position were clearly defined often also felt that they had received clear instructions on how to perform their tasks within the organization. Diverse opinions emerged in the context of how quickly people were informed about the decisions of their immediate superiors. A significant number of neutral responses (25%) were observed in response to Statement 44. This phenomenon indicates potential problems that may impact intra-organizational communication and decision-making. Communication problems can reduce the effectiveness of tasks performed. One of the postulates of the NPM concept according to Ferlie E. Fitzgerald L. and Pettigrew is to reduce the size of organizations and decentralize management, which are important tools for improving the efficiency of public sector organizations (Ferlie, Fitzgerald, Pettigrew, 1996, pp. 10-15).

6. Conclusions

It is worth noting that the respondents' responses varied depending on their age. Younger managers showed a more critical approach in responding to older people. This suggests that the younger generation expects a higher level of delegation of responsibility and autonomy. The development process will not be possible without cooperation, partnership, and shared responsibility among public entities. This is reflected primarily in the shift from an administrative system to a system of decentralization and delegation of responsibility, which is one of the elements leading to an increase in the role of human and social capital, a reduction in social exclusion, poverty, and social inequalities, an improvement in quality of life, and an increase in the competence of social welfare organization employees. The conclusions of this article provide public policy managers with information on the current state of affairs and the need to pursue decentralization processes in response to the changing socioeconomic environment. Managerial decentralization processes are of great importance in improving organizational efficiency and the effectiveness of social services. A new approach to social service delivery is currently being proposed - "transformation design"—based on relationships, technology, collaboration, and service design "from the bottom up" rather than centrally imposed. Social welfare organizations operate within a networked, self-organizing system. Managerial decentralization significantly impacts service delivery, decentralizes and

deconcentrates power, and promotes proactive management and catalyzes interagency and intersectoral collaboration.

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GENDER DIFFERENCES IN PERCEPTION AND BEHAVIOR TOWARDS CYBER THREATS – RESEARCH RESULTS AMONG FINANCIAL SERVICES USERS IN POLAND

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Purpose: This study aims gender differences in the perception of cyberthreats and cybersecurity behaviours among users of financial services in Poland. The paper seeks to determine whether men and women differ in their attitudes, risk assessment, and protective practices in the context of rapidly expanding digital banking and online financial services.
Design/methodology/approach: The research was conducted using the CAWI method on a sample of Polish users of financial services. Statistical analyses included the Pearson's chi-square test and the Mann–Whitney U test, allowing the identification of significant gender-based differences in the perception of cyberthreats and cybersecurity behaviours.
Findings: The results show that although men and women assess their knowledge of cyberthreats similarly, their practical behaviours differ. Women are more likely to apply additional security measures—such as complex passwords, biometric authentication, and two-factor authentication—and to regularly monitor their bank accounts. Men tend to express a higher sense of digital security. Differences were also observed in the perceived responsibility of institutions for ensuring cybersecurity.
Research limitations/implications: The study is limited by the use of self-reported data and a non-probabilistic sampling method. Future research could expand the sample, include behavioural tracking measures, or compare findings across countries.
Practical implications: The findings indicate the need to differentiate educational and communication strategies in cybersecurity. Financial institutions and public agencies should tailor training materials and awareness campaigns to gender-specific behavioural patterns.
Social implications: By highlighting gender-related differences in cybersecurity practices, the study supports initiatives aimed at improving digital safety and reducing exposure to cyber threats. The results may inform public policy and contribute to more effective national cybersecurity education programmes.
Originality/value: This study provides one of the few empirical analyses of gender differences in cybersecurity behaviour specifically within the context of financial services in Poland. It offers new insights for researchers, practitioners, and policymakers by combining perception-based and behaviour-based measures of cybersecurity.
Keywords: cybersecurity, gender differences, cyberthreats, financial services users, digital safety.
Category of the paper: Research paper.
JEL Code: D83, D91, G21.

1. Introduction

In an era of intense digitization of the economy and society, cybersecurity issues have become crucial for both individuals and public and private institutions. The dynamic development of information and communication technologies (ICT) and the growing popularity of online banking, social media, and e-commerce mean that internet users are increasingly exposed to cyber threats. According to a report by the European Union Agency for Cybersecurity (ENISA, 2024), as many as 84% of internet users in EU countries have experienced at least one cybersecurity incident in the last three years. In this context, it is crucial to understand how different social groups – including women and men – perceive the risk of cyber threats, what protective strategies they employ, and how they respond to data breaches.

Cybersecurity is defined as "the ability to protect information systems, networks, and data from cyberattacks, their unauthorized use, damage, or destruction" (Kuzior et al., 2024). The literature emphasizes that the effectiveness of cybersecurity depends not only on technology but also on the human factor – knowledge, awareness, and behavior of users (Metalidou et al., 2014). For this reason, research on behavioral aspects of cybersecurity is gaining importance, combining IT with psychological, sociological, and economic perspectives.

Previous studies on online user behavior have repeatedly highlighted the importance of gender differences in the use of digital technologies, risk assessment, and response to threats (Cele, Kwenda, 2023; Sulaiman et al., 2022). Women are more likely to be cautious and more prone to following security rules, while men demonstrate greater confidence in using digital tools but are also more likely to engage in risky behavior online (Alrababah, Iqbal, Khan, 2024). These differences stem from both social factors (e.g., stereotypes regarding technological competence) and psychological factors (e.g., different levels of risk perception, emotional reactions, and motivation to learn cybersecurity principles). From an economic and organizational perspective, understanding these differences has practical implications. Knowledge about the different behavioral patterns of women and men can help financial institutions, public administration, and technology companies design more effective educational strategies, information campaigns, and digital security training programs. International research findings (including the Global Cybersecurity Index and ITU 2023) show that countries with higher levels of public awareness of cybersecurity experience fewer incidents involving individual users. In this context, examining gender differences can provide valuable information on areas that require specific educational support.

In Poland, as in many other European countries, there is an increase in the number of cyber incidents affecting both individual users and businesses. Data from CERT Polska (2024) shows that the most common threats are phishing, social engineering attacks, login credentials theft, and malware installed on mobile devices. With the development of online banking and mobile

payments, user trust in the digital environment is becoming increasingly important. Research indicates that women are more likely than men to express concerns about losing financial data, while men are more likely to downplay the risk (Al Doghan, 2024). Such differences may affect not only the level of individual security but also the rate of adoption of modern financial technologies, such as mobile payments or investment apps.

The aim of this article is to identify and analyze gender differences in the perception and behavior toward cyberthreats among financial services users in Poland. In an era of dynamic development of digital technologies, this issue is particularly important from the perspective of both financial science and digital security. Analyzing gender differences in risk perception, security measures used, and responses to digital threats will allow for a better understanding of the factors determining user behavior in the online environment. The obtained results contribute to the development of knowledge about the social determinants of cybersecurity and can serve as a basis for practical recommendations for financial institutions and public policymakers.

The originality of this study lies in its empirical focus on gender differences in both the perception of cyberthreats and actual cybersecurity behaviours among financial services users in Poland. Unlike many previous studies that concentrate primarily on technological aspects of cybersecurity or on general internet use, this research combines perception-based and behaviour-based measures within the specific context of digital financial services. By addressing a nationally specific yet underexplored setting, the study fills a gap in the literature and contributes empirical evidence relevant for both academic research and practical cybersecurity policy.

2. Methods

The study was conducted using an online survey (CAWI) on a sample of 1539 financial service users, including 864 women (56.1%) and 675 men (43.9%). Financial service users were defined as those using online banking and other forms of digital financial services. Respondents represented a variety of age groups, education levels, and places of residence. The largest group were participants aged 18-24 (45.4%), while those over 55 constituted 19.5% of the sample. The majority of respondents had higher education (52.4%) or secondary education (46.4%). Nearly half of the respondents lived in rural areas (45.8%), and 23% lived in cities with populations between 50,000 and 100,000. Household income per person was most often in the range of PLN 4001-6000 (25.7%) or above PLN 6000 (25%). Most households had two (34.7%) or four (26.1%) people. The study was conducted on a non-randomly selected sample.

The following research hypotheses were formulated in this study:

H1: Men rate their knowledge of cyber threats in online banking higher than women.

H2: Women demonstrate a higher level of concern about cyber threats than men.

H3: Men are more likely than women to report feeling safe when using online banking.

H4: Men are more likely than women to trust non-bank financial institutions.

H5: Indications regarding industries perceived as leaders in cybersecurity differ by gender – men are more likely to choose banks and fintech companies, while women are more likely to choose service institutions (e.g., public administration, online payment operators).

H6: Men are more likely than women to use technological security measures (e.g., biometrics, 2FA), while women are more likely to follow precautionary measures (e.g., regularly changing passwords).

H7: Men are more likely than women to use the same passwords across different services.

H8: Women are more likely than men to regularly monitor their bank accounts to detect unauthorized transactions.

Statistical analysis methods appropriate for qualitative and ordinal data were used to verify the hypotheses. The Mann-Whitney U test was used to assess differences between two independent groups. This is a nonparametric statistical test used when the dependent variable is ordinal or when the data distribution deviates from normality, thus not meeting the assumptions of parametric tests (Moczko, Bręborowicz, Tadeusiewicz, 2013). The test analyzes the ranks of observations assigned to both groups, assessing whether there are significant differences between them. Results are presented using the U statistic, which is then converted to a p-value to determine statistical significance (Chicco, Sichenze, Jurman, 2025). The chi-square test of independence (χ^2) and Cramér's V coefficient, which allows for determining the strength of the relationship between the analyzed characteristics, were used to examine the relationships between qualitative variables (Wiktorowicz, Grzelak, Grzeszkiewicz-Radulska, 2020). A significance level of $p < 0.05$ was used in all analyses.

The V coefficient values were interpreted according to the following criteria: 0.10 indicates a weak relationship, 0.30 indicates a moderate relationship, and 0.50 indicates a strong relationship. This coefficient ranges from 0 to 1, regardless of the number of categories in the contingency table (Prajzner, 2022; Wiktorowicz, Grzelak, Grzeszkiewicz-Radulska, 2020). The tables also provide degrees of freedom (df), determined based on the number of categories in the variables analyzed.

3. Results and discussion

This section of the article presents the results of an analysis of differences between women and men in their perceptions and behaviors toward cyberthreats in the context of using e-banking and digital financial services. The analysis encompassed subjective assessments of knowledge about digital threats, levels of concern and trust in financial institutions, and practices for securing bank accounts. The results are presented in the order of the research hypotheses.

Table 1 presents the results of the analysis of differences in self-assessed knowledge of cyber threats in e-banking by gender. The results of the Mann-Whitney U test did not reveal statistically significant differences between women and men ($U = 279634.5$; $p = 0.102$). The mean rank for women (783.85) was slightly higher than for men (752.27), which may indicate that women report a slightly higher level of knowledge, but this difference remains statistically insignificant. This indicates that the level of subjective knowledge of digital threats is comparable between both genders. Consequently, hypothesis H1, which assumed that men rate their knowledge of cyber threats higher than women, was not supported.

Table 1.
Gender differences in self-assessment of knowledge about cyber threats

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
Self-assessment of knowledge about cyber threats	279634.5	752.27	783.85	0.102

Source: Own work.

The obtained results are consistent with some previous studies indicating a lack of significant gender differences in perceived cybersecurity competence or behaviors. For example, Branley-Bell et al. (2022) found that gender was not a significant predictor of information security behaviors in a study that included practices such as password generation, device security, and software updates ($n = 579$), which may support the thesis of a systematic reduction in gender differences in this area, resulting, among other things, from similar levels of exposure to digital technologies.

Table 2 presents the results of the analysis of differences in the level of concern about cyber threats related to e-banking by gender. The results of the Mann-Whitney U test revealed no significant differences between women and men ($U = 280881.0$; $p = 0.2008$). The mean rank of women (782.41) was higher than that of men (754.12), which may indicate a slightly higher level of concern among women, but this difference remains statistically insignificant. Therefore, hypothesis H2, according to which women demonstrate a higher level of concern about cyber threats than men, was not confirmed.

Table 2.
Gender differences in the level of concern about cyber threats in e-banking

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
Level of concern about cyber threats	280881.0	754.12	782.41	0.2008

Source: Own work.

The literature finds evidence that women are more likely than men to report higher levels of concern or risk perception in the digital space (Stevens et al., 2024). McGill and Thompson (2018) also indicate that although women perceive the effects of potential security incidents as more severe (higher perceived severity), they do not feel more vulnerable to such threats than men. In light of these studies, the result of our study—the lack of a significant gender difference in the level of concern—may suggest that in the context of e-banking, both genders have similar risk perceptions, and the specific nature of e-financial services may partially offset the differences observed in other areas of digital activity.

Table 3 presents the results of the analysis of differences in the sense of security when using e-banking by gender. The question was rated on a five-point scale (1 – I definitely do not feel safe, 5 – I definitely feel safe). The results of the Mann-Whitney U test confirmed the existence of statistically significant differences between women and men ($U = 231{,}435.0$; $p < 0.001$). The mean rank of men (680.87) was lower than that of women (839.64), which – considering the direction of the scale – means that men were more likely to report a higher level of security when using e-banking. Therefore, hypothesis H3, which assumed that men were more likely than women to report feeling secure in the e-banking environment, was confirmed.

Table 3.
Gender differences in the sense of security when using e-banking

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
A sense of security against cyber threats	231435.0	680.87	839.64	<0,001*

Source: Own work.

Interpretation of these results indicates that men are more likely to report a high sense of security when using online banking, which may be associated with a higher level of technological confidence. However, a higher sense of security does not necessarily reflect a true level of preparedness to cope with cyberthreats. This phenomenon is confirmed by the results of Polish population studies (Warsaw Institute of Banking, 2025), in which men more often indicated that they felt safe in the digital environment, despite simultaneously being aware of numerous threats related to using the internet and social media. This study also noted that residents of large cities aged 45+ more often reported a higher sense of security, while education level did not differentiate this indicator.

The results of this study suggest a discrepancy between risk assessment and a sense of security in women and men. Although both groups perceive digital threats similarly, women are significantly more likely to feel less safe in the online banking environment. This may be due to differences in the subjective sense of control over the security of digital services, rather than actual levels of knowledge or experience. At the same time, women's higher caution may

have a protective effect, while men's greater self-confidence—if not accompanied by appropriate vigilance—may increase their vulnerability to security incidents.

Table 4 presents the results of the analysis of differences in the level of trust in non-bank financial institutions regarding cybersecurity by gender. Responses were rated on a five-point scale (1 – I strongly distrust, 5 – I strongly trust). The results of the Mann-Whitney U test indicate statistically significant differences between women and men ($U = 220918.5$; $p < 0.001$). The mean rank of women (851.81) was higher than that of men (665.29), which – considering the direction of the scale – means that women were more likely to declare a higher level of trust in non-bank financial institutions. Hypothesis H4 (men are more likely than women to trust non-bank financial institutions) was therefore not confirmed.

Table 4.
Gender differences in the level of trust in non-bank financial institutions in terms of cybersecurity

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
Trust in non-bank financial institutions	231435.0	680.87	839.64	<0,001*

* $p < 0,05$ – statistically significant results.

Source: Own work.

The obtained results indicate that women in the study sample declared a significantly higher level of trust in non-bank financial institutions than men, which contradicts some previous research. The literature on fintech and digital financial services often emphasizes that women are more cautious, more likely to be concerned about security issues, and less likely to use innovative financial solutions. For example, Chen (2023) describes the so-called "fintech gender gap," indicating that women are less likely than men to use fintech services due, among other reasons, to greater concerns about privacy and security. Similarly, Sikakebieke and Kuanova (2025) demonstrated that women in emerging markets are characterized by a lower propensity to adopt digital financial services and a lower level of trust in them.

At the same time, other studies demonstrate that gender differences in trust are not clear-cut and may depend on context. Sholevar and Bachmann (2025) emphasize that gender alone does not determine the level of trust in financial services. Meanwhile, the results of Yadav et al. (2024) show that women's trust in digital services increases when solutions are perceived as safe, intuitive, and user-friendly.

Considering these results, the fact that women in the study sample are more likely to trust non-bank financial institutions than men may suggest that, in the Polish digital services market, traditional gender differences in perceived security are gradually weakening, or even partially reversing. It is possible that the transparency of interfaces, communication emphasizing security, and positive user experiences lead women to perceive such entities as more trustworthy. At the same time, the results suggest that trust-building strategies in the financial environment should take into account the different security expectations of women and men and their different sensitivity to risk factors.

Table 5 presents the results of the analysis of the relationship between respondents' gender and the perception of various industries and institutions as cybersecurity leaders. The Pearson χ^2 test revealed statistically significant differences ($p < 0.05$) in eight of the nine analyzed categories. This indicates that the perception of cybersecurity leaders varied depending on the respondents' gender. The obtained Cramér's V coefficient values ranged from 0.035 to 0.233, indicating that the relationship between respondents' gender and the perception of specific industries as cybersecurity leaders is weak.

The strongest relationships were observed for online payment operators (V = 0.231) and insurance companies (V = 0.233), where the correlation reached a moderate level. For other categories—such as banks, technology companies, public administration, telecommunications companies, shopping platforms, and fintech companies—V values ranged from 0.056 to 0.108, indicating weak relationships. The lowest coefficient value was observed in the "other" category (V = 0.035), where no statistically significant differences were found.

Table 5.
The relationship between gender and the industry perceived as a leader in cybersecurity

Industry / institution	χ^2	df	V	p-value
Banks	18.06	1	0.108	< 0.001*
Technology companies	5.19	1	0.058	0.0227*
Public administration	8.29	1	0.073	0.004*
Telecommunications companies	7.74	1	0.071	0.0054*
Online payment operators	82.26	1	0.231	< 0.001*
Insurance institutions	83.45	1	0.233	< 0.001*
Shopping platforms	4.78	1	0.056	0.0288*
Fintechs	12.87	1	0.091	< 0.001*
Other	1.90	1	0.035	0.1678

* $p < 0,05$ – statistically significant results.

Source: Own work.

Table 6 presents the gender breakdown of responses regarding the perception of industries and institutions as leaders in cybersecurity. Men were more likely than women to identify banks (86.7% and 78.1%, respectively), and fintech companies (13.3% and 7.6%). Women, on the other hand, were more likely to identify technology companies (27.4% vs. 22.2%), public administration (12.2% vs. 7.6%), telecommunications companies (1.4% vs. 0%), online payment operators (34.7% vs. 14.2%), insurance institutions (11.8% vs. 0%), and shopping platforms (8.3% vs. 5.3%). In the "other" category, the percentage of responses was negligible in both groups (<1%).

Table 6.
Structure of responses by gender regarding the perception of industries and institutions as leaders in the field of cybersecurity (in %)

Industry / institution	Women (%)	Men (%)
Banks	78.1	86.7
Technology companies	27.4	22.2
Public administration	12.2	7.6
Telecommunications companies	1.4	0.0
Online payment operators	34.7	14.2
Insurance institutions	11.8	0.0
Shopping platforms	8.3	5.3
Fintechs	7.6	13.3
Other	0.0	0.4

The question was multiple choice, so the percentages presented in the table do not add up to 100%.

Source: Own work.

These results confirm that women more often associate cybersecurity with consumer and service institutions, while men more often associate it with the financial and technology sectors. This indicates different patterns of digital security perception depending on gender. Hypothesis H5, which assumed that indications regarding industries perceived as leaders in cybersecurity differ by gender, was confirmed.

The results of our study partially correspond to the results of population-based studies conducted in Poland. The Warsaw Institute of Banking (2024), in its report "Cyberbezpieczny Portfolio", conducted on a representative sample of adult Poles, indicates that banks are clearly recognized as leaders in cybersecurity (54% of responses). Technology companies (30%) and uniformed services such as the military (29%) and the police (28%) also rank highly. These results confirm the dominant position of banks in the public consciousness as entities responsible for cybersecurity.

According to Chen (2023), men are more likely to use fintech services than women, which may contribute to a stronger association of these institutions with digital security. Furthermore, research on the adoption of mobile payments and trust in digital services indicates that women place their trust more heavily on the perceived security and transparency of solutions, as well as on the quality of communication regarding security (Murphy, Tocher, 2011). This may explain why, in this study, women were more likely to identify online payment operators, technology companies, and public administration as leaders in cybersecurity – these institutions are often perceived as responsible for digital infrastructure and for implementing security standards.

Hossain's (2019) study on the adoption of mobile payments found that perceived risk negatively impacts customer trust, and trust is a key factor in building loyalty to mobile services. The author also emphasizes that gender moderates the relationships between perceived security, trust, and the adoption of mobile payments, further indicating that the importance of security may differ between women and men. The results of this study therefore fit into the broader context of literature confirming that trust-building mechanisms in digital services are

gender-specific and may translate into the perception of various industries as cybersecurity leaders.

Table 7 presents the results of the analysis of the relationship between respondents' gender and the methods used to secure access to bank accounts. All analyzed relationships were statistically significant ($p < 0.001$). Cramér's V coefficient values ranged from 0.089 to 0.524, indicating weak to strong relationships. The strongest relationships were observed in the absence of additional security measures ($V = 0.524$) and in the use of two-factor authentication ($V = 0.342$).

Table 7.
The relationship between gender and the use of bank account security methods

Dependent variable	χ^2	df	V	p-value
Using a strong password (a combination of letters, numbers, and special characters)	12.27	1	0.089	< 0.001*
Different passwords for different accounts (e.g. bank, email, social media)	44.23	1	0.17	< 0.001*
Change your password quarterly or more often	37.93	1	0.157	< 0.001*
Two-step verification (SMS code, in-app confirmation)	180.09	1	0.342	< 0.001*
Biometrics (fingerprint, facial recognition)	108.04	1	0.265	< 0.001*
No additional security measures	421.99	1	0.524	< 0.001*

* $p < 0,05$ – statistically significant results.

Source: Own work.

To determine the direction of the relationship, an analysis of the structure of responses by gender was conducted (Table 8). The results indicate that women are more likely than men to declare the use of all analyzed security measures – both traditional (strong passwords, different passwords, regular password changes) and technological (biometrics, two-factor authentication). The lack of additional security measures was significantly more common among men (44.4%) than women (1.7%).

Table 8.
Structure of responses by gender regarding the methods used to secure a bank account (%)

Security method	Women (%)	Men (%)
Strong password (combination of letters, numbers, special characters)	75.3	67.1
Different passwords for different accounts (e.g. bank, email, social media)	37.2	21.3
Change your password quarterly or more often	16.7	6.2
Two-step verification (SMS code, in-app confirmation)	77.1	43.6
Biometrics (fingerprint, facial recognition)	48.6	22.7
No additional security measures	1.7	44.4

The question was multiple choice, so the percentages presented in the table do not add up to 100%.

Source: Own work.

The results suggest that women demonstrate a higher level of concern for bank account security and greater awareness of cybersecurity. Hypothesis H6 (men are more likely than women to use technological security measures, while women are more likely to adhere to precautionary measures) was not confirmed.

The co-occurrence of multiple cybersecurity practices among female respondents suggests the presence of behavioural clustering in digital security strategies. Women simultaneously report significantly higher use of strong and diversified passwords, biometric authentication, and two-factor verification, indicating a more holistic and integrated approach to account protection rather than isolated defensive actions. Although formal cluster analysis was not conducted in this study, the observed pattern of combined safeguards points to the existence of distinct behavioural profiles in cybersecurity practices, which may differentiate users not only by gender but also by their overall security orientation.

A study by Liu et al. (2025) demonstrated that gender influences the use of digital financial services and risk responses, which may explain women's increased vigilance regarding security. Coopamootoo and Ng (2023) indicate that women are more likely than men to use online security advice and are more likely to use security measures. These results are consistent with the findings, which indicate that women are more likely to report using various security measures (strong passwords, 2FA, biometrics). This difference may result from women's higher risk perception or lower technological confidence, which translates into the use of more security measures.

Table 9 presents the results of the analysis of differences between women and men in using the same passwords across various online services, including online banking. The gender differences were statistically significant ($U = 250105.5$; $p < 0.001$). Men's mean rank (831.47) was higher than women's (721.97), indicating that men are more likely than women to use the same passwords across various accounts, such as banks, email, and social media. The results indicate men's lower level of caution when it comes to password management and a greater propensity for risky behaviors related to digital security. Hypothesis H7 (men are more likely than women to use the same passwords across various services) was confirmed.

Table 9.
Gender differences in the use of the same passwords on different websites

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
Using the same passwords on different websites	231435.0	680.87	839.64	<0.001*

* $p < 0,05$ – statistically significant results.

Source: Own work.

The latest survey, "Poles' Attitudes Toward Cybersecurity" (Warsaw Institute of Banking 2025), conducted on a representative sample of adult Poles (n = 1008), revealed a low level of use of password security tools. Only 10% of respondents reported using password generators that create strong, difficult-to-crack combinations. One in three respondents (32%) creates passwords themselves, basing them on their own word associations. However, 19% of respondents – primarily those aged 18-34 – store passwords in a password manager, providing them with a higher level of protection.

Table 10 presents the results of the analysis of differences between women and men in the frequency of monitoring bank accounts to detect unauthorized transactions. The results of the Mann-Whitney U test ($U = 229671.0$; $p < 0.001$) indicate statistically significant differences between the sexes. The question used a five-point scale, with lower scores indicating more frequent bank account monitoring (1 = daily, 5 = no monitoring). The mean score for men (861.75) was higher than for women (698.32), indicating that men monitor their bank accounts less frequently than women.

The results suggest that women are more systematic and vigilant in monitoring financial transactions, which may reflect their higher level of cybersecurity caution. Hypothesis H8 (women are more likely than men to regularly monitor their bank accounts to detect unauthorized transactions) was supported.

An important empirical finding of this study is the perception–behavior gap observed among male respondents. While men report a higher sense of security when using digital financial services, this subjective confidence is not accompanied by corresponding protective behaviours, such as regular account monitoring or diversified password use. This mismatch between perceived safety and actual cybersecurity practices may increase vulnerability to cyber incidents and shows that self-reported feelings of security do not necessarily reflect users' actual level of protection.

Table 10.
Gender differences in bank account monitoring frequency

Variable	U	Mid Rank (Men)	Mid Rank (Women)	p-value
Bank account monitoring frequency	229671.0	861.75	698.32	< 0.001*

* $p < 0,05$ – statistically significant results.

Source: Own work.

In the context of the literature, these findings can be interpreted as part of a broader trend: according to studies by Liu et al. (2025) and Coopamootoo and Ng (2023), women are more likely to take preventative measures and demonstrate greater awareness of digital threats than men. Women are more likely than men to use security advice and more actively implement protective measures regarding digital services. At the same time, Lobão's (2024) study indicates that men tend to overestimate their risk tolerance, which can actually lead to lower risk perception and lower vigilance. Therefore, financial institutions should consider differentiated communication strategies—including incentives and reminders to regularly monitor acccounts—to increase vigilance among all users, especially men.

4. Summary

The study revealed gender differences in cybersecurity behavior in online banking. Although women and men report similar levels of awareness of threats and concern, women are more likely to take preventative measures—using complex and diverse passwords, utilizing two-factor authentication and biometrics, and regularly monitoring their accounts. This indicates a higher level of operational vigilance and awareness of the potential consequences of security incidents. Men, on the other hand, more often report feeling secure when using financial services, although this does not always translate into the implementation of appropriate security measures. The noticeable discrepancy between a high sense of security and a greater propensity for risky behavior may increase their vulnerability to cybersecurity incidents. The results also indicate different trust patterns: men are more likely to perceive banks and fintech companies as security leaders, while women assign a greater role to banks and payment processors. In practice, this suggests the need for differentiated communication approaches.

Based directly on the identified empirical patterns, cybersecurity communication and education strategies should be differentiated by gender. Given men's higher subjective sense of security combined with weaker protective behaviours, interventions targeting male users should prioritize reminders for regular transaction monitoring, warnings against password reuse, and automated alerts. In contrast, women's more frequent use of advanced security measures suggests that educational efforts should focus on reinforcing these behaviours and sustaining engagement with technological safeguards such as biometrics and two-factor authentication. Such targeted approaches may enhance the effectiveness of cybersecurity policies and reduce users' exposure to digital financial risks.

Knowledge about the different behavioral patterns of women and men can support financial institutions, public administration, and the technology sector in more effectively designing targeted educational and communication strategies regarding cybersecurity. Access to tailored messages may contribute to more informed and responsible user behavior in the digital environment, thereby reducing society's vulnerability to cybersecurity incidents.

This study was based on a non-random sample, which limits the generalizability of the results to the entire population of financial services users in Poland. The study also focused on gender, omitting other factors that could significantly differentiate attitudes and behaviors, such as age, education, level of digital literacy, technological experience, and cultural background. Future research would benefit from a multidimensional approach and the inclusion of behavioural data, allowing for a more comprehensive assessment of cybersecurity practices in real-world settings.

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