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FOREWORD

We are delighted to present the latest number of Silesian University of Technology. Scientific Papers. Organization and Management Series. The main theme, "Towards the Future of Management", encompasses a range of research topics in management and innovation.

This edition of the journal delves into diverse management challenges and strategies in different sectors, including healthcare, energy, and emerging technologies. It encompasses a spectrum of articles that emphasize the need for innovative approaches to address contemporary issues. Each contribution enriches management theory and practice, underscoring the evolving and dynamic nature of today's business landscape.

Aleksandra Czupryna-Nowak
Mateusz Trzeciak

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ORGANIZATION AND MANAGEMENT SERIES NO. 186

APPLICATION OF AI IN CRISIS MANAGEMENT

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Purpose: Artificial intelligence (AI) can be applied in various areas of crisis management. It can provide numerous benefits concerning speed, effectiveness and precision of actions. AI accelerates the process of massive amounts of data processing, such as sensor data, satellite images, social data streams and much more. This enables to make quick analysis of a situation and make quick decisions in order to monitor various sources of information in real-time and detect early signals of a crisis. Advanced algorithms can identify patterns and anomalies enabling a quick response. AI can be used to model various crisis scenarios based on available historical and current data. This way it is possible to predict the probable effects of a given crisis and prepare for various situations. AI can analyze social media data to monitor community sentiments, identify potential threats and manage crisis communication. Automatic sentiment analysis systems can help understand society's response to a crisis. Advanced AI systems can be used to predict human behavior in various crisis scenarios. This allows to understand better how people may react and what their needs are in a given time. AI can help detect and combat cyber attacks, which constitute a serious threat, especially when it is necessary to maintain critical infrastructures. Integrating AI into crisis management requires caution because decisions made by AI systems should be consistent with ethical standards and they must consider the human supervision and assessment of the crisis situation.
Design/methodology/approach: The paper analyzes the AI methods applied during crises. The results of interviews conducted with students, teachers and authors' personal experiences are provided.
Findings: AI is a new way of solving problems, especially during crises. The new technologies determine the way and the speed of problems solving.
Originality/value: Originality based on the interviews and post-crisis (COVID) points of view are the value.

Keywords crises, AI, Chat GPT.

Category of the paper: Research paper, Viewpoint.

1. Introduction

In today's dynamic educational environment, where teachers, students, and educational institutions have to cope with various challenges, the application of artificial intelligence (AI) is becoming a significant research and implementation area (Banasik, Kempa 2023; Usidus 2023a, 2023b, 2023c, 2023d; Lindebaum, Fleming, 2023). In particular, the development of AI technology is offering new perspectives in the field management crisis in education. It enables faster reactions to sudden situations and more effective coordination of activities. This paper focuses on the analysis of specific applications of artificial intelligence in the context of management crisis in education. It also examines how modern technologies can support educational systems in coping with the challenges that educational surrounding variability provides (Fazgalić, 2022; Grioux, 2021).

ChatGPT is an advanced technology of artificial intelligence that may have many applications in various fields (Van Dis et al., 2023). Here, there are presented a few examples:

- Customer service: ChatGPT may serve as an automatic assistant answering customer questions and solving problems.
- Content generation and copywriting: ChatGPT is a powerful content generation tool that can create articles, blogs, posts on social media and much more.
- Translations and multilingualism: ChatGPT can help translate foreign languages and deliver information in many languages.
- Education and virtual tutors: ChatGPT can help do homework and prepare to examinations. For example, ChatGPT can be used to generate various tests or translate didactic materials in foreign languages. Additionally, ChatGPT can help students understand complex concepts by summarizing scientific papers or other texts.
- Entertainment and storytelling: ChatGPT can create scenarios and dialogues in the film and theatre industry generating creative and original ideas.
- Analytics and text-based data analysis: ChatGPT can be used to test data and analyze trends providing valuable information for companies and researchers.

The article contains an introduction, related works, ChatGPT analysis, discussion, and conclusions.

2. Related works

Intelligence is perceived as a feature of an individual who interacts with the external environment or deals with a problem or a situation. Intelligence is related to the ability to succeed, which implies the existence of goals. It emphasizes on learning (Ratten, Jones, 2023;

Burger et al., 2023; Korzynski et al., 2023), adaptation, and experience. Many definition of intelligence have been defined by Legg and Hutter (Legg et al., 2007), including some taken from the AI domain.

Intelligence can be perceived as the ability to use sense perception in order to understand even potentially unknown situations and confront them with the existing knowledge.

Artificial intelligence focuses mainly on the data analysis. According to (Jagadish et al., 2014), data sciences are based on data management and analysis. On one hand, data management covers acquisition, content extraction, integration and data representation. On the other hand, data analysis refers to the analysis and interpretation based on people. The stage of data management is devoted to data perception. Data analysis aims at providing the user the content that may be interpreted and then the decisions can be made. The sub-stage analysis concentrates on detection of patterns and correlations (for statistical purposes) in order to ensure the decision level appropriate for the interpretation based on people (Benaben et al., 2019; Hu et al., 2023).

Real-time Big Data applications are related to the industry, e.g., financial and stock markets, intelligent transport, warning systems etc. These applications are crucial because they help improve the quality of life, limit risk and rescue people (Mohamed, Al-Jaroodi, 2014). Due to the real time requirements, many challenges focus on collecting, transmitting, processing and visualizing huge amounts of data.

Metamodel of teamwork, which has been defined for the needs of crisis management, was described in (Lauras et al., 2015). It consists of two layers: a **primary layer**, which explains concepts and relationships in every teamwork situation and a **specific layer**, which contains concepts derived from basic ideas and which more precisely describe notions of a given field. The core is of agnostic nature; however, the layer is dedicated to the domain of management crisis.

3. ChatGPT analysis

Artificial Intelligence (AI) is a continually developing science field that has been shaping our digital reality for several decades. Since early theoretical considerations to contemporary apps based on deep learning, AI's history reveals some extraordinary journeys during which researchers and innovators have been conquering new lands in the field of intelligent devices.

In the beginning of Artificial Intelligence, from the 1940s to the 1960s, researchers experimented with innovative concepts and methods that aimed at creating machines that were able to think and make decisions similarly to humans. The modern era of Artificial Intelligence is a dynamic period in which researchers exploit advanced methods and technologies to create intelligent systems capable of solving complex problems. Among essential Artificial

Intelligence methods, which play an important role in various fields, used to analyze data or recognize patterns, it is possible to distinguish the following:

- Deep Learning – it is one of the modern most revolutionary artificial intelligence methods. It is based on neural multi-layer networks that automatically learn the representation data through information processing. That approach significantly has improved tasks performance such as image recognition, language analysis and predictions.
- Reinforcement Learning – it is a method in which the system agent makes decisions in an environment and his actions are rated by means of reward and punishment. Algorithms of reinforcement learning can use improvement strategies to maximize long-term benefits. This approach is applied, among others, in computer games, robotics and process optimization.
- Natural Language Processing (NLP) – Natural Language Processing is an area of AI that covers the human language understanding, interpreting and generating. Advanced NLP algorithms provide texts analysis, languages translations, image descriptions creation and interactions with users in a way which is close to the interpersonal communication.
- Deep Neural Networks (DNN) - Neural Networks of Deep learning is considered as a powerful tool in Artificial Intelligence. DNNs consist of many neuron layers that model complicated data dependencies. They are used in various fields, from images processing to financial trends forecasting.

3.1. ChatGPT – functioning rules

GPT algorithm or Generative Pre-trained Transformer is called a family of Artificial Intelligence models based on Transformer architecture. A key aspect of GPT is the pre-training, i.e., preliminary learning model on big data collection, which allows to acquire general linguistic skills. Here is a description of the GPT algorithm:

- Transformer Architecture: GPT is based on Transformer architecture, which focuses on attention mechanisms. This allows to analyze the sentence context effectively and to understand the dependence between various words in the text.
- Pre-training: This model is called the pre-training with the usage of the linguistic big data collection. In the case of GPT, the pre-training covers the prediction of the next words in a sentence. This enables the model to understand the text grammar, context and meaning.
- Fine-tuning: After initial learning, the model can be adjusted (fine-tuning) to specific tasks. That may concern different fields, such as machine translation, text generation, questions answers.

- Autoregression: GPT generates a text autoregressively, which means that every next word is generated based on the previous one. That allows for the creation of smooth and consistent texts.
- Main Multiplication (Multi-Head Attention): The main multiplication mechanism allows the model to focus on various aspects of the text, which increases the model's ability to analyze the context.
- Number of Layers: GPT usually consists of many layers of transformers. The bigger number of layers, the more advanced understanding of data dependencies.

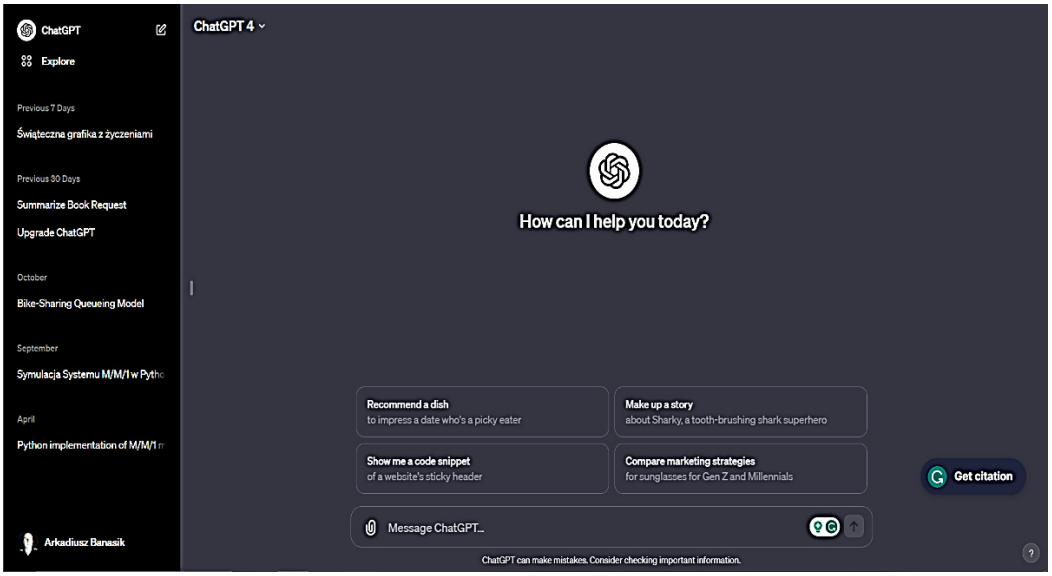

Figure 1. ChatGPT main window.

Source: https://chat.openai.com/, 29/10/2023.

In the case of ChatGPT, to generate answers based on the previous text, the sequential context is used. This model operates on a big collection of textual data. It allows the model to understand the language structure, grammar and semantic contexts.

Figure 2. ChatGPT sample question.

Source: https://chat.openai.com/, 29/10/2023.

In practice the Markov chains are implemented as weights (parameters) inside the model. They are customizable during the training based on the relationship among words in sequences. Therefore, ChatGPT, a linguistic model based on GPT, can "remember" previous text parts and use them to generate consistent and contextually related answers.

Let's consider an example of using Markov chains for words prediction in sentences, for example, let's assume that there is a limited set of words: {w1, w2, w3}, representing three possible words in a given context, we want to predict the next word in a sentence based on the previous two words.

Example transitions matrix:

$$P = \begin{bmatrix} 0.3 & 0.5 & 0.2 \\ 0.2 & 0.4 & 0.4 \\ 0.1 & 0.6 & 0.3 \end{bmatrix}$$

Verses represent previous words, and columns represent possible following words.

P[i,j] means the probability that the next word will be a j-th word, provided the previous two words are i-th and (i-1) these words.

Exemplary initial state may look like:

Initial state =[0.4 0.3 0.3]

If there is a sentence starting with "w1 w2 w3", it is possible to predict the next word by multiplying the initial state by the matrix transitions:

Predicted next word = Initial State × P

The probability schedule for the following words in the context of the previous words will be got. By means of this simple method of using Markov chains it is possible to predict the sequence words in sentences.

It's worth noting that although this model is able to consider the context, it does not possess the access to specific sources of information and generated answers are based on statistics and patterns observed in the training set.

GPT has become one of the most advanced language models, capable of generating high-quality text, replying to questions, translating and performing many other linguistic tasks.

3.2. ChatGPT – specificity of crisis applications

ChatGPT is the advanced artificial intelligence technology with many applications advisable for students and teachers during education crisis. ChatGPT is a type of the algorithm of natural language processing. It is able to learn how to understand the context and generate new statements contextually. Thanks to this algorithm it is possible to reply to questions, talk, explain and develop new texts.

ChatGPT may constitute help with school assignments and exams preparations. For example, the ChatGPT can be used to generate course tests sets or to translate teaching materials into other languages. Moreover, ChatGPT can also help students understand complex concepts by summarizing scientific or other texts.

For teachers, ChatGPT can constitute a tool to create interactive lessons and curricula. For example, teachers may use ChatGPT to prepare lesson scenarios or generate personalized emails to students. ChatGPT may also help teachers understand students' problems through the analysis of answers and suggestions referring to the methods of explaining the thought issues or teaching materials.

In crisis situations, such as the COVID-19 pandemic, ChatGPT can ensure constant availability of information and support for students and teachers. ChatGPT may help deliver information on topics during the remote teaching and learning, provide teaching materials, and answer students' questions. Additionally, ChatGPT can help create personalized teaching programs and deliver information on physical and mental health problems. ChatGPT may also help analyze students' answers and suggestions concerning problem explanations or teaching materials.

However, it should be remembered that ChatGPT, like any other artificial intelligence technology, has its drawbacks and limitations. In particular, ChatGPT can generate inaccurate or unimportant answers if not appropriately trained or supervised. Additionally, ChatGPT can reflect prejudices present in the training data. It can lead to bias and inaccuracies in responses.

3.3. ChatGPT – pros and cons

ChatGPT, like any other artificial intelligence technology, has advantages and disadvantages. Here there are a few key points that should be taken into account.

Advantages of ChatGPT:

- Natural language interaction: Using the ChatGPT makes natural language interaction possible. It allows the users to communicate with devices in a more humane way. That can make interactions more intuitive and users friendly.
- Versatility: ChatGPT can be applied for wide scope of tasks, such as questions reply, text generation, recommendations delivery, brainstorms and many others.
- 24/7 Availability: Once implemented, ChatGPT can provide help and information availability 24 hours a day.
- Scalability: ChatGPT can run many conversations simultaneously. So, it is scalable for companies and platforms whose demand the involvement of many users simultaneously.
- Smaller work load: ChatGPT can help reduce agents' involvement by automatizing some tasks and interactions. This way they are allowed to be focused on more complex or specialized tasks.

Disadvantages of ChatGPT:

- Lack of understanding: ChatGPT frequently lacks fundamental understanding of contexts and nuances. It generates responses based on patterns that were taught while training. It sometimes may lead to inaccuracies or unimportant answers.

- Bias and inaccuracies: If data was not appropriately supervised and monitored, ChatGPT responses might reflect prejudices present in the training data. It may also generate inaccurate or false information.
- Ethical concerns: There exist ethical concerns referring to artificial intelligence used to generate content connected with creating potentially harmful, misleading, or inappropriate matters.
- Dependence on training data: ChatGPT replies are based on training data. If training data contained mistakes or restrictions, they might be reflected in results.
- Lack of creativity and common sense: When ChatGPT can generate text, it lacks natural creativity and common sense. It may struggle with tasks demanding true creativity or a deep understanding of the world.
- Security threats: If ChatGPT was not correctly secured, it might be used for malicious purposes, such as generating convincing but false content on fraud or disinformation campaign purposes.
- Loss of interpersonal interactions: Relying on interactions with artificial intelligence may limit fundamental interpersonal interactions, which may provide social and psychological consequences.

3.4. Alternatives for ChatGPT

Artificial intelligence is highly popular in the application of various tools. This has caused the creation of many alternatives for ChatGPT. Here there are the most popular of them :

- Microsoft Bing: Bing is the search engine that uses advanced artificial intelligence algorithms to generate personalized search results. Bing may help search for information, answer to questions and deliver recommendations. Bing can generate texts in a specified style or format, such as stories, poems, articles, code programming, etc.
- Jasper: Jasper is the platform chatbot that uses artificial intelligence to generate answers to questions and conversations with users. Jasper may be used variously, for example, customer service, leads generation, information delivery, etc.
- Google Bard: Google Bard is the tool to generate poems in various styles and formats. Google Bard may be used for numerous goals, such as creating poems, songs, stories, etc.
- YouChat: YouChat is the platform of chatbot. It uses artificial intelligence to generate answers to questions and conversations with users. YouChat may be used for customer service, leads generation, information delivery, etc.
- Chatsonic: Chatsonic is the chatbot platform that uses artificial intelligence to generate answers to questions and conversations with users. Chatsonic may be used for various applications such as customer service, leads generation, information delivery, etc.

- Character AI: Character AI is the artificial intelligence platform that uses a learning machine algorithm to generate personalized recommendations and content. Character AI can be used for various goals, such as creating customized training programs and recommendations regarding health and fitness and many others.
- Chinchilla AI: Chinchilla AI is the artificial intelligence platform that uses machine learning algorithms to generate personalized recommendations and content. Chinchilla AI can be used for various goals, such as creating customized training programs and recommendations regarding health and fitness and many others.

4. Discussion

AI can increase efficiency and save time through automating routine tasks. It enables the employees to focus on more complex and strategic aspects of work by optimizing production processes, transport planning and energy consumption management to minimize the negative influence on the natural environmental. Improvement of medical diagnoses, development of more effective medications, drugs and therapies, acceleration of scientific research in the field of molecular biology, increase road safety, reduction of road accidents, optimization of road traffic through the development of autonomous cars, are the areas where the use of AI in monitoring systems, data analysis, technology of image recognition, increase safety in public spaces, airports or CCTV systems. This is just happening in many places worldwide.

Common usage of AI causes threats such as: privacy violations, identity theft or illegal use of personal data. AI automation can lead to the loss of workplaces in some sectors, which can generate social tensions. Algorithms based on historical data can reproduce existing prejudice and discrimination. These can lead to unequal treatment of social groups and machines overload. It may lead to the loss of skills and experienced human staff in some areas. The lack of uniform standards and regulations may lead to abuse and irresponsible AI technology applications.

AI can be used for machine translations, but in this, as in any other case, you should be careful and carefully analyze the proposals presented by AI. Queries and commands should be formulated very precisely - otherwise we may get quite strange answers. For example, AI can translate: "social tension" as "social voltage", "it is based on" as "it lean against", "it is devoted to" as "it is crucified" or "foreign languages" as „languages of aliens".

That is why implementing AI technology requires a sustainable approach that considers benefits and potential threats. It has to be ensured that the development in this field will serve society as a whole.

5. Conclusions

Nowadays AI is applied in many fields. It is not possible to predict what direction the artificial intelligence development will be heading and what benefits and threats it will bring. What ethical challenges can arise from using AI in management of crisis situations, especially when collecting and analyzing personal data? How to ensure the appropriate data security to avoid abuse and privacy violations while using advanced technology during crisis? Discussion in these areas may help define the best practices and technology development paths for AI in order to make it the best solution in a crisis situation.

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EDUCATION IN TIME OF PANDEMIC CRISIS – CASE STUDY

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Purpose: The crisis caused by the Covid-19 pandemic has seriously impacted the way we work, learn and behave in everyday life. We were forced to work from home, i.e. work remotely, and learn using methods that were rarely or even not used until the pandemic. Switching from classes at the university with direct contact with the teacher to online classes had advantages, but also some disadvantages. Some universities already had some experience in conducting online classes and knew how to use them for various types of studies. Other universities took advantage of the platforms offered by international organizations, prepared new forms of education and adapted the program to their technical capabilities. New forms of education turned out to be a big challenge for both students and professors. The aim of the study was to compare the methods of distance education used both in universities with extensive experience and in universities where distance learning, at least due to applicable legal regulations, was less popular.
Design/methodology/approach: The article analyzes the distance learning methods used by universities. The results of interviews conducted with students, teachers and the authors' personal experiences are described.
Findings: We have discovered that students have no problems using online education techniques and highly value the opportunity to use materials prepared by lecturers and made available on remote education platforms. Moreover, they derive satisfaction from the opportunity to learn independently and search for materials on the Internet. One of the main conclusions was that the future seems to belong to a blended learning system, combining physical and online learning.
Originality/value: The value is the originality based on the interviews and post COVID point of view.

Keywords: pandemic crisis, online education, case study.

Category of the paper: Case study, Viewpoint.

1. Introduction

As the modern world is becoming more and more connected, there appear a lot of various global threats. The COVID-19 pandemic did not stop at national borders. It affected many people regardless of nationality, education level, income, or gender. Education was no exception. This crisis exposed many shortcomings and inequities in education systems, for example, the limited access to broadband connections and hardware needed to provide online Education, the lack of supportive environments necessary to focus on learning, and the mismatch between resources and needs.

According to research by UNESCO (UNESCO, 2020), out of 38 OECD countries and eight partner countries covered by the Education at a Glance 2020 Program, the People's Republic of China was the first to close schools in response to the COVID-19 pandemic. By the end of March 2020, educational institutions were closed in all 46 Education at a Glance 2020 Program countries: 41 countries closed schools nationwide, and five countries (Australia, Iceland, the Russian Federation, Sweden, and the United States) closed schools sub-nationally or locally (Figure 1). However, not all countries affected by the pandemic implemented this imposed educational innovation. For example, primary schools in Iceland remained open because school children's classes consisted of less than 20 pupils. Most primary and lower secondary schools in Sweden have remained open, while upper secondary schools have mainly switched to distance learning since mid-March 2020. In Poland, schools were closed for 43 weeks.

The COVID-19 pandemic also severely impacted higher Education as universities closed their headquarters and countries closed their borders. Although higher education institutions quite quickly replaced face-to-face lectures with online learning, it was not easy to conduct some classes in the form of exercises or laboratories that required access to specific resources that, for various reasons, students could not afford. Significantly, this crisis has raised questions about the value offered by university education, which includes establishing social relationships apart from the educational content.

In the long run, the COVID-19 pandemic and its results observed in Education will have economic consequences. Using historical growth regressions, it has been estimated that the loss of continuous learning can lead to a loss of skills, and people's skills are related to their productivity. The long-term economic impact of this loss, which equals one-third of a year of schooling, has been estimated for the current group of students. According to the study's authors, the gross domestic product (GDP) may be lower by 1.5% on average by the end of the century. For example, in the United States, the loss of 1.5% of future GDP would correspond to a total economic loss of $15.3 trillion (Hanushek et al., 2020).

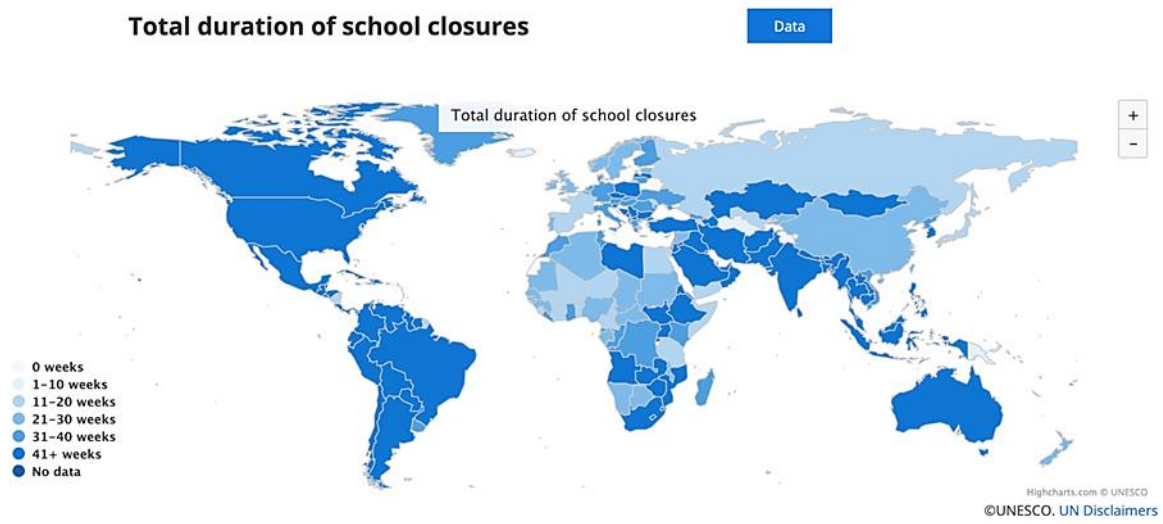

Figure 1. Total duration of school closures.

Source: https://webarchive.unesco.org/web/20220629024039/https://en.unesco.org/covid19/educationresponse/, 26.06.2023.

Numerous countries applied various tools to replace face-to-face Education, including instructional packages (textbooks, worksheets, and printouts), radio education, educational television, and online instructional resources. Countries tended to implement several tools to reach as many students as possible. The most famous device used in distance education was connected to Internet educational platforms (Schleicher et al., 2020). These Online platforms were used in almost all OECD and partner countries. Online learning tools included educational content, formalized curricula, or real-time teacher-led lessons via virtual meeting platforms. Thanks to this opportunity, students could acquire knowledge at their own pace and at any time convenient. In France, the already existing distance learning program "Ma classe à la Maison" was made available to all primary and secondary school students (Ministère de l'Éducation Nationale et de la Jeunesse, 2020). In Estonia, cooperation with private services allowed students to access rich educational content free of charge during school closures. Greece enabled real-time virtual classes with other online learning tools (Ministry of Education and Religious Affairs, 2020; Schleicher et al., 2020). In Poland, various Internet platforms were used to conduct online courses in real-time, as well as tools facilitating remote access to educational materials and platforms enabling knowledge verification. The article contains introduction and related works, case study, discussion and conclusions part.

2. Related works

The crisis caused by the COVID-19 pandemic has disrupted existence around the world, hence many researchers have studied its impact on various areas of life. Henry A. Giroux (Giroux, 2021) describes how the Covid-19 crisis affected politics, especially taking into account the events in the USA during this period. Already in 2017, the title of the 2017 Mathematics Education and Society conference was: "Mathematics and life in times of crisis". Conference participants predicted social and climate crises.

Now we know that these problems can also be caused by a pandemic (Ezeibe et al., 2020; Banerjee, 2020). Rittel and Webber (Rittel et al., 1973) formulated a theory of problems that natural scientists and social planners deal with, they proposed the concept of a "bad problem" to describe problems that are inevitable, serious human problems that cannot be avoided. In 1992, the concept of the "risk society" (Beck, 1992) was developed and the theory of changing the risk to which man is exposed in connection with possible crises, ranging from natural disasters to man-made disasters, was created.

Many researchers describe problems in Education in different countries of the world and ways to solve them (Gonçalves, 2020; Tejedor, 2020; Bozkurt, 2020). They also point to the negative assessment of students of the transition to virtual learning systems, because it is associated with an increase in teaching load. E-learning has contributed to the negative impact of remote learning on the lives of students and teachers, and the Covid-19 crisis has highlighted the gaps in basic digital skills among young students.

Information and its analysis is the basic assumption for creating science and Education. Science and Education are at the forefront of changes that will extend to other areas of life, so they must be the first to overcome the difficulties of adapting to change. The most important is the incorporation and establishment of rules for using artificial intelligence in science and Education. After being solved, the indicated challenges and problems will introduce a modern look at both processes and stabilize work in this area until the next innovation that will revolutionize the approach (Fazgalić, 2022; Usiuds 2023a, 2023b, 2023c, 2023d; Van Dis et al., 2023; Banasik, Kempa, 2023).

3. Approaches presented by different universities – case study

The pandemic has caused changes in the education process. All educational community members had to cope with distance learning methods. The universities' authorities need to cope with pandemic changes. That cause the development of distance learning procedures. The analyzed approaches are based on AGH University of Science and Technology (AGH),

and Massachusetts University of Technology (MIT), and Silesian University of Technology (SUT).

3.1. AGH University of Science and Technology

During the period of total or partial closure of university premises, the universities were organizing the educational process in various ways. At the AGH University of Science and Technology in Cracow, the e-Learning Center made a major contribution to supporting higher Education during the COVID-19 pandemic. The rules for organizing and conducting the remote Education were defined by the University Rector's Regulations No 17/2019 of May 15, 2019 and 52/2021 of September 10, 2021. The regulations consisted of the condition that academic teachers had to complete the training in the scope of e-learning basics and the ability to use the University's e-learning platform (UPEL) provided by the university e-Learning Center (CeL). Completion of this training was confirmed by the University certificate issued by CeL. The regulations also defined detailed rules for organizing and conducting classes with the implementation of distance learning requirements, methods and techniques as well as e-learning tools.

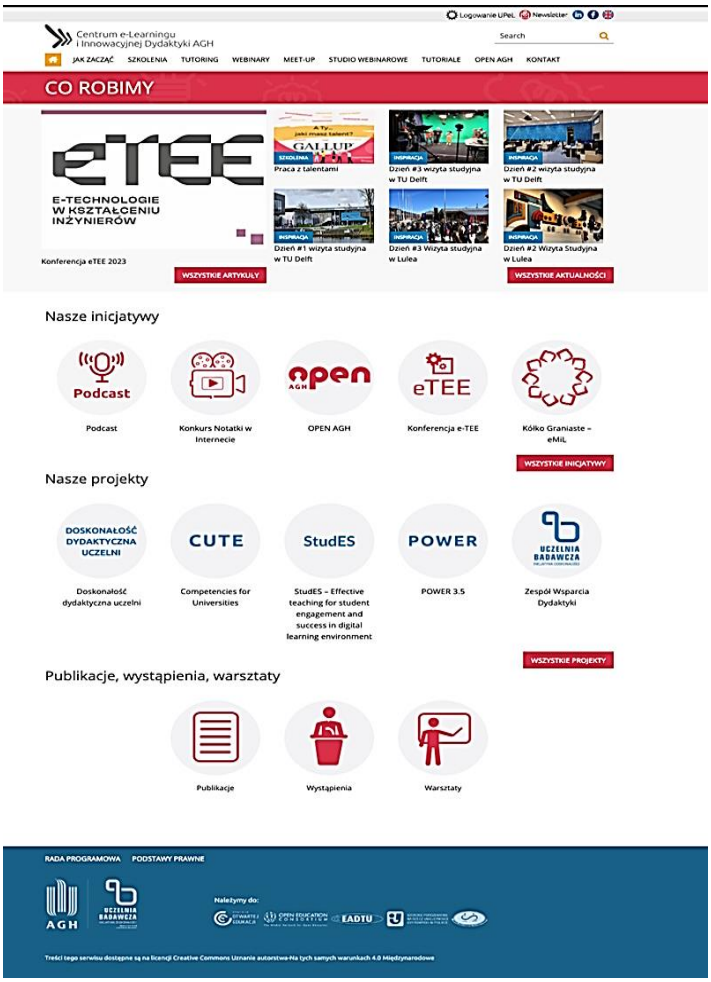

Figure 2. Website of the AGH e-learning Center.

Source: www.ce..agh.edu.pl, 3.07.2023.

Specific principles for organizing and verifying the learning outcomes defined in the study programs, in particular credits, exams, and diploma exams, as well as the rules of remote learning supervision, the rules for registering or recording the remote classes or lectures with the application of electronic means of communication provided by participants or academic teachers, were also included in the Rector's regulations.

Up till now, the AGH e-Learning Center has been offering technical and didactic support. It suggests the lecturer's numerous pieces of training and webinars. The UPEL platform gives many opportunities to activate students. It streamlines the process of collecting final theses or carrying out online tests. It is integrated with the Virtual University.

In the opinion of the University students, the method of classes or lecture organization, which was adopted at the University during the remote learning period, enabled, to a large extent, the implementation of the didactic process. With the consent of the lecturer, remote lectures were recorded. It facilitated the acquisition of knowledge provided to students. Online classes did not cause many problems. However, laboratories, during which it was required to use specialized equipment available only in university laboratories, were carried out in a rather specific way. The teacher running the laboratory classes was recording a given experiment. Then, the recording was made available to students along with the relevant measurement results, based on which the students were supposed to prepare the final experiment report.

Of course, this form of presenting knowledge, initiated by specific circumstances, cannot replace the students' opportunity to work in a special laboratory environment and obtain the experiment results independently. However, in the student's opinion, the adopted forms of conducting classes were a sufficient replacement for classroom classes during COVID-19-related restrictions.

3.2. Massachusetts University of Technology (MIT)

MIT OpenCourseWare (OCW) is a free, publicly accessible, openly licensed digital collection of high-quality teaching and learning materials presented in an easily accessible format. Browse through, download, and use materials from over 2500 MIT on-campus courses and supplemental resources, all available under a Creative Commons license for open sharing. That is the free online alternative for students not involved in the process of studies at MIT.

MIT also has the proper course available only for registered people in its faculties. All classes are made similarly:

- Materials containing lecture highlights,
- Exercises or lab descriptions,
- Theoretical requirements for the exercises and labs.

That approach seems to be adequate for online learning. Of course, the online materials were accompanied by online lectures for all classes. In modern times, the lectures are in hybrid mode.

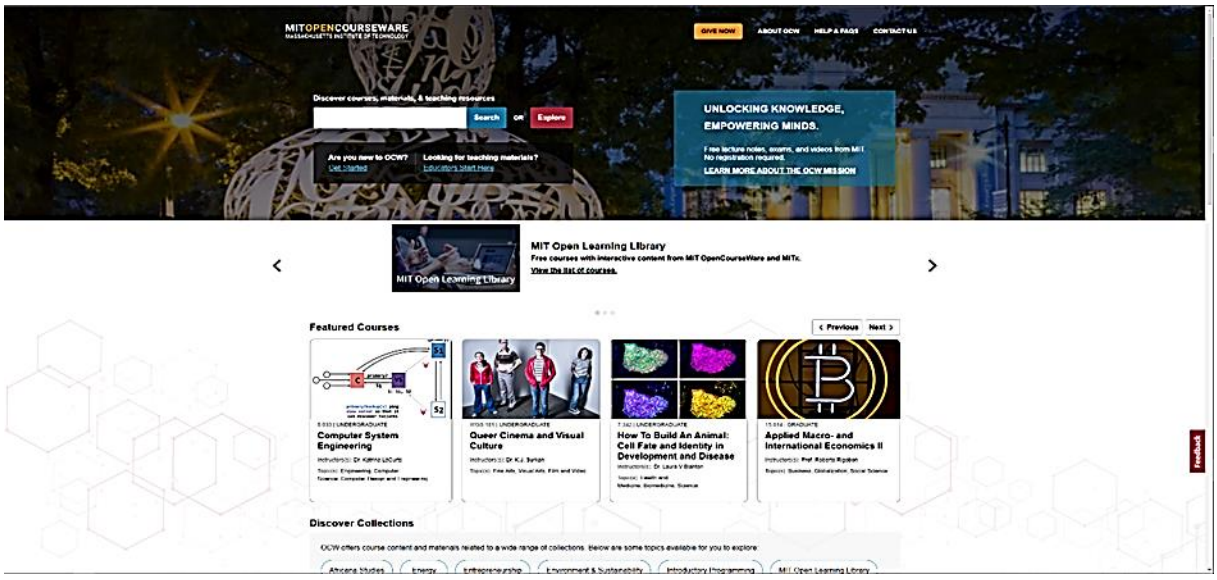

Figure 3. Website of the MIT Opern Courseware.

Source: https://ocw.mit.edu/, 29.08.2023.

3.3. Silesian University of Technology (SUT)

The rules for organizing and conducting remote Education were defined by the University Rector's Regulations No. 200/2020, which allow lecturers to make their classes online. The possibility of online learning was prepared for all kinds of classes: lectures, exercises, and laboratories.

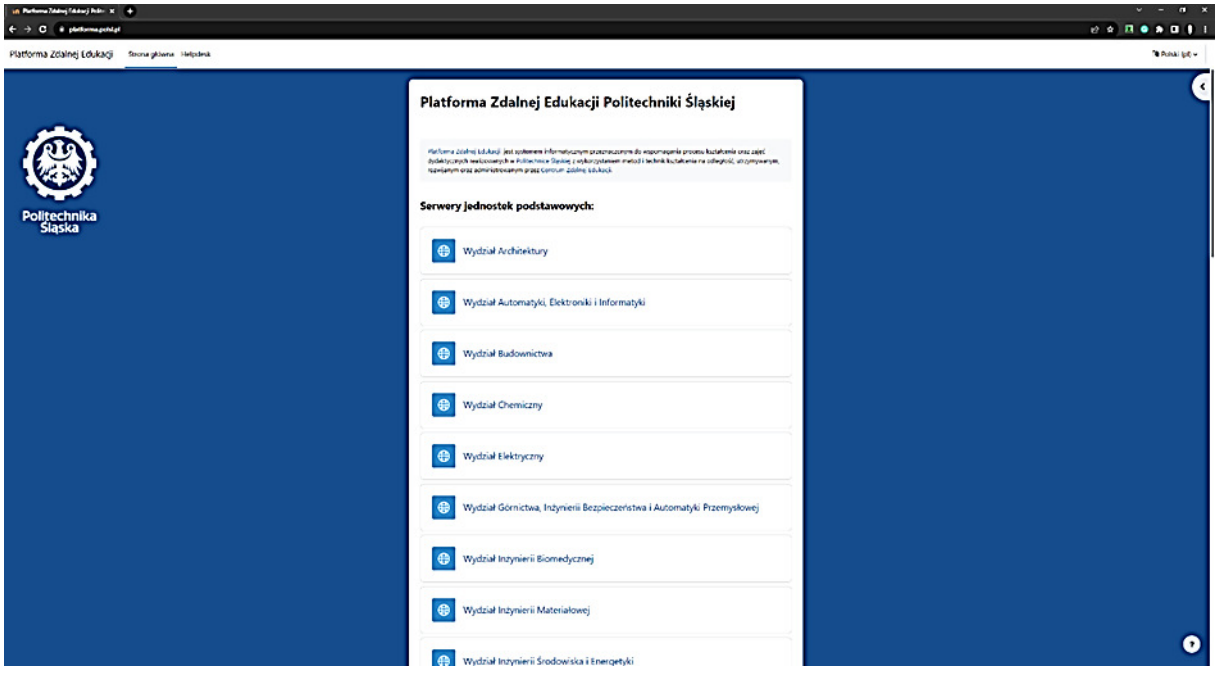

Figure 4. Website of the SUT e-learning platform.

Source: https://platforma.polsl.pl/, 29.08.2023.

The regulations also proposed tools for online teaching. The selected tools were communication tools and e-learning platform for online materials. Also, the synchronic form of classes was an option for lecturers; the other possibility was asynchronous (recorded) lectures and other courses in a synchronic way.

The regulations also proposed a way of confirming students; identity for credits and exams and presented a way of proceeding with those critical parts of the learning process.

4. Discussion

The pandemic has increased efforts to develop distance learning and e-learning methods. The prepared materials were made to help students cope with all subjects., The necessity forced a change of attitude towards the methods mentioned above. Both sides – students and lecturers- had to change the reality of the learning process with no personal contact.

The learning process was focused on achieving goals, but in the pandemic years, goals were to be completed by students on their own. The course materials had to be prepared more precisely and have some theoretical background to help students solve the problems.

The worst part for students and lecturers was not having personal contact, which caused some mental problems during classes. The issues were also a part of evaluating the students in their houses. In those cases, personal contact was necessary before the pandemic years.

The newly recorded material for students was a good part of the learning process, but nowadays, they are indicating eye-to-eye lectures as a better way for their Education. Also, the new artificial intelligence tools for the learning process should be considered as a step toward the change in the educational path.

In the case of SUT, students also demand more mathematical classes during their Education. That shows the approach for the required knowledge. On the other hand, some students prefer to have as many online classes as possible, especially on maters' degrees. From the authors' point of view, that approach is unsuitable for the final results of studies.

The discussion was based on interviews with students of different years of studies on the Faculty of Applied Mathematics in SUT.

5. Conclusions

The text also allows the use of endnotes[1], which should be developed in the **Footnotes** section. It should only contain information that significantly affects the understanding of the issues discussed in the paragraph, and which could distract the reader if placed in the text.

The appropriate approach for the learning process is needed. All available possibilities for providing knowledge should be used during the educational process. The scope should be the best possible way of teaching for our students.

The newest methods should be implemented in the learning process, including tools for learning and methods for applying Artificial Intelligence.

Currently, when it is possible to learn in direct contact with the lecturer, students point out that some methods developed during distance learning still can be used. Students really appreciate the materials prepared by teachers and available online, especially the ability to re-listen to a lecture that was recorded and made available to students, and the ability to consult projects without having to come to the university. The materials available online help in better mastering the subject of classes. Moreover, students use online sources related to the subject matter to a greater extent than before the Covid-19 pandemic. Interestingly, they want to do so. It can be observed that this forced online learning has taught students to study independently.

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THE ENTERPRISE GOODWILL VALUATION – RANKING OF POLISH BRANDS

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Purpose: Article discusses the valuation of company brands, focusing on Polish enterprises. It delves into the increasing importance of intangible assets like brand value in the modern economy.
Design/methodology/approach: The paper presents a detailed methodology for valuing brands, which includes analyzing financial reports, surveys, and stock exchange data. The study highlights the complexity of brand valuation, considering factors like intellectual capital, goodwill, and market volatility.
Findings: It emphasizes the need for a multifaceted approach in valuation, integrating various methods to achieve a more accurate assessment. Additionally, it presents a list of the most valuable brands in 2021, demonstrating the dominance of certain sectors like technology and retail in brand value. The research concludes that there is no single, definitive method for brand valuation, underscoring the subjective nature of this process.
Originality/value: This paper is base on Polish enterprises, which provides appropriate data. The presented methodology is a original approach.

Keywords: Brand Valuation, Intangible Assets, Financial Analysis, Goodwill Evaluation.

Category of the paper: Research paper.

1. Introduction

Theory and practice of value-based management is not a fad, but a permanent trend of development of modern economics. The need for the valuation of various assets existed for a very long time. Value, exchange value, and value in use are basic economic categories. The development of stock exchanges has increased the amount of assets in trade, and situations when they have to be valued. The quest for enrichment and growth in the value of assets has always been an integral feature of the development of mankind. This is not just a matter of attitudes defined as "homo economicus". To speak about the increase in value, one needs to measure the value first.

In the modern world, an increasingly, important role is played by intangible assets. The importance of intellectual capital (knowledge) and other elements that can be considered components of intangible assets, in comparison to physical capital, is growing.

Brand value can be considered as a critical part of any company's intangible assets. These kind of non-physical assets, such as patents and brand names, are having an increasing influence on a company's overall value. A 2020 analysis found that intangibles made up 90% of the S&P 500's market value, an increase of 22 percentage points since 1995[1].

The article presented below is a consequence of the ranking of Polish brands prepared by the author in 2021, prepared for Rzeczpospolita newspaper. The author used a specially developed brand valuation methodology to value Polish brands. More than 200 Polish enterprises from various sectors were subject to valuation.

Data for brand valuation were obtained from:

- a survey specially prepared for this study,
- financial reports of companies sent by the companies themselves,
- financial reports posted on enterprise websites,
- reports included in the National Court Register,
- stock exchange data.

2. The enterprise goodwill valuation

Falling rates of return on capital invested in the sphere of production, lead to directing capital to the sphere of the new services (the "third wave" of A. Toffler), which define information (the market value of resources related to information and knowledge) as a third kind of matter (in addition, to weight and energy). Therefore, in these companies, intangible resources have a growing importance, in relation to material resources. B. Cornell used the term "organisational capital", by which he means intangible assets and goodwill (Cornell, 1999), p. 21).

Looking at it from the point of view of the financial statements as a primary source of information about the property and financial position of any company, a complaint often appears, that these statements do not take into account the intangible factors. Intellectual capital is the main source of competitive advantage of the modern enterprise. Discussions on how to define and measure intellectual capital, intangible assets, and goodwill, have been pending for a long time. The word "firm" (trade mark) is often used interchangeably, even in professional publications, with the word "company", which can lead to improper identification of goodwill of the company, with the value of the company.

[1] Global 500 Report.

Accounting law defines intangible assets as the right to property suitable for business use over a period longer than one year, acquired by the economic unit, which may include in particular:

- copyrights,
- rights to inventions, patents, trademarks,
- know-how.

Intangible assets also include acquired goodwill. This happens, when there is so-called[2] '**positive goodwill'**. This is defined as the excess of the cost of acquisition over the fair value of the net assets of the acquired company. Such value is amortized. In an opposite situation, **negative goodwill occurs**, which is classified as revenue accruals charging other operating income. It is an attempt of valuation of intangible assets, not included in the balance sheet, and affecting the valuation of the company. These assets include, among others, portfolio of customers, market positions, and others. In many situations, usually after 5 years, goodwill is transferred to the income or expenses, and disappears from the balance sheet of the company.

International accounting standards (IAS 38) define intangible assets more precisely. The inclusion of an intangible asset in the balance sheet, must meet several conditions:

- ability to identify (separateness),
- exercising of control,
- future economic benefits,
- the ability to reliably determine the value.

This approach to goodwill, used in accounting, is a consequence of the principle of double-entry bookkeeping. It is, in the opinion of some, a factor artificially created for the convenience of accountants, in connection with acquisitions transactions (goodwill is the difference between the price paid and the fair value).

The use of accounting regulations to determine the value of the company is limited. These regulations include only goodwill on enterprise acquisition, or an organised part of it. Therefore, only the goodwill generated internally, is partly taken into account, without taking into account the entire value of the company.

Goodwill is, therefore, perceived differently by accountants, who treat it as a component of intangible assets (positive goodwill), and measure only in specific situations, and differently by those, who carry out valuations of companies, not based on accounting regulations. The latter are looking for value-creating factors, not included in the balance sheet of the company. There is, therefore, a need for a broader approach to the valuation, and for a more integrated company's balance sheet, if the reports are to accurately reflect the company's economic and financial position.

[2] Define by accounting law.

Goodwill has no intangible nature, is associated with the particular company (not present by itself), and is often independent of the cost of company acquisition. It is unstable, and has no direct ability to create profit. This leads to wide differences of opinion regarding the valuation of goodwill (very subjective nature of the valuation).

The gap between the market value and the book value, is commonly referred to as 'goodwill'. Goodwill with such a definition, is calculated as the difference between market value and book value. This can be expressed using the following formula:

$$\frac{G}{BV} = \frac{MV}{BV} - 1$$

where:

G – goodwill (goodwill),

BV – book value of the company,

MV – market value.

Such an approach does not, however, include the fact that some elements of goodwill can be included in the book value. In 2009, Brand Finance Company performed an analysis of 37,000 companies listed on 53 stock exchanges. The value of the company was divided into tangible and three groups of intangible assets.

Table 1.

Structure of the total value of companies, USD trillion

Specification	2001	2002	2003	2004	2005	2006	2007	2008
Tangible assets	11.2	12.3	12.9	14.1	14.7	16.8	22.0	20.5
Goodwill - the result of take up	2.2	2.5	2.7	3	3.4	3.8	4.8	3.7
Disclosed intangible assets (excluding goodwill)	1.2	1.4	1.4	1.5	1.7	1.9	3.0	2.7
Undisclosed intangible assets	16.4	11.8	17	19.4	22.3	25.4	29.8	6.7

Source: Brand Finance Global Intangible Finance Tracker 009.

Analysis of listed companies shows, that in many cases, the market value of companies is significantly higher than their book value. This shows the importance of intangible assets, not included in the balance sheets of companies, for the value of the company. Ignorance of these values in the financial statements, is a consequence of difficulties in their correct valuation, resulting in high variability and subjectivity of financial results.

It should be emphasised that this difference does not necessarily indicate the presence of positive goodwill, but it could indicate incorrect (under-valued) accounting valuation of assets. Book valuation may be correct, in terms of the applicable rules, but not necessarily, in terms of actual or market value of the property. In this situation, the widespread acceptance that the difference between the market value and book value is the firm (trade mark or goodwill) value is wrong.

The big problem is, therefore, correct valuation of intellectual capital and other intangible assets. According to T. Copeland, T. Koller, and J. Murrin (Copeland, 1997) organisational capital value can be evaluated, based on the ability of its individual elements to generate income. Part of the goodwill may be brand (trademark). In this respect, too, there are some

differences. Some point to the diversity of companies and brands, not treating the brand as part of goodwill.

One area of use of the company trade mark is doing franchise business, namely granting by one entity to another entity, the right to conduct business under its own name, using a proprietary trademark in exchange for remuneration. Derived from the same income, franchise value may be the basis for the valuation of the trade mark, or even the entire goodwill. This does not mean that several issues regarding the valuation, itself, do not appear here, but is merely a statement of fact, that the conditions for making such a valuation (listed in accounting regulations) and taking into account the results in the financial statements, exist.

Evaluating the trademark as a part of the goodwill may be easier, than the valuation of goodwill. There are several methods of valuation of the trademark:

1. Cost method:
   - historical cost,
   - according to the replacement cost.
2. Income method:
   - discounted cash flow,
   - brands premium,
   - licence fees (royalties).
3. Market methods:
   - comparable market value,
   - comparable rate of royalties.

Cost methods are based on the summation of the costs incurred, to promote the brand. The basic problem concerns the difficulty in determining the impact of expenses (including misguided) to create value.

Income methods are trying to estimate future revenues associated with the use of the brand, which is the additional revenue from price premium (the sum of surplus of the prices of branded products over prices for similar, non-branded products). Market multipliers (of earnings historically generated by the brand) are often used, taking into account the fact, that generally, market valuations are considered to be the best method of valuation. One can use market prices for similar brands, or existing licence fees, for comparison[3]. Therefore, either a static approach to the valuation based on the assets of the company, or the valuation of future income streams, is possible. In the first of these approaches, the valuation of the company consists of the net asset value, plus the goodwill measured as profit multiplier (e.g. in production companies), or a percentage of turnover or sales (e.g. in retail companies). In such a situation, company value (CV) is equal:

[3] You can read more about this in: M. Bojańczyk, Enterprise valuation and value based management.

$$CV = NAV + n * NP \text{ or } CV = NAV + \% * S$$

where:
NAV – net asset value,
NP – net profit,
S – annual sales,
n – times the profit.

The first of these formulas is often used for industrial companies, and the second one for commercial enterprises. One can find many modifications of these formulas used in the past. The need to take goodwill into account seems obvious, but the existing methods of its valuation are far from sufficient. The implementation of property methods does not seem to solve this problem. Goodwill, if it exists, must sooner or later, turn into revenues of the company. This leads to the conclusion that the estimation of the value of the company should be based on income methods.

The organisational structure and speed of decision-making are also important. An unstable market shortens the time at the company's disposal to make a decision. This increases the importance of the intangible assets, that increase flexibility in decision-making, and decreases the importance of physical assets, that reduce such flexibility, significantly.

3. The most valuable brands in 2023

There are many institutions around the world that try to value brands using various valuation methodologies. One of the most recognizable is the Global 500 Report. Below are the 10 most valuable brands in 2023.

Table 2.
The most valuable brands in 2023

Rank	Brand	Brand Value (B)	Country	Sector
1	Amazon	$299.3	U.S.	Retail
2	Apple	$297.5	U.S.	Tech
3	Google	$281.4	U.S.	Media
4	Microsoft	$191.6	U.S.	Tech
5	Walmart	$113.8	U.S.	Retail
6	Samsung Group	$99.7	South Korea	Tech
7	ICBC	$69.5	China	Banking
8	Verizon	$67.4	U.S.	Telecoms
9	Tesla	$66.2	U.S.	Automobiles
10	TikTok/Douyin	$65.7	China	Media

Source: Global 500 Report, https://brandfinance.com/insights/global-500-2023-report-published

Looking at brand value based on sector, you can see that tech continue to dominate.

Table 3.
The most valuable brands in 2023

Rank	Sector	% of Total	Total Brand Value (B)
1	Tech	19.4%	$891.2
2	Retail	15.0%	$690.0
3	Media	14.0%	$645.2
4	Banking	10.2%	$467.4
5	Automobiles	8.6%	$397.3
6	Telecoms	7.3%	$334.6
7	Commercial Services	3.8%	$174.0
8	Oil & Gas	3.7%	$171.0
9	Engineering & Construction	3.3%	$149.5
10	Insurance	2.0%	$93.0

Source: Global 500 Report, https://brandfinance.com/insights/global-500-2023-report-published

It is quite difficult to compare valuations prepared by different institutions, because the methodologies are usually described in a rather general way, and detailed assumptions and solutions are not disclosed by these companies.

4. The impact of instability on valuation

Market volatility increases the importance of flexibility, understood as the ability to quickly adapt to changing conditions. Companies that do not have their own production assets with high fixed costs, are more flexible, having the ability to smoothly switch production, in order to quickly respond to new opportunities and challenges of globalization and increased instability.

The enormous instability in the global economy that we are currently experiencing means that many valuation models that worked well in conditions of stability become less adequate in conditions of enormous instability. The pandemic affected, among others, to changes in the demand structure and the financial situation of many enterprises. Aid programs addressed to various industries, regardless of the assessment of their correctness and effectiveness, have a significant impact on the functioning of enterprises. All this makes modelling economic processes and company valuation, including brand valuation, difficult. Crisis conditions require the use of "crisis pricing". Financial results and company valuation based on data from 2019. will probably be completely different than the one made on the basis of the 2020 data.

These general considerations lead to two key conclusions:

1. company valuation cannot be based on only one method - this has a key impact on the number of questions and the structure of the questionnaire, which was used to value the brands of Polish enterprises;
2. it will probably be necessary to use an expert approach consisting in the possibility of the expert subjectively increasing or decreasing the value of the company, e.g. by 15%;

3. when using two or three valuation methods, it will be necessary to assign weights to individual methods. Their final determination will be made after collecting data from enterprises;
4. if there are problems with obtaining information from enterprises, it may be necessary to simplify the company's valuation model, which will have an impact on its quality.

5. Valuation of Polish brands - main research results

The quality of the obtained result depends on the quality of the information used - what is at the output is the result of what was at the input.

In Poland, there is a great reluctance of enterprises to disclose their financial results. It is very rare to find at least basic financial results on the websites of individual companies. This means that these companies are not transparent and there is often a fear that they may want to hide something. This can unfortunately have an impact on the assessment of brand value.

It is much better to obtain financial data from public enterprises, which, whether they like it or not, have certain disclosure obligations. Such disclosure is rewarded by stock investors through higher valuations of public companies relative to non-public companies. Transparency "pays off".

Financial data can also be obtained from the National Court Register, but not all companies publish them there. Companies that have nothing to be proud of are especially reluctant to do so. The penalty for not including data in the National Court Register is very low, so they do not have to worry about it too much. In May 2021, when valuations were prepared, most companies have not yet published data for 2020.

It is commonly pointed out that brand valuation cannot be based on only one method. When using two or three valuation methods, especially when the results will not differ much from each other, such an estimate can be considered more accurate.

Difficulties in obtaining reliable information and the non-quantitative nature of various phenomena affecting the valuation make it often necessary to use an expert approach, which involves the possibility of the expert subjectively increasing or decreasing the brand value, e.g. by 15%. Such corrections were applied to the valuation of selected brands.

Problems with obtaining information from enterprises resulted in the need to simplify the brand valuation model in relation to the original assumptions. The method used here was mainly based on potential license fees (franchising). The discounted cash flow (DCF) method was used here, according to the following formula:

$$WM = \frac{CF_1}{(1+d)^1} + \frac{CF_2}{(1+d)^2} + \frac{CF_3}{(1+d)^3} + \ldots + \frac{CF_n}{(1+d)^n} + \frac{RV}{(1+d)^n}$$

where:

WM – brand value,

CFn – value of cash flow from possible license (franchise) fees or price premiums in year n.

n – length of the projection period.

d – discount rate.

RV – residual value.

The residual value was determined using the formula:

$$RV = \frac{CFn * (1+g)}{d - g}$$

where g – growth rate after the forecast period.

The obtainable license fees were discounted and added up. The basis for determining license fees was revenue from the sale of the entire enterprise or revenue from the sale of individual brands. The need to use several sources of information resulted in some difficulties in data comparability.

The quality of the results was improved by using sales profitability (the ratio of net profit to net sales) as a factor correcting the final result. It is difficult to accept the estimation of brand value only on the basis of sales revenues without taking into account the margin or profit achieved by individual companies. In selected cases, stock exchange valuations were also used (P/E and P/BV ratios).

In order to obtain information directly from enterprises, a questionnaire was prepared.

Table 4.

Main items in the questionnaire

QUESTIONNAIRE – main items
1/ contact details
2/ net revenues from the sale of the enterprise
3/ net revenues from sales of individual brands
4/ net profit of the enterprise
5/ net profit of the enterprise
6/ net profit of the enterprise
7/ equity of the enterprise
8/ average cost of external financing
9/ asset value
10/ brand relevance index

Source: own study.

The questionnaire was constructed in such a way as to enable the estimation of the value of companies at using the following methods:

a) in the first approach to valuation of goodwill, the difference between the market value and the book value of the enterprise was used. The book value is the value of the

enterprise's equity as of the balance sheet date (question 7 of the questionnaire). The market value of the company was determined based on the P/E ratio (stock exchange data for individual industries were used);

b) method based on potential license fees (franchising). The DCF valuation methodology was used here. The obtainable license fees over the 5-year period and the residual value was discounted and aggregated. The basis for determining license fees was the revenues from the sales of the entire enterprise or revenues from the sales of individual brands (question 3 and 4 of the questionnaire). The discount rate was determined on the basis of WACC (question 7 and 8 of the questionnaire);

c) high sales revenues and high market value are not only a consequence of high company value and therefore it is worth additionally using, for example, the "brand importance index" when making choices by the consumer. This is the estimated (percentage) impact of the brand on the sales volume or price premium on products. This should be supported by consumer surveys. However, this is very costly and that is why here we only want to obtain the opinion of the companies themselves (question 10 of the questionnaire);

d) using a weighted average to determine the final value of the company.

Below are presented the 20 most valuable Polish brands in 2021.

Table 2.
Most valuable Polish brands in 2021

No	Brand	Brand value assessment in PLN million	Sector	Source of data
1	PKO ORLEN	9 869,0	Oil & Gas	*
2	Jeronimo Martins Polska S.A. (Biedronka)	7 267,7	Retail	*
3	PGNiG SA	6 026,6	Oil & Gas	*
4	PGE	5 224,6	Energetical	***
5	Grupa Lotos SA GK	3 322,8	Oil & Gas	*
6	GK PZU	3 322,0	Finance/banking	***
7	KGHM	3 115,1	Mining	***
8	GK Tauron	2 166,0	Power engineering	***
9	Lotto	1 599,3	Other	*
10	PKO Bank Polski	1 504,6	Finance/banking	*/***
11	Asseco Poland SA GK	1 475,7	IT	*
12	Energa	1 445,2	Power engineering	***
13	Grupa Azoty SA GK	1 410,6	Chemical	*
14	Bank Pekao SA GK	1 292,1	Finance/banking	*
15	Inter Cars SA GK	1 120,2	Automobiles	*
16	Żabka	1 067,5	Retail	**
17	PLAY	1 000,8	Telecommunication	***
18	Grupa Warta	964,9	Finance/banking	*
19	Dino	948,9	Retail	**
20	Budimex	926,4	Construction	***

The following data sources were used for calculations: *questionnaire, **GFK, ***annual reports posted on the websites of individual companies, ****financial statements included in the National Court Register, *****other information (internet, stock exchange quotes.

Source: own calculations according to own methodology.

6. Summary

The research results on the valuation of a company's brand presented above are of a subjective (expert) nature. They are the result of the author's own valuation model and the assumptions made by the author. These types of analyzes are currently very difficult due to the enormous instability in the global economy and the resulting, among others, high variability of financial results.

The research conducted on the valuation of a company's brand leads to several key methodological conclusions:

- there is no single brand valuation method that could be considered as a method allowing for an objective valuation,
- the above, quite commonly accepted conclusion leads to the conclusion that it is better to use several methods,
- the selection of brand valuation methods is subjective (expert) in nature, which leads to different valuations of the same brands by different researchers,
- when using several valuation methods, the subjective share of a given method in the final result has a very significant impact on the final result.

Enterprises that are monopolies pose a specific valuation problem, especially when the main shareholder is the State Treasury. This includes, among others: enterprises in positions 1, 2 and 4. Monopolies usually have better results than other enterprises because they use monopoly rents. If the main shareholder is the State Treasury, there is a serious risk that such enterprises will be treated in a privileged manner.

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STRATEGIES AND PREMISES OF EARNINGS MANAGEMENT IN PUBLIC COMPANIES LISTED ON THE WARSAW STOCK EXCHANGE – THE RESULTS OF SURVEY RESEARCH

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Purpose: The paper's main aim is a holistic presentation of genuine motives, strategies and patterns of earnings management phenomenon in public companies listed on the Warsaw Stock Exchange.
Design/methodology/approach: The survey was carried out among 124 finance managers and public companies' accounting services representatives from the Polish capital market. The research sample selection was random (exhaustive testing); the survey was conducted in June-August 2023.
Findings: During the research, it turned out that 29% of respondents admitted to implementing EM practices in firms they represent. Interviewees declared the use of various accrual-based and real EM instruments in a complementary way. The dominant EM strategies proved to be income smoothing and avoidance of earnings reduction, while the main reasons for EM implementation respondents included creating the image of a more profitable company (compared to the largest competitors), meeting market analysts' expectations regarding the level of reported financial result and showing better development prospects for the company.
Research limitations/implications: This paper allows for identifying the level of willingness to implement earnings management practices among executives of public companies and, as well as measuring the awareness of finance managers and representatives of accounting services regarding the possibilities of using particular instruments and techniques of accrual-based and real earnings management in business practice.
Originality/value: This study fills a gap in the literature regarding the accounting data quality reported among listed companies in Poland. Most studies on the issue of earnings management focus on estimating the scale and scope of the practices mentioned above using specific regression models. Empirical research based on survey techniques in which respondents professionally responsible for financial reporting in listed companies would present their views or experiences regarding earnings management is rarely seen.

Keywords: accrual-based earnings management, real earnings management, public companies, survey research.

Category of the paper: research paper.

1. Introduction

A holistic approach to the issue of earnings management (EM) is reflected in the statement that this phenomenon includes practices aimed at the intervention in the accounting process to demonstrate the achievement of the desired economic results and, on the other hand, an integrated set of instruments for its implementation, which results in the inability to demonstrate the level of earnings known to the management, and at the same time which would normally be reported in the company's financial statements. This concept arose from the increasing importance of reported accounting data and the relationship between reporting and the market capitalization of enterprises and is reflected, among others, in assumptions: the agency theory (Jensen, Meckling, 1976), the contract theory (Hart, 1988), the signal theory (Ross, 1977) or the threshold management theory (Burgstahler, Dichev, 1997). Thanks to the use of appropriate accounting policy instruments and operational activities, it will be possible to present the company's financial situation in the intended way in the eyes of selected groups of its stakeholders.

The paper's main aim is to present the results of empirical research on a multi-aspect analysis of the EM phenomenon on the Polish capital market, conducted among finance managers and representatives of financial and accounting services of public companies listed on the Main Market of the Warsaw Stock Exchange (WSE). The adopted research approach allowed the analysis of the prevailing objectives, motives and techniques of accrual-based and real EM practices, including the consequences of its implementation in the SARS-CoV-2 post-pandemic period. The following hypotheses operationalized the presented research aim:

- H.1. In public companies listed on the WSE, accrual-based- and real EM strategies are used on the principle of complementarity.
- H.2. The dominant EM strategy, emphasizing the final results from the enforcement of these activities, is the income smoothing technique.
- H.3. According to the assumptions of the agency theory, the core prerequisite for implementing EM practices in public companies is the desire to maximize the personal benefits for management staff.

Despite the attempts to explain and expand the existing knowledge about the EM, unified and universal concepts that sufficiently reflect this phenomenon's motivations and implementation paths have not evolved. Moreover, it is increasingly noticed that most empirical research focuses on the aetiology of earnings manipulation in a fragmentary manner (Jansen et al., 2012). Therefore, the scope of research presented in the paper includes important and current issues. On the one hand, in light of the accounting scandals of recent years, EM practices have become interesting from the perspective of diverse discussions regarding the quality of financial statements; on the other hand - transparency and the nature of decisions made to increase the company's value. Furthermore, a closer look at real EM matter or trade-off analyses

concerning the Polish capital market is a segment of theoretical and empirical studies that has not been fully explored scientifically. Finally, most studies on the issue of shaping financial results in listed companies in Poland focus on estimating the scale and scope of EM using specific regression models. Empirical research based on survey techniques in which respondents professionally responsible for financial reporting in public companies would present their positions, views or experiences regarding such a "sensitive" issue is rarely seen. Hence, the paper will significantly contribute to the current knowledge on the point of EM in the Polish capital market.

2. Earnings management phenomenon – outline of the subject matter

The concept of EM is related to the accrual principle, which requires recognizing the financial effects of economic operations when they occur, ignoring the period when monetary assets are received or paid. The implementation of the accrual principle and the resulting matching principle is accompanied by a certain degree of freedom that managers have in recognizing revenues and profits as well as costs and losses. EM practices are based on accounting policy instruments that affect the size and structure of the financial result. The use of discretion and flexibility in selecting accounting policies provides the opportunity to choose the desired solutions in terms of accounting data shaping, but only within the limits set by the accounting law.

There are many definitions of EM in the scientific literature (see: Schipper, 1989; Healy, Wahlen, 1999; Leuz et al., 2003; Mulford, Comiskey, 2005; Walker, 2013; Bachtijeva, 2021). Diverse terminological approaches to EM point out that this phenomenon can be considered from the perspective of the reporting purposes set by managers (Dechow, Skinner, 2000; Piosik, 2013; Grabiński, 2016, Artienwicz et al., 2020; Strakova, 2021), techniques for earnings manipulation (McKee, 2005; Roychowdhury, 2006; Toumeh, Yahya, 2019; Bachtijeva, Tamulevičienė, 2022), the impact of EM on the company's value (Sankar, Subramanyam, 2001; Gunny, 2010), the transparency of the relationship between financial statements and the economic results (Parfet, 2000; Ronen, Yaari, 2008; Wójtowicz, 2010), etc.

Scott (2000) emphasized that EM practices can come in two forms: efficient earnings management, which improves the information value of the financial result, and opportunistic earnings management, which maximizes the utility function of management. Regardless of the assumed effect of operations aimed at shaping the financial result, EM activities can be implemented using two groups of instruments. The first are instruments covering strictly accounting choices and involving accrual reporting values modelling (consistent with the accrual-based EM concept). The second one considers economic instruments involving the creation or modification of real economic transactions to obtain the intended level of earnings

(cohesive with the concept of real EM). As noted Roychowdhury (2006), real EM recognizes departures from normal operational practices, motivated by managers' desire to mislead at least some stakeholders into believing certain financial reporting goals have been met in the normal course of operations. Activities consistent with the real EM concept differ from EM practices based on solutions that use flexibility in selecting accounting policies. Their characteristic features are more difficult and cost-intensive implementation, more common negative consequences of deploying, and a lower risk of detecting the intentionality of low-level reasons for the actions taken (Vladu, 2015).

The paramount strategies of EM, which consider the consequences of implemented earnings manipulation in the enterprise, include (Remlein et al., 2021):

- income smoothing, which involves the deliberate elimination of "ups" and "downs" in reported financial results by reducing and retaining profits in years of prosperity and their accounting use in periods of worse economic conditions;
- big bath, which consists of striving to increase reported profits in subsequent periods by charging items that may negatively impact the financial result in the future. At the same time, big bath practices worsen the poor economic results achieved in the financial period under consideration;
- window dressing, relating to all practices carried out shortly before the end of the financial year in order to improve selected positions of the company in the financial statement;
- avoidance of accounting loss, referring to the prospect theory, according to which investors evaluate information about a minimum profit more positively, as opposed to information about a minimum loss;
- avoidance of earnings reduction, relating to the belief that decreasing profits in several subsequent periods is generally perceived by the company's stakeholders as a basic signal of deteriorating financial standing.

All mentioned EM strategies can be implemented using a wide range of accounting techniques, the classification of which is difficult because each accounting method or estimate may have an integral connection with EM. A graphical presentation of the relationship between concepts, strategies and techniques of EM is depicted in Figure 1. It draws special attention to two important research perspectives. The first is the presumption that accrual-based- and real EM practices can be implemented on the principles of complementarity and substitutability (Zang, 2012; Chen et al., 2012; Paulo, Mota, 2019). The second highlights that, due to their specificity, capital groups have wider opportunities to shape financial results than individual enterprises. In their case, the balance sheet policy can be approached on two levels, considering accounting solutions typical for a firm preparing financial statements on general principles and accounting practices applicable only within capital groups.

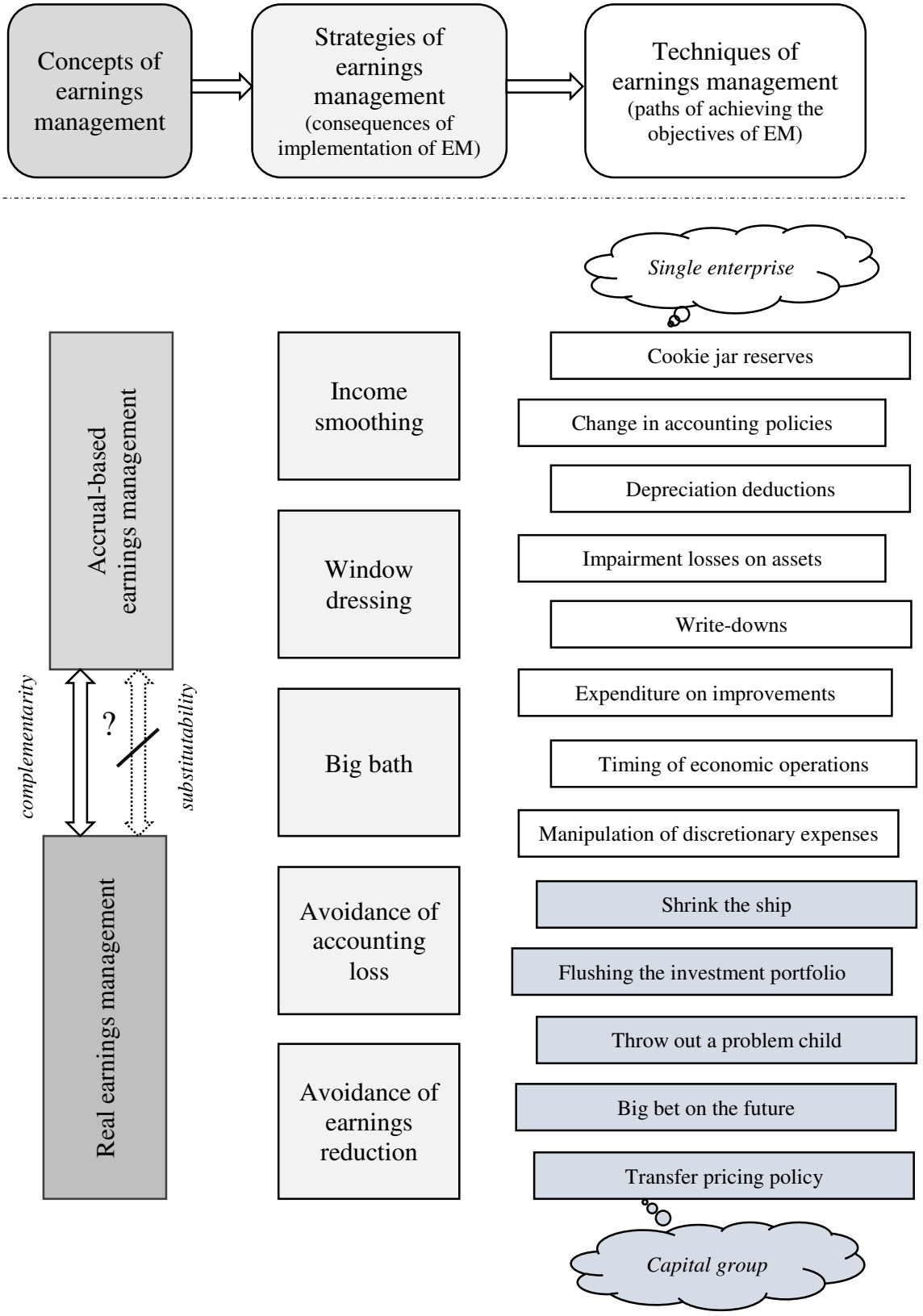

Figure 1. Selected concepts, strategies and techniques of earnings management in public companies.
Source: own elaborations.

Empirical research in Poland on the EM phenomenon and the quality of reporting information is relatively scarce (Michalak, 2018). The studies mentioned above cover three main strands, including:

- research on the degree of shaping the financial result in connection with specific incentives (see: Brzeszczyński et al., 2011; Gajdka, 2012; Istrate et al., 2017; Cherkasova, Rasadi, 2017; Lizińska, Czapiewski, 2018; Valaskova et al., 2021);
- research on identifying factors influencing the scope of EM practices (Michalak et al., 2012; Piosik, 2013; Comporek, 2017; Piosik, Genge, 2020; Michalkova, 2021; Comporek, 2022; Lizińska, Czapiewski, 2023);
- analysis of the perception of the quality of reporting information disclosed by listed companies by company stakeholders (Cieślak, 2011; Błażyńska, 2015; Świetla, Zieniuk, 2017; Cygańska et al., 2019).

Most of the empirical analyses that focus on EM issues, which are prepared for the Polish capital market, are based on the use of econometric models enabling the extraction of individual subcategories of accruals and the determination of indicators illustrating abnormal levels of cash flows from operations, production costs or discretionary expenses. These procedures allow for a preliminary estimate of the scale and directions of activities aimed at the intentional manipulation of reporting data, although it should be emphasized that each of the EM models has its limitations. However, only some of the research represents questionnaire studies, by which it is possible to better recognize the specificity of EM and earnings quality in reporting entities. The most important conclusions from their execution are presented below.

Cieślak (2011) surveyed the opinions of employees dealing with accounting in small and medium-sized enterprises about accounting regulations and their postulated need to improve. The research sample consisted of 324 respondents, and its selection was purposeful. One of the aspects taken into account in the study was the respondents' opinions on assessing the quality of financial statements. Almost half of the respondents believed the published financial reports were as reliable as needed. However, the percentage of interviewees stating that they believed the financial statements were falsified was similar. Every fourth respondent considered that they had only heard about the falsification of reporting items more often than they had personally encountered these practices.

Piosik (2013) tried to answer whether employees of financial and accounting departments and managers can practically use EM techniques and strategies in business practice. The research sample included 42 enterprises and 23 capital groups. The obtained results of empirical research show that, in the opinion of the respondents, the most effective EM instrument is to conduct economic transactions on such terms as to ensure the achievement of the reporting goal. The study's authors also proved that frequently used EM techniques were the manipulation of depreciation and write-offs and the creation and release of provisions. Moreover, interviewees indicated that EM strategies aimed at a steadily growing profit (from period to period) and avoided showing losses were extensively implemented in their firms.

Piosik collected evidence that in the studied sample, there are positive relationships between the EM scale and the company's size (assessed from the perspective of generated revenues and employment). He concludes that employees of finance and accounting departments (both rank-and-file and those holding managerial positions) have a low awareness and insufficient knowledge of the possibility of shaping profits (losses).

Błażyńska (2015), researching 334 investors, asked respondents, among others, to point out the importance of individual elements of the financial statements. The surveyed investors indicated the following order of importance of the financial reports, namely: profit and loss statement (94% of respondents described it as decisive or important), statement of financial position (93% of respondents) and statement of cash flows (80% of respondents). The results of Błażyńska's study on satisfaction with the quality and the scope of financial statements revealed that only 8% of interviewees believed that the financial statement was complete, and as many as 78% had no clear opinion on this issue. Besides this, the respondents highlighted a lack of precise information in the financial statements about the company's forecasts of results, asset replacement plans, assumptions made when measuring fair value, estimation methods used, and transactions with the parent company, i.e. those areas of accounting that can be used during the implementation of EM practices.

Świetla and Zieniuk (2017) researched the scale of the use of accounting policy instruments in meeting the objectives of business entities or in deliberate falsification or blurring of the image resulting from financial statements. Based on the responses of statutory auditors, they collected evidence that companies operating in the Polish market tend to adapt their accounting policy regarding estimated valuation to the company's goals. However, most respondents agreed that the companies they audited do not use accounting policy instruments in the field of valuation to blur or falsify the company's financial standing deliberately.

Cygańska et al. (2019) conducted research evaluating Polish accounting students' ethical attitudes towards the EM phenomenon. In this study, the impact of gender, age and professional experience on the assessment of ethical attitudes of managers in the purposeful shaping of the reported income level was analyzed. The research showed that the specificity of both EM concepts (accrual-based EM versus real EM) determined the image of ethical attitudes towards accounting manipulations, whereby the accounting type of EM was assessed more critically than earnings manipulations by operating decisions.

3. Research methodology

The study presented in the paper is part of a broader research project, “Impression management or information preparation? Motives and paths of earnings management in the time of the COVID-19 pandemic”, aimed at in-depth analysis of the main premises for

implementing EM practices in public companies and determining basic strategies for implementing the assumed objectives of aggregate-based and real EM. Moreover, the purpose of the project was to obtain answers to the questions of how earnings manipulation determines the quality of reported data and whether these practices are acceptable from an ethical point of view in the eyes of finance managers and employees of accounting departments of listed companies.

The postulated subject of the research was to conduct survey interviews among representatives of all non-financial public companies listed on the Main Market of the Warsaw Stock Exchange (N = 335). The target group of respondents included finance managers, accounting employees and other professionals authorized by representatives of the company's management staff at the level of the owner, president/vice president, member of the management board, and general director. The selection of the research sample was random (exhaustive testing). The sample was taken from data from the Central Statistical Office and the Dun & Bradstreet business intelligence agency.

Ultimately, 124 respondents representing diverse public companies agreed to participate in the research. They were asked questions regarding, *inter alia*, such issues as:

1. How often did the respondents encounter accounting practices involving the use of freedom in balance sheet regulations to create a false image of the financial position of an enterprise?
2. How do respondents assess the general intensity of EM activities in the public companies they represent?
3. How do respondents estimate the intensity of particular EM tools (techniques) in the public companies they represent?
4. In which periods of the financial year are the practices related to earnings manipulation particularly intensified?
5. What are the most important objectives for EM implementation in the company they represent?
6. How do respondents perceive the importance of the main premises (motives) for EM activities in their company?

For clarity, it should be emphasised that the survey research was conducted in June-August 2023, and the Marketing Research Centre “CBM Indicator” was responsible for its implementation.

4. Empirical results

The first step of the empirical research was to ask how often respondents encountered accounting practices involving the use of freedom in balance sheet regulations to create a false image of the company's financial standing in their business practice. This research shows that more than half of the interviewees (56.5%) declared they experienced the mentioned practices occasionally, while every fourth respondent (27.4%) stated that they often encountered activities comprising the EM phenomenon (Figure 2).

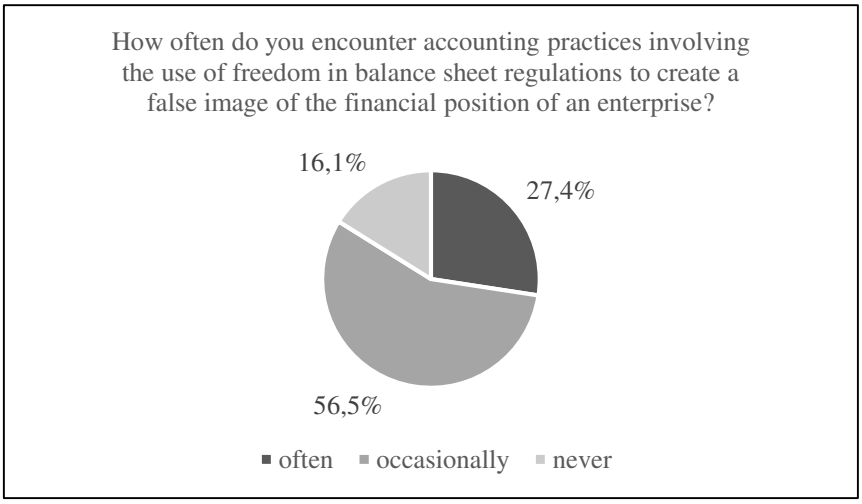

Figure 2. The structure of answers to the question regarding the frequency of encountering accounting practices allows to creation of a false image of the company's financial standing by respondents.

Source: own elaborations.

Interestingly, although the most interviewees declared that while performing their professional duties, they encountered accounting practices that allowed them to manipulate the company's financial standing, only 29% of respondents confirmed that EM activities are implemented in the company they represent (Figure 3). Moreover, only slightly over 3% of the respondents admitted that these operations are implemented frequently throughout each fiscal year. In further research, this group of respondents were asked for a closer characteristic of the specificity of EM activities in listed companies.

In the first instance, the peculiarities of the interdependencies between implementing accrual-based and real EM practices in public companies listed on the WSE were examined. It is worth emphasizing that 35 out of 36 respondents (97.2%) stated that accrual-based- and real EM strategies are used on the principle of complementarity in the firms they represent, thereby confirming the first research hypotheses. Similar conclusions regarding the relationships between varied EM concepts are included, among others, in studies by Matsuura (2008), Chen et al. (2012), and Hamza and Kortas (2019).

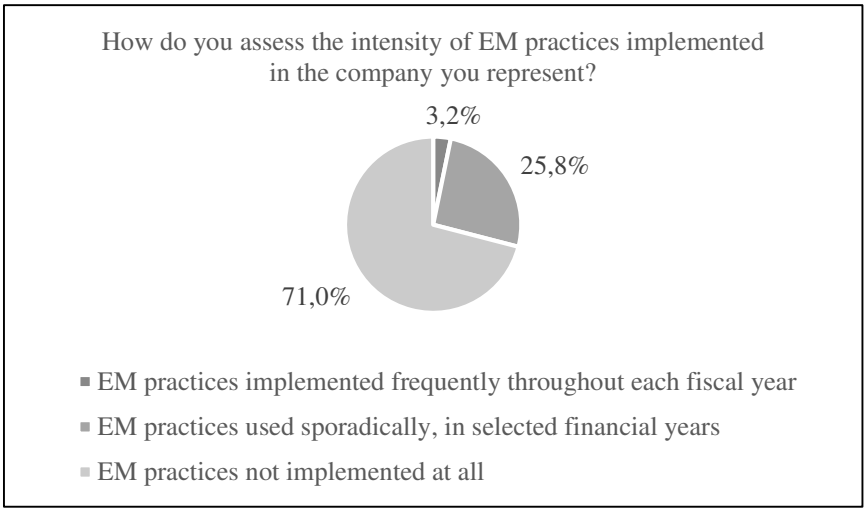

Figure 3. The structure of answers regarding the intensity of implementing EM practices in the companies the respondents represent.

Source: own elaborations.

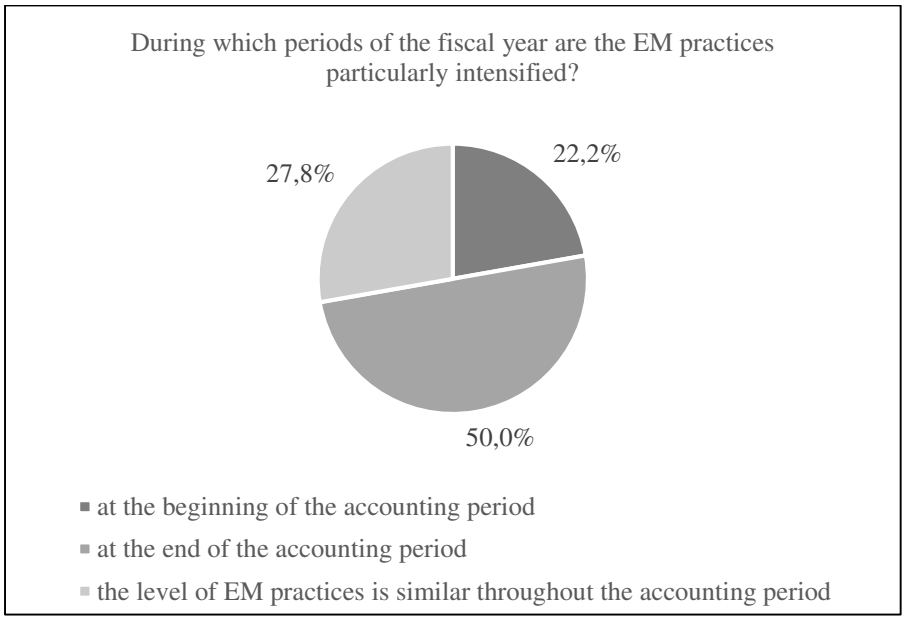

Figure 4. The structure of answers regarding the intensity of implementing EM practices in particular periods of the fiscal year.

Source: own elaborations.

Regarding the issue of the EM implementation period, half of the respondents declared that the intensification of the practice related to the intentional shaping of financial results occurred at the end of the accounting period (Figure 4). Approximately 28% of respondents stated that the EM severity is similar throughout the fiscal year, while about 22% of the interviewees indicated that the increase in EM practices is typical for the beginning of accounting years.

The next part of the empirical research concerns the most important objectives towards which the optics of EM practices implementation are directed (Figure 5). More than half of the respondents (55.6%) declared that earnings manipulation through EM activities is motivated to pursue income smoothing, consequently positively verifying the second of the research hypotheses. This strategy is based on manipulating the time profile of individual reporting items to make the reported profits less volatile. At the same time, the intended action of executives is to prevent excessive increases in the company's financial results in the long term. Nearly 39% of interviewees stated that avoiding earnings reduction is important in shaping the financial result. The premise for such an outlook is that, according to the prospect theory, investors value profits, losses, and their fluctuations differently (Artienwicz, 2018). The subjective feeling associated with the deterioration of the financial result by a given amount is stronger than the satisfaction with improving the result by the same amount. Every fourth respondent admitted that EM practices in the company they represent are taken for the broadly understood purpose of increasing profits. The reasons and motives for earnings manipulation upwards have a variety of backgrounds and range from the desire to meet analysts' expectations to incentives related to the realization of bonuses or maintaining a competitive position in the financial market (which was reflected in the further part of the research). Notably, a small percentage of interviewees stated that EM practices may be aimed at avoiding the avoidance of accounting losses or big baths. It should be added that respondents could select more than one item when answering this question.

In-depth empirical research also allowed for a preliminary identification of the most important premises (motives) for the implementation of EM practices in public companies (Table 1). The distribution of answers obtained by respondents shows that the dominant prerequisite for EM enforcement was an effort to create the image of a more profitable company compared to the largest competitors in the sector. Previous research has shown that public companies tend to disclose higher profits than the average in the sector to attract new investors (Dakhlallh, 2020). Nearly 95% of interviewees considered showing better development prospects for the company (which is explained, among others, in signal theory) and meeting market analysts' expectations regarding the level of reported financial results (which, in turn, is consistent with the assumptions of the thresholds theory) as a very important or quite important premise of EM implementation. On the other hand, according to respondents, EM practices are rarely motivated by opportunistic reasons (low motives; performance bonus) or financial strategies implemented in the company (dividend payment policy). Thus, the third research hypothesis set in the introduction of the paper was negatively verified.

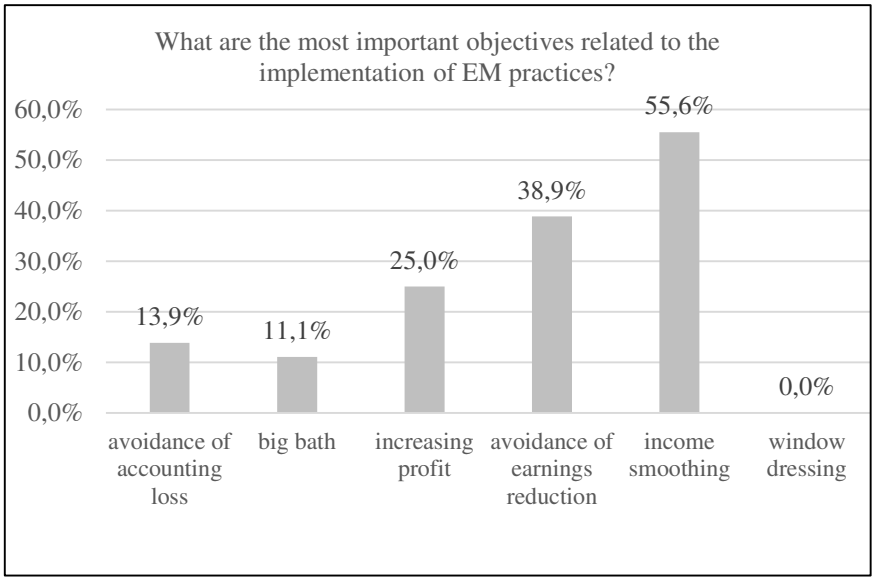

Figure 5. The share of respondents pointing to the most important objectives of implementing EM practices in public companies.

Source: own elaborations.

Table 1.
The importance of the main premises (motives) for implementing EM practices in public companies in respondents' opinion

Premise (motive)	The importance of premise (motive)			
	Very important	Quite important	Quite irrelevant	Completely irrelevant
maximizing personal benefits for management staff	5.6%	38.9%	52.8%	2.8%
reducing the tax burden in a given financial year	16.7%	55.6%	22.2%	5.6%
showing better development prospects for the company	16.7%	77.8%	5.6%	0.0%
creating the image of a more profitable company compared to the largest competitors	25.0%	69.4%	5.6%	0.0%
meeting market analysts' expectations regarding the level of reported financial result	19.4%	75.0%	5.6%	0.0%
protecting the company against excessive dividend policy	8.3%	44.4%	44.4%	2.8%
maintaining or increasing the company's creditworthiness	11.1%	61.1%	25.0%	2.8%

Source: own elaborations.

From an instrumental point of view, an important element of the research was the analysis of the accrual-based EM techniques widely used in public companies listed on the WSE (Table 2). According to the respondents, shaping financial results was implemented using a various spectrum of accounting practices. EM techniques related to the change of applied accounting policies involve the use of financial principles relating to such issues as accounting for the financial year, principles of valuation and depreciation of fixed assets (which was particularly noted by respondents), rules of asset inventory, inventory recording methods, principles of valuation of assets and liabilities, etc. The EM technique of manipulating depreciation and improvement expenditures focuses mainly on the possibility of distorting the

categories of operating expenses. The general principles of recognizing depreciation methods state that they should most faithfully reflect how the enterprise consumes the asset's economic benefits. Another important EM technique, according to respondents, is controlling expenses for renovations and improvements of fixed assets. Improving a fixed asset involves its reconstruction, expansion, and modernization and increases its value in use. Therefore, the incurred expenditure increases its initial value, which becomes a new basis for determining depreciation write-offs. Additionally, if the conditions for recognizing a significant improvement of a fixed asset are met, costs are activated in the company. Analyses of Table 2 indicate other finding worthy of comment. Namely, in the business practice of public companies, accounting manipulations by creating and terminating provisions are prevalent. Creating provisions involving the appropriate division of net profit and allocating it to achieve specific company objectives usually occurs when the financial result is better than expected. This situation causes a reduction of the reported financial result for a given accounting year and its "shifting" to later years of worse economic conditions, in which the release of provisions will increase the reported financial profit (loss).

Table 2.
The use of particular accrual-based EM tools (techniques) in public companies in respondents' opinion

Accrual-based EM technique	Frequency of use		
	Frequent use	Average use	Occasional or no use
Creation and release of provisions	19.4%	58.3%	22.2%
Selection and change of the fixed asset valuation model	13.9%	72.2%	13.9%
Selection and change of depreciation and amortization methods	27.8%	63.9%	8.3%
Write-offs for permanent impairment of fixed assets	25.0%	19.4%	55.6%
Allowances for the value of inventory and/or receivables	19.4%	69.4%	11.1%
Controlling expenses for renovations and improvements of fixed assets	27.8%	55.6%	16.7%
Faulty presentation of R&D works	5.6%	16.7%	77.8%

Source: own elaborations.

The final stage of empirical research was aimed at a closer examination of the techniques of real EM implemented in public companies listed on the Polish capital market (Table 3). The obtained results of questionnaire research prove that nearly 14% of respondents admit that in public companies, a frequently implemented method of manipulating earnings is an abnormal reduction of discretionary costs, including SG&A expenses. The vast majority of interviewees (70%) declared that a common practice (average use) in the firms they represent is accelerated invoicing, i.e., recognizing revenues before they are realized (which can be strictly considered accounting fraud). Another important technique of real EM is the excessive acceleration of sales revenues and operating cash flows at the end of the period, resulting either from offering abnormal price discounts or adopting a very liberal policy of managing short-term receivables.

Table 3.
The use of particular real EM tools (techniques) in public companies in respondents' opinion

Real EM technique	Frequency of use		
	Frequent use	Average use	Occasional or no use
Abnormal reduction of SG&A expenses	13.9%	38.9%	47.2%
Abnormal reduction of R&D expenses	5.6%	19.4%	75.0%
Accelerated invoicing and manipulation of the revenue recognition period	5.6%	69.4%	25.0%
Structuring and timing of economic operations	2.8%	41.7%	55.6%
Acquisition or divestiture of subsidiaries	0.0%	5.6%	94.4%
Sales acceleration resulting from above-average discounts	2.8%	44.4%	52.8%
Sales acceleration resulting from the liberal deferred payment policy	2.8%	55.6%	41.7%

Source: own elaborations.

5. Summary

Transparency and credibility of reporting information are crucial in managing modern organizations. Financial statements should provide data that will be useful to a wide range of users and reflect current revenues and costs, unambiguously present the company's core activities' results, and illustrate direct links between reported profits (losses) and operating cash flows. However, economic practice shows that implementing EM activities can distort these features.

The survey research results among finance managers and representatives of accounting services emphasize the importance of EM practices in public companies listed on the Polish capital market. The existence of areas of free choice makes it possible to use accounting policy and economic transactions to manipulate the level of the reported earnings. During the research, it turned out that 29% of respondents admitted to implementing EM practices in firms they represent. Moreover, interviewees declared the use of various accrual-based and real EM instruments in a complementary way. The dominant EM strategies proved to be income smoothing and avoidance of earnings reduction, while the main reasons for EM implementation respondents included creating the image of a more profitable company (compared to the largest competitors), meeting market analysts' expectations regarding the level of reported financial result and showing better development prospects for the company.

The limited number of respondents willing to participate in the research causes the presented results of empirical analyses do not fill the condition of generalization and cannot be directly applied to all public companies listed on the WSE. However, it should be emphasized that the research sample size may be determined by the fact that the undertaken issue of earnings manipulation may be considered highly sensitive. Indeed, EM practices are perceived by many accounting theorists and practitioners as activities balancing on the verge of law.

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DATA CONCERNING COVID-19 CASES IN POLAND AT THE END OF THE PANDEMIC

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Purpose: The main purpose of this article is to analyze and understand trends in COVID-19 cases in Poland during what is considered the end of the pandemic.
Design/methodology/approach: The article uses data visualization methods to assess trends and identify key factors influencing the dynamics of the pandemic. The analysis included data on the pandemic in the period from 1 January, 2023 to 30 June, 2023. On 1 July, 2023, the state of epidemic threat in Poland was canceled.
Findings: Analysis of epidemiological data showed that the number of new COVID-19 cases in Poland showed a gradual decline during the period considered to be the end of the pandemic. This reduction in case numbers has been consistent across regions of the country, although some areas have seen periodic increases. The data clearly demonstrate the significant impact of vaccinations in reducing the number of new infections and severe disease outcomes. Regions with higher vaccination rates saw lower COVID-19-related hospitalizations and deaths.
Research limitations/implications: The surveys discussed in this article may contribute to further empirical studies, including but not limited to initiating works to improve the pandemic analysis.
Practical implications: The study provides important information that can be used by public health decision-makers to shape effective pandemic response strategies. The results highlight the importance of maintaining and adapting intervention measures, such as vaccination, to control the spread of the virus and reduce the number of severe cases.
Originality/value: This study stands out from other works on the COVID-19 pandemic by its unique focus on the final stage of the pandemic in Poland. While most studies focus on the early stages of the pandemic or its global impact, our study offers detailed insight into local aspects of pandemic management and its evolution in a specific country. We present a comprehensive analysis that combines epidemiological data, the impact of health policy, social behavior and vaccination effectiveness.

Keywords: pandemic, COVID-19, data analysis, Poland.

Category of the paper: General review, Research paper.

1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has significantly impacted people's lives (Kumar et al., 2021; Baloch et al., 2020). In Poland, as in other countries, the pandemic has caused significant challenges for the health care system, economy, and society (Grifoni et al., 2020; Ciotti et al., 2020). Although high numbers of infections and deaths characterized the first waves of the pandemic, later stages brought changes in the dynamics of virus transmission, partly due to the introduction of vaccination programs and other intervention measures. By 30 June 2023, 6,517,852 cases of COVID-19 infections and 119,626 deaths were registered in Poland.

The SARS-CoV-2 virus belongs to the coronavirus family that causes COVID-19. This virus is transmitted through droplets, i.e., through contact with an infected person who coughs or sneezes. It is recommended to follow basic hygiene rules to avoid infection, such as frequently washing hands with soap and water, wearing masks where it is impossible to maintain a safe distance, avoiding touching the face, and carrying social distance (Jelnov, 2020; Suryasa, 2021).

Our research aims to provide insight into how Poland dealt with the final phase of the pandemic, which may be valuable in planning future public health strategies and responding to potential future pandemic-like events. We also present conclusions that can help understand the effectiveness of current actions and pave the way for improvements in the future.

The analysis used data from the Ministry of Health, the Chief Sanitary Inspectorate, and other national and international sources. This data includes case numbers, hospitalizations, deaths, and information on vaccination rates. The article uses data visualization methods to assess trends and identify critical factors influencing the dynamics of the pandemic. The analysis included data on the pandemic from 1 January 2023 to 30 June 2023. On 1 July 2023, the state of epidemic threat in Poland was canceled by the government. In this introduction, we present the context and goals of our research, which aim to shed light on the current epidemic situation in Poland and its national and global implications (COVID, 2023).

The article consists of two parts. The first part concerns the history of the pandemic, especially the initial period. It describes the main decisions regarding restrictions introduced in Poland to limit the spread of the SARS-CoV-2 virus. The second part concerns data from 1 January 2023 to 30 June 2023. The article ends with conclusions. The study's findings have significant practical value for health policymakers, healthcare professionals, and researchers. They provide essential information that can help better understand the dynamics of the pandemic and shape more effective public health strategies. The analysis results can also serve as a basis for future research and analysis on managing the pandemic and its social and economic effects. The study makes a new contribution to the scientific discourse on COVID-19 by expanding the understanding of the pandemic through a detailed analysis of its later stages.

2. SARS Covid-19 pandemic in Poland – historical outline

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, began in December 2019 in the Chinese city of Wuhan. It soon spread worldwide, becoming a global health, social and economic challenge (Abid et al., 2020). It became a pandemic in March 2020, when the World Health Organization (WHO) announced that COVID-19 infection was already affecting many countries worldwide (WHO, 2023; Khoo et al., 2020).

In Poland, research on the coronavirus began on 31 January 2020. They were carried out by the National Institute of Public Health - National Institute of Hygiene (NIZP-PZH). As of 29 February 2020, 307 tests were performed, and 28 were pending. The tests were conducted in two laboratories in Warsaw: NIZP-PZH and the Provincial Infectious Diseases Hospital in Warsaw. Centers in Olsztyn and Wrocław have been prepared for research. The remaining laboratories in Poland were preparing to start their tests. At the same time, in other countries, the number of samples tested (as of 29 February 2020) is France - 800, Austria - 350, and the USA - about 450. On 6 March 2020, there were already 13 laboratories in Poland, and the number of tests carried out increased to 900; five were positive. Patient Zero appeared in Poland on 6 March and was a person who came to Poland from Germany. From that moment on, restrictions on mass gatherings began to be introduced. On 8 March 2020, the Chief Sanitary Inspector recommended canceling all mass events organized indoors for over 1000 people.

On 10 March 2020, the Rector of the University of Warsaw canceled all lectures and classes for students, doctoral students, and listeners from 11 March to 14 April 2020, except for those held remotely. At the Jagiellonian University, the Rector canceled lectures for students, doctoral students, and physical education classes. The Rector of the Wrocław University of Science and Technology and the chairman of the College of Rectors of Universities in Wrocław and Opole announced that from 11 March 2020, "all forms of teaching" at 14 public universities in the Lower Silesian Voivodeship and the Opole Voivodeship will be suspended. Classes at the University of Warsaw were also suspended. Courses at the University of Adam Mickiewicz in Poznań from 11 March 2020 until further notice. On the same day, a meeting of the National Security Council on actions regarding COVID-19 was held. Prime Minister Mateusz Morawiecki canceled all mass events.

In Poznań, a decision was made that all schools, kindergartens, nurseries, and other city institutions will be closed as a preventive measure for two weeks (i.e., from 11 to 24 March 2020). On 11 March 2020, Prime Minister Mateusz Morawiecki and the ministers (respectively: health, national education, and higher education) Łukasz Szumowski, Dariusz Piontkowski, Jarosław Gowin announced the closure of educational institutions for two weeks (i.e., March 12-25, 2020) as a preventive measure. There were no classes from Thursday, 12 March 2020, but children could come to classes (if their parents could not take care of them), and only from

Monday was there a complete closure. The closure concerned, in particular, all schools (public and private), kindergartens, nurseries, secondary schools, and universities. Two days later, the Prime Minister announced that starting 15 March 2020, Poland's borders would be closed to air and rail traffic. Passport controls were also introduced at all land borders, and only Polish employees and citizens were allowed to enter the country. After crossing the border by land, there would be a 14-day quarantine, breaking, resulting in a fine of 5,000 zloties. A ban was introduced on public gatherings of more than 50 people, including state and religious gatherings. On 25 March 2020, the Minister of Interior and Administration, Mariusz Kamiński, announced at a press conference the decision to extend the border closure, based on international law, in connection with the development of the epidemic in Europe and around the world - by 20 days until 13 April 2020 (the previous period lasted ten days, March 15-25, 2020). Kamiński emphasized that the restrictions do not apply to the flow of goods, which will continue to flow freely. The first loosening of restrictions took place on 20 April 2020. Since then, restrictions have been slowly lifted, but you should still wear a nose and mouth cover and disinfect your hands in closed spaces, including public transport. Until July, there was a decline in the number of people infected with coronavirus - the number of fatalities decreased and the number of recoveries increased.

In total, six waves of the pandemic could be observed in Poland: 1st wave until August 2020, 2nd wave until November, 3rd wave until April 2021, 4th wave until December 2021, 5th wave in February 2022, and 6th wave in September 2022. The individual waves of the pandemic are presented in Figure 1.

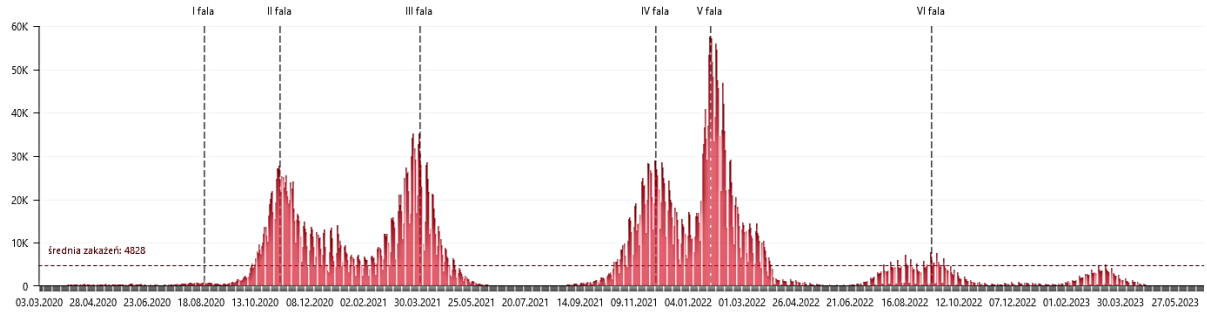

Figure 1. Number of confirmed SARS-CoVID-19 infections in Poland during the pandemic.
Source: https://koronawirusunas.pl/, 8/10/2023.

Figure 2 shows the number of deaths due to Covid-19 and comorbidities. The pandemic caused by the SARS-CoV-2 virus is a highly contagious virus. This virus is transmitted mainly through droplets, close contact with an infected person, and by touching surfaces on which viruses are found and then touching the face, nose, or mouth. A characteristic of SARS-CoV-2 is that infected people can transmit the virus even when they do not yet show symptoms, contributing to its high contagiousness. COVID-19 mortality rates varied by region, age group, availability of health care, and many other factors. Covid-!9 had a higher mortality rate than many other viral diseases.

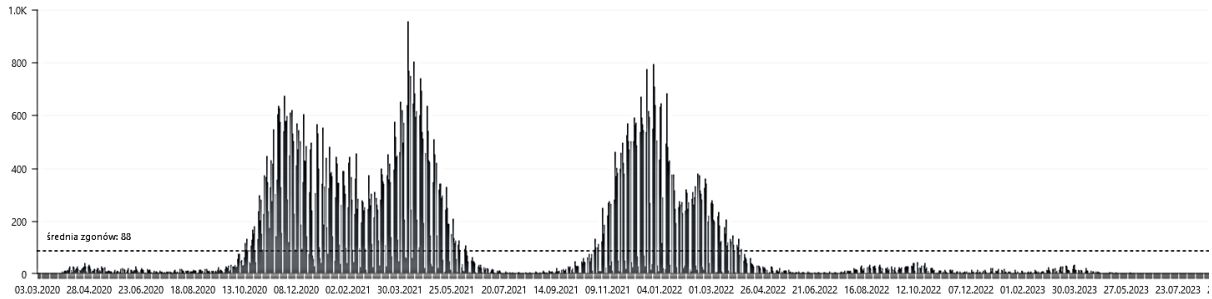

Figure 2. Number of deaths due to COVID-19 and comorbidities in Poland.

Source: https://koronawirusunas.pl/, 8/08/2023.

Wilson et al. (Wilson, 2020) estimated the risk of death of people suffering from COVID-19 at 3.5% in China and, on average, 4.2% in other 82 surveyed countries around the world. Jelnov (Jelov, 2020), based on panel studies on a sample of 156 countries around the world, showed that COVID-19 probably does not spread to more than a few percent of the population but leads to a relatively high mortality rate of approximately 10% on average. A similar situation also occurred in Poland. The COVID-19 mortality rate in Poland until 30 June 2023 was about 1.84%. It can be described as for every 100 people infected with the virus, approximately 1.84 died from the disease. It should be noted that the mortality rate in other countries was much higher. For example, in France, Finland, and Belgium, as of 14 June 2020, it was over 16%. However, in the case of Malta, Slovakia and Cyprus it was only 2%. Hungary and Finland, which have one of the lowest levels of coronavirus infection, have experienced very high COVID-19 mortality rates. In the case of Luxembourg, however, an inverse relationship can be observed, i.e., a very high level of COVID-19 infection in the population is associated with a relatively low mortality rate.

3. Covid-19 pandemic in Poland in 2023

In the first half of 2023, there was an epidemic threat in Poland related to the COVID-19 pandemic. This status was abolished on 1 July 2023. The epidemic threat was introduced in Poland on 16 May 2022; previously, the state of the epidemic was in force. Although the state of epidemic threat has been lifted, not all solutions and restrictions from the pandemic have been canceled. It was decided to introduce a state of epidemic threat due to the evaluation of the virus. The appearance of the Omicron variant in 2022 meant that, despite a similar number of cases, the number of people hospitalized and deaths decreased (Del Rio et al., 2022). Forecasts regarding the development of the pandemic in Poland in 2022 are presented in the following figures (from 3 to 5).

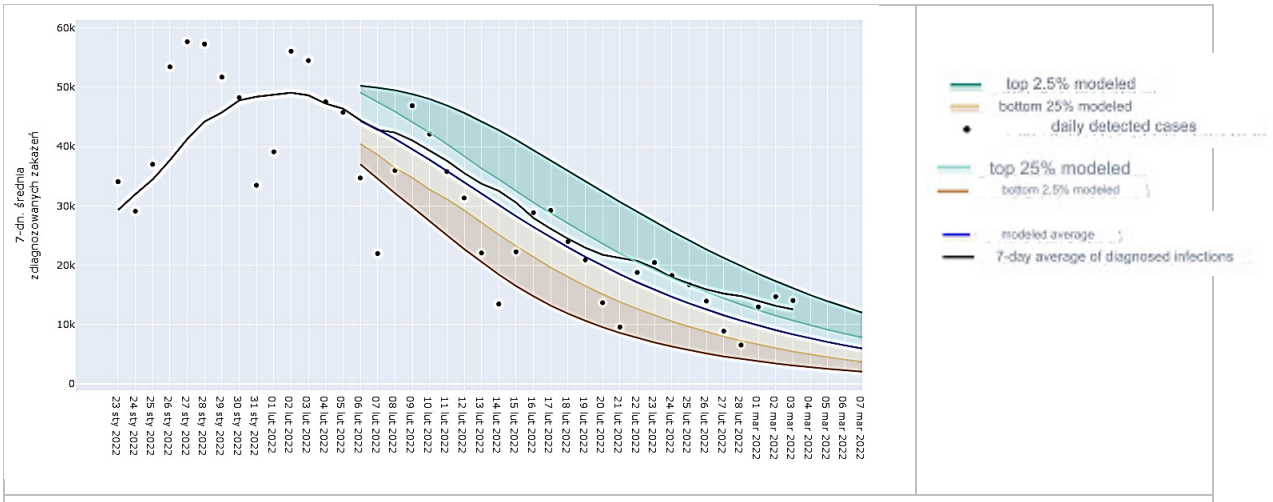

Figure 3. Short-term forecast of the development of the pandemic after 6 February 2022 - number of diagnosed cases.

Source: www.macos.pl, 15/06/2022.

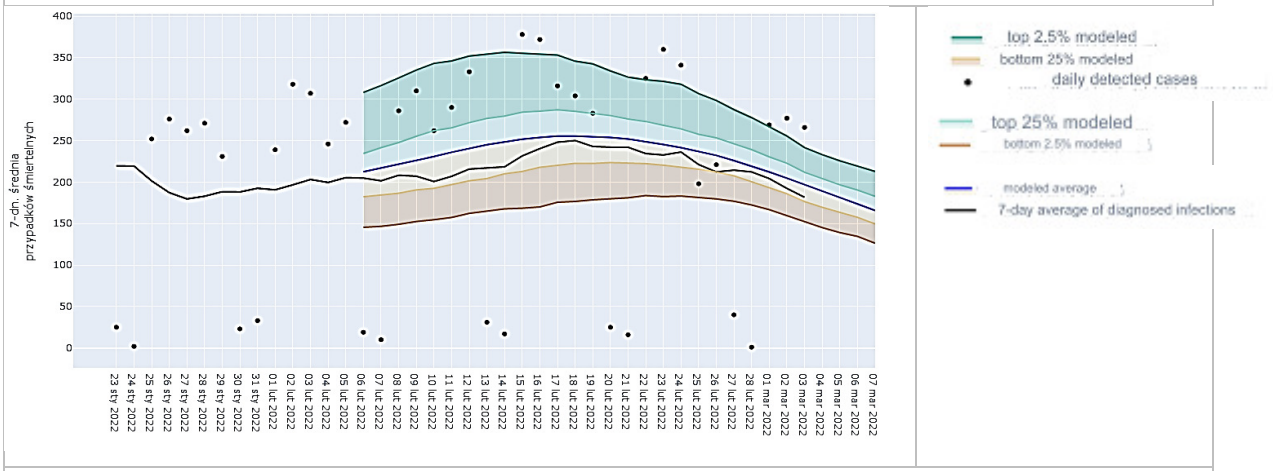

Figure 4. Short-term forecast of the development of the pandemic after 6 February 2022 - number of fatal cases.

Source: www.macos.pl, 15/06/2022.

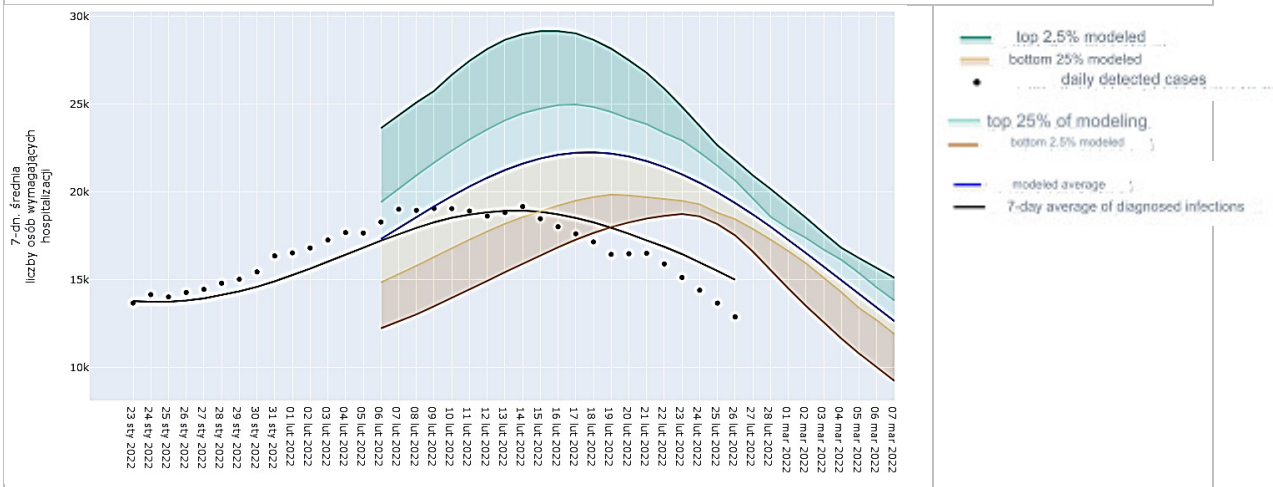

Figure 5. Short-term forecast of the development of the pandemic after 6 February 2022 - number of people requiring hospitalization.

Source: www.macos.pl, 15/06/2022.

The World Health Organization (WHO) has published a report predicting the future of pandemics and epidemics. With a short time horizon (3-5 years), this report was not a prediction of the future, but an invitation to consider the different directions that current and future pandemics may take. The report generally focused on the emergence of new pathogens, mutations of existing pathogens, global human mobility, climate change, antibiotic resistance, and social and economic inequality. Highlighting these risks in the WHO report was intended to increase awareness and prepare for various scenarios that may arise in the future in the context of infectious threats. These scenarios aimed to identify possible threats and solutions, discuss implications, and propose actions to prevent or mitigate the impact of current and future infectious threats.

The Institute for Health Metrics and Evaluation has developed a model for forecasting the trajectory of the COVID-19 pandemic until 2023, considering the possibility of the emergence of new virus variants and various intervention strategies. This model predicted additional infections, hospitalizations, and deaths based on multiple scenarios, such as the emergence of a new Omicron-like variant, a variant with a high ability to break immunity, and a scenario without the emergence of a new variant. Projections indicated different outcomes depending on the characteristics of future COVID-19 variants (COVID-19 Forecasting Team, 2022) {ioannidis, 2022).

Overall, forecasts for 2023 were varied and depended on many factors, including the emergence of new virus variants and the effectiveness of interventions such as vaccinations and personal protective equipment.

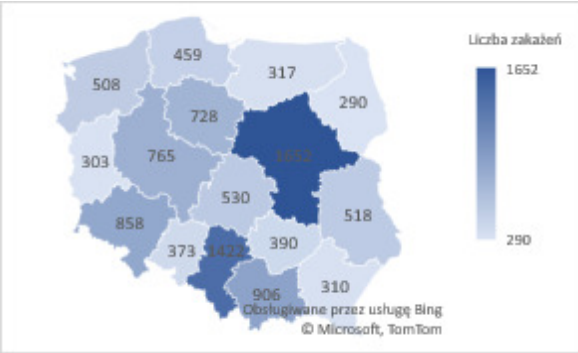

Figure 6. Number of new infections in individual voivodeships in January 2023.

Source: Own study.

Figure 7. Number of new infections in individual voivodeships in February 2023.

Source: Own study.

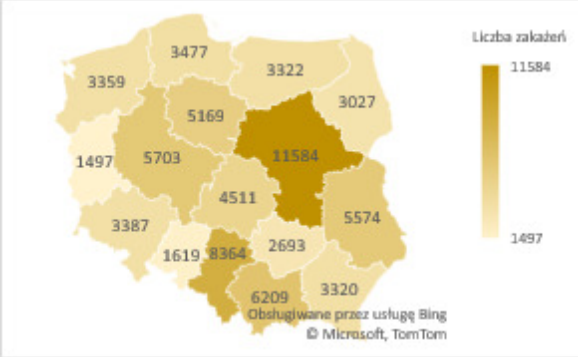

Figure 8. Number of new infections in individual voivodeships in March 2023.

Source: Own study.

Figure 9. Number of new infections in individual voivodeships in April 2023.

Source: Own study.

Figure 10. Number of new infections in individual voivodeships in May 2023.

Source: Own study.

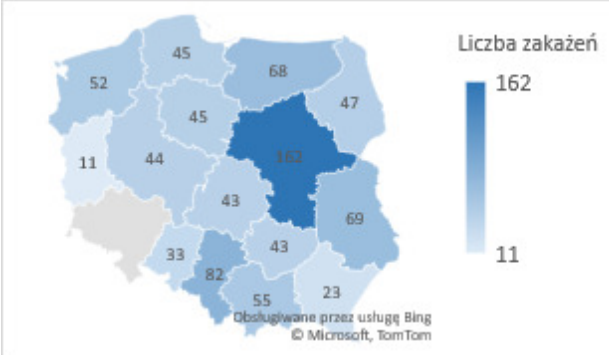

Figure 11. Number of new infections in individual voivodeships in June 2023.

Source: Own study.

In January 2023, the number of COVID-19 patients in Poland increased. The following figures (Figures 3 to 6) show the number of patients in individual voivodeships in subsequent months. 149419 people were infected with Covid-19 from 1 January to 30 June. The decreasing number of COVID-19 patients was mainly influenced by vaccinations offered from 2021 worldwide. Figure 11 shows the number of people vaccinated as of 10 January 2022. By 30 June 2023, 6,517,852 cases of COVID-19 infections and 119,626 deaths were registered in Poland.

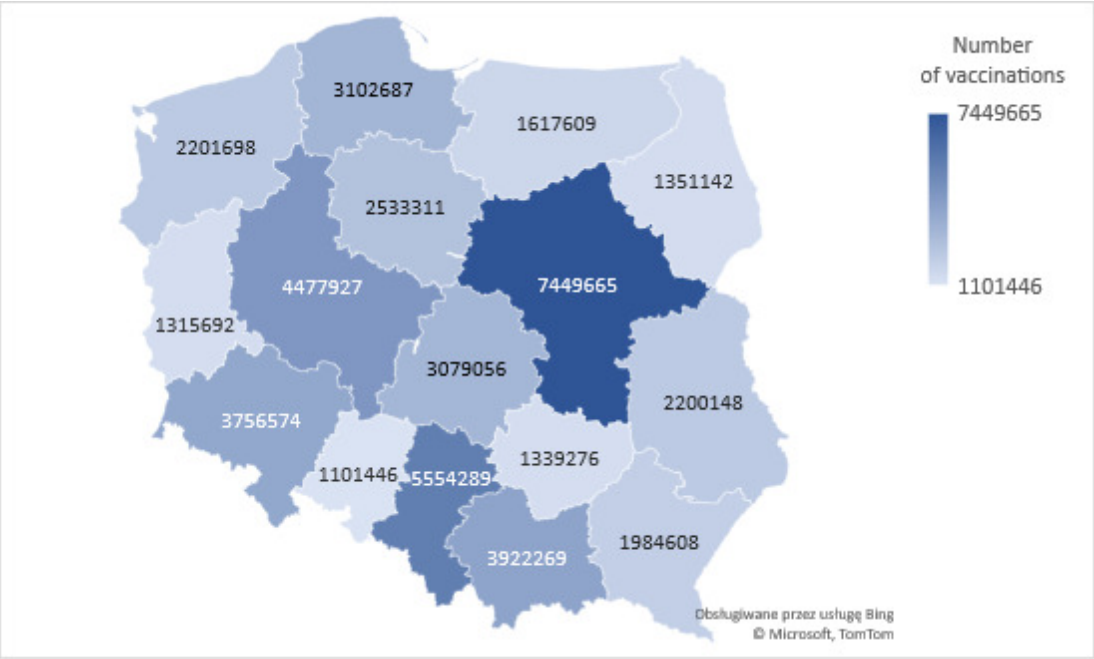

Figure 11. Number of vaccinations performed in individual voivodeships as of 10 January 2022. Source: Own study.

The analysis of data on COVID-19 cases in Poland in the period considered to be the end of the pandemic provides essential information on the dynamics of the virus and the effectiveness of the actions taken. We have observed a significant decrease in new cases, which can be interpreted as a positive effect of vaccinations and naturally acquired immunity in the population. However, although less numerous, persistent cases indicate the need to continue monitoring the situation and adapting public health strategies. The spread of new variants of the SARS-CoV-2 virus, including Omicron, had a significant impact on the dynamics of the pandemic. Although case numbers have been lower compared to earlier waves of the pandemic, the diversity of virus variants continues to pose a significant challenge to public health systems. The results highlight the importance of vaccinations as a critical tool in the fight against the pandemic. There is a clear correlation between high levels of immunization and lower numbers of hospitalizations and deaths. It indicates the effectiveness of vaccinations in preventing severe disease.

4. Conclusions

The COVID-19 pandemic has brought many lessons and conclusions that may be valuable for future emergencies and social, medical, and economic development. The pandemic has demonstrated the importance of planning and responding quickly and effectively to health crises. The preparedness of health systems, flexibility in decision-making, and global coordination are critical to effectively responding to the pandemic. The pandemic has

highlighted the need for international cooperation and solidarity between countries. Actions undertaken as part of international cooperation, such as sharing knowledge, medical resources, and vaccines, are crucial to limiting the spread of the virus and the pandemic's effects. The pandemic resulted in intense scientific and innovative development. The rapid growth of diagnostic tests, vaccines, and antiviral drugs are examples of scientific achievements in the fight against the pandemic. Continued investment in research is crucial to preventing future health threats. The COVID-19 pandemic has created a mental health crisis for many people around the world. It is necessary to increase awareness and support for people affected by stress, social isolation, and other psychological effects of the pandemic. Education and communication also turned out to be very important during this period. Effective communication and public education are essential in crises. Reliable information, clear messages, and public education are crucial to reducing panic, increasing awareness, and practical preventive actions. The pandemic ended in July 2023, but there is still a need to be vigilant about potential changes in the virus and to maintain readiness to respond to possible future health threats. With the knowledge and experience gained from this difficult time, societies can respond more effectively to future health challenges, moving towards a more resilient and flexible society.

In summary, data on COVID-19 cases in Poland at the end of the pandemic provide valuable clues about the effectiveness of current public health strategies and indicate areas requiring further monitoring and research. Our results highlight the importance of an integrated approach, combining medical, behavioral, and policy strategies, to effectively manage the pandemic and its effects.

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LEVELS OF AI APPLICABLE IN SMART CITIES

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Purpose: A Smart City is the most essential ideology for city development. Technologies based on Artificial Intelligence are an indispensable part of this ideology. There is no smart city level in which its elements are not used. The article overviews the areas where cities have used technology based on Artificial Intelligence. The article aims to examine and present various applications of Artificial Intelligence in the context of smart cities. The article aims not only to identify and analyze the multiple levels at which AI can be used to improve the quality of life of residents and the efficiency of city services but also to draw attention to the challenges and potential implications related to the implementation of these technologies. Practical examples supported theoretical considerations.
Design/methodology/approach: The article uses a literature search. An in-depth analysis of the techniques used in Polish cities, not only those boasting the name of smart city, was carried out.
Findings: During research on the use of Artificial Intelligence in smart cities, several key areas were identified in which AI has a significant impact: traffic and transport management, energy management and sustainable development, public safety, waste, and natural resources management, services for residents and spatial planning and urban development. These results can serve as a basis for further research and development of AI implementation strategies in urban contexts.
Originality/value: The critical value of the article is its ability to identify and analyze both the opportunities and challenges associated with implementing AI in cities. The article contributes to a deeper understanding of smart cities' potential benefits and risks through a balanced approach considering technological, social, ethical, and environmental aspects.

Keywords: smart cities, Artificial Intelligence.

Category of the paper: Research paper.

1. Introduction

The recent population migration in Poland has resulted in the expansion of cities. Therefore, their development seems to be the natural order of things. This is all the more so because, as an artificial human creation, the city has a chance to develop new ideas, ventures, and innovative technologies (Sikora, 2013). In the digital transformation era, cities worldwide face the challenge of adapting to rapidly changing technologies and growing expectations of residents (Czupich, 2016; Papa, 2015). At the level of urban development, we talk about the concept of a Smart City, i.e., intelligent cities in which the life and development of people are better and more straightforward. Currently, smart city is used interchangeably with the names digital city and sustainable city, indicating the direction of transformation that cities are undergoing (Stawasz, 2016). The development of the smart city concept has been the story of the last dozen or so years. In 2015, views on smart cities introduced an approach based on the creative involvement of residents, i.e., the Smart City 3.0 model. According to the Smart City 3.0 model, cities must be open to the active attitude of residents in creating their development. The authorities' role is to create conditions to actively use the residents' creativity. This applies primarily to encouraging residents to use modern technologies and develop technological solutions. The Smart City concept is based on six pillars: smart economy, smart environment, smart people, smart governance, mobility, and quality of life (Allam, 2018).

Artificial Intelligence has become one of the key elements driving the development of the smart city concept. Thanks to its ability to analyze large data sets, learn from experience, and make decisions. Technologies based on artificial Intelligence can open the door to new possibilities in city management. They are starting from road traffic optimization to advanced public safety systems (Skalfist, 2020).

This article aims to explore the different levels at which AI is used in the context of smart cities, highlighting its potential benefits and challenges. As cities become increasingly computerized and connected, AI plays a crucial role in processing the vast amounts of data generated by city systems and residents, transforming them into useful information and intelligent solutions.

The article begins with a literature review on the role of AI in smart cities, then moves on to analyze specific applications of AI in various aspects of urban life, such as traffic management, public safety, resource management, public health, and interaction with residents. Then, the article focuses on specific areas in which the smart city concept is developed and examples of the use of artificial Intelligence in Polish cities.

2. Smart city ideology

There are many definitions of a smart city in the literature. They differ in the distribution of accents between the approach to technology, functionality of cities, and social issues. N. Komninos claims that a smart city is an area consisting of four main elements (Komninos, 2008): the population carrying out knowledge-based activities or a group of such activities; digital spaces of e-services and online tools for knowledge management, effectively operating institutions and procedures in the field of knowledge creation and the ability to be innovative and solve problems emerging for the first time. It is safest to provide a definition that covers all the ingredients mentioned. This is the definition presented by the Committee of Digital and Knowledge-based Cities in 2012: A smart city is "a city that uses information and communication technologies to increase the interactivity and efficiency of urban infrastructure and its components, as well as to raise the awareness of residents" (Trzesicki, 2020). It seems that the smart city concept is a natural consequence of the evolution of cities. This evolution took place starting from the city of knowledge, through the idea of a digital city, a smart city, to the vision of an ecological city, finally reaching the concept of a smart city (Łabędzki, 2022).

According to K. Łabędzki (Łabędzki, 2022), three generations of smart cities can be distinguished. The first generation concerns advanced technologies, and the solutions offered are unified and do not correspond to the individual characteristics of the city. When implementing cutting-edge technologies, the city authorities do not consult the city's residents on the need for their implementation. The second generation assumes that the city authorities are at the center of attention. The task of the city authorities is to look for solutions tailored to urban needs. The third generation of smart city ideology emphasizes the initiative of residents. In the third generation, residents express their opinions, needs, and expectations. Local government administration plays an advisory role here or supports the communication channel (Greser, 2022).

The problematic nature of the elements that make up every modern city makes it a complex socio-economic system. The development of this complex system depends mainly on the relationships between the components. Advanced information and communication technologies - ICT - are essential in the modern city. Using ICT technology results primarily in cost reduction (Skalfist, 2020).

3. The use of artificial Intelligence in smart cities

Artificial Intelligence (Różanowski, 2007) is an advanced field of computer science that focuses on creating and developing computer systems capable of performing tasks that traditionally require human Intelligence. These tasks include but are not limited to, pattern recognition, learning, reasoning, problem solving, perception, natural language processing, and decision making. Artificial Intelligence, in its basic form, is represented by algorithms that imitate the cognitive functions of the human mind, processing data and information from the environment, which allows machines to learn, adapt, and make autonomous decisions on their own (Kowalczewska, 2021).

Różanowski (Różanowski, 2007) distinguishes two approaches to the issues of artificial Intelligence: vital artificial Intelligence (strong AI) and the second approach - weak artificial Intelligence (weak AI). In the current reality, artificial Intelligence can be divided into three main categories, depending on the scope of its capabilities and advancement (Sądel, 2015):

1. Artificial Narrow Intelligence (ANI) - refers to AI systems that are designed and trained to perform a specific task. Such systems do not have general awareness or self-awareness but operate within a limited task scope. Examples include speech recognition programs, recommendation systems on streaming services, and chess algorithms,
2. artificial general Intelligence (AGI) - this is a hypothetical level of AI in which machines could demonstrate intellectual abilities comparable to humans, including the ability to learn, understand, adapt and apply knowledge to a wide range of tasks. AGI remains mainly in the sphere of theoretical research.
3. Artificial superintelligence (ASI) is a level of AI that would exceed human Intelligence in all aspects, from creativity and emotional abilities to social and technical skills. ASI is the subject of scientific and philosophical speculation, and its potential creation raises many ethical and safety-related debates.

Artificial Intelligence (AI) is increasingly crucial in city management, enriching and improving its functions. Thanks to advanced technology and learning algorithms, AI can analyze vast amounts of data, providing valuable information and forecasts that help make decisions to improve residents' lives. Artificial Intelligence can be used in many areas of city management.

Table 1.
Application areas of AI in Smart City

Area of application	Characteristic
Traffic and transport management	AI helps optimize urban traffic, manage public transport systems, and plan infrastructure. You can discuss how intelligent traffic light systems, camera data analysis, and traffic sensors contribute to smoother traffic and reduced traffic jams.
Energy management and sustainable development	AI can optimize energy consumption in public buildings, monitor and manage renewable energy systems, and predict energy demand. Such solutions include intelligent street lighting and energy management systems in buildings.

Cont. table 1.

Public safety and surveillance	AI is used to analyze images from city cameras to improve security, but this also raises privacy and ethical issues. Balancing security and privacy can be discussed.
Waste and natural resources management	Intelligent systems can help optimize waste collection, monitor air and water pollution levels, and manage natural resources.
Services for residents	AI can improve communication between residents and city authorities, e.g., through intelligent chatbots, problem-reporting systems, or personalized public services.
Spatial planning and urban development	Using AI to analyze large data sets can help in better spatial planning and urban development management, e.g., by analyzing demographic trends, resident behavior, or climate change.

Source: Own study.

3.1. Artificial Intelligence (AI) in traffic and transport management - Smart mobility

Traffic and transport management in the context of smart cities using artificial Intelligence (AI) is a dynamically developing field that opens new opportunities for more effective, safer, and more sustainable urban mobility management. AI plays a significant role in urban transport, starting with optimizing traffic lights. By analyzing data from cameras and traffic sensors in real-time, these systems can adapt traffic signals to current conditions, contributing to smoother traffic flow and reduced traffic jams.

Smart mobility is a system that provides mobility services tailored to users' preferences and corresponding to the city's sustainable development priorities through modern technologies (Aleta, 2017). The literature on the subject (Papa, 2015) shows two main approaches to smart mobility: technology-oriented and consumer-oriented strategies. The technology-oriented approach is based on applying information technology to transport infrastructure. According to this view, the development of intelligent mobility is possible thanks to the introduction of widespread digitization of means of transport. According to Grucza (Grucza, 2018), the "technocentric" orientation leads to dehumanization and loss of a sense of autonomy and thus wastes even the most innovative solutions. Therefore, implementing elements of smart mobility in cities requires cooperation with their inhabitants.

The aim of intelligent transport, apart from improving traffic and communication, is also to expand infrastructure using the latest ICT solutions, create intelligent mobility offers, use various digital solutions, such as smart parking, car-pooling, trip planning, car-sharing, bike-sharing, MaaS (Mobility-as-a-Service), ride-hailing or micro-mobility. It is also the development and implementation of solutions based on the technology of intelligent communication and data transmission systems (IST) or intelligent transport systems (ITS) (Zaheer et al., 2019).

The use of artificial Intelligence in the field of road traffic optimization is revolutionizing road traffic management. This makes significant improvements in flow, safety, and transport efficiency possible. This is due to the ability of artificial Intelligence to analyze vast amounts of data from cameras, sensors, GPS systems, and other sources in real-time. An additional advantage of Artificial Intelligence is the ability to predict the analyzed data. This enables the identification of traffic patterns, congestion, and road hazards. When road accidents occur, artificial Intelligence can react quickly, redirecting traffic and thus minimizing disruptions.

In Poland, the Intelligent Transport System (ITS) has been introduced in many cities. For ITS to function, it is necessary to equip roads with specific devices - measurement sensors, cameras, weather stations, variable message signs - along with supporting structures, build a communication network, provide software, and create facilities for people supervising the system's functioning. Such a system has been implemented in Chorzów. The role of ITS in Chorzów is to improve traffic in public and individual transport. It is an extensive system that supports several subsystems, particularly priorities for public transport vehicles and the linear traffic control and management subsystem. Drivers receive information about city traffic conditions, alternative roads, and available parking spaces. The system includes a visual monitoring system for intersections, including cameras for automatic license plate recognition. A similar system was created in Wrocław. The city of Gdańsk has used an intelligent transport system. TRISTAR monitors public transport routes and informs passengers about the departures of public transport vehicles. The ITS system in Bydgoszcz aims to shorten travel time by tram and motor vehicles. The Bydgoszcz ITS consists of subsystems, including traffic control with video monitoring, public transport management with dynamic stop information, parking information, and vehicle guidance to alternative routes.

Another area where traffic and transport management is being developed is using low-emission buses. In 2023, the city of Sosnowiec purchased 16 hybrid buses that offer great amenities for passengers - including USB chargers, Wi-Fi, monitoring of the passenger space and the surroundings at the front, rear, and right side of the bus, emission-free driving only on electric drive in designated zones in city centers, automatic system for detecting and extinguishing fire in the engine compartment and heating unit, air conditioning for the entire truck. Moreover, Sosnowiec is the first Polish city to introduce on-demand night public transport. The organizer of night bus transport is the city in cooperation with Blees. To use this form of returning home at night, you must use a particular application available on Google Play and the App Store. A passenger who wishes to travel will receive information about how long it will take for the bus to arrive at his stop. The bus will stop in the same places where tram stops are located on the street. In areas where the location of the tram stop makes it impossible for the bus to stop safely, there will be so-called virtual stops. The website www.sosnowiec.blees is available, which contains all applicable information, a map of stops, and instructions on how to use public transport.

Road safety is another area where artificial Intelligence is making a significant contribution. One of the most visible safety applications is traffic lights at pedestrian crossings. Traffic light systems dynamically adjust to the number of people waiting at crossings, crossing, and their speed. This is especially important for older people, children, and people with disabilities. For this reason, VALKKY systems implemented in many cities are critical, as they detect and signal pedestrians who want to cross the road. The first such system in Poland was used by the

city of Chorzów in 2012. Currently, such systems are used in many cities[1]. Similar solutions were utilized in Sosnowiec, where the sidewalks in the area were rebuilt, additional lighting was provided, and sensors were installed. In addition, automatic speed measurement devices were installed so that the driver and passers-by knew the speed at which the car was approaching. An innovation is the installation of the STOP PHONE system. Thanks to it, anyone with a special smartphone application will receive a warning when approaching a pedestrian crossing.

3.2. Application of Artificial Intelligence in energy management and sustainable development

Artificial Intelligence can have wide applications in environmental protection and is used to monitor, predict, and solve energy management and environmental protection problems. Smart grids use AI to optimize energy supply by predicting demand and adjusting production. This not only increases energy efficiency but also helps to reduce costs. Currently observed changes in the area of energy transmission and distribution are inextricably linked to the concept of intelligent energy networks, in which there is communication between all participants of the energy market, aimed at providing energy services while ensuring cost reduction and efficiency increase, as well as the integration of distributed energy sources. Smart networks are related to the development of new IT technologies, and the means to introduce the mentioned smart networks is to modernize existing networks and optimize all their elements. Optimizing energy transmission and distribution using artificial intelligence-based solutions requires much base data for analysis. Smart measurement systems are crucial for the functioning of smart energy grids and, therefore, for implementing solutions based on Artificial Intelligence.

New technologies and methods of energy storage enable intelligent integration with the power grid infrastructure and - which was an urgent goal - reduce the number of starts of fuel generators. Battery energy storage systems (BESS) provide extended operating time through intelligent management of connected loads. They can also be seamlessly integrated with alternative energy sources such as solar panels or fuel cells. This approach minimizes the use of generators and reduces their environmental impact. BESS installations will ultimately evolve to a model where users have their energy resources, providing them with the performance, reliability, and cost-effectiveness needed to support computing resources for Artificial Intelligence.

Energy-saving systems are An example of using Artificial Intelligence for environmental protection. Such a system was used in Lublin. It is an intelligent street lighting system. Lanterns reduce the light output when they do not detect movement and increase it when they see an approaching pedestrian, cyclist, or car. In Łódź, the portal rewitalizacja.uml.lodz.pl was created, which allows the inhabitants of Łódź to obtain comprehensive information on both the

[1] Based on: https://www.nist.gov.pl/rozwiazania-w-zakresie-smart-city-w-polsce

revitalization activities carried out in the city and the condition of the revitalization area. The portal is also a tool to support the monitoring processes of the Municipal Revitalization Program in terms of ongoing projects and changes in the socio-economic situation of the area. The portal also offers orthophoto maps, oblique photos, and 3D data on the city space. Through the portal, residents can also submit electronic applications for certificates confirming the location of real estate in the revitalization area. They will also find other information and news about activities in the area. In Ełk, sensors for measuring dust concentration were installed to monitor the city's air quality. The devices have the function of measuring air pollutants: suspended dust PM2.5 and PM10, ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), benzene (C6H6), and carbon monoxide (CO). Two "EcoPolls" were also installed; they measure the concentration of air pollutants: PM1, PM2.5, PM10, and HCHO formaldehyde, as well as air temperature, pressure, and humidity. At the same time, they signal air quality using LED lighting according to the Polish Air Quality Index adopted by the Chief Inspectorate of Environmental Protection.

3.3. Artificial Intelligence in the field of public safety

Artificial intelligence systems are used in smart cities to monitor and ensure public safety. For example, video surveillance systems equipped with artificial Intelligence can identify suspicious behavior, detect incidents, and alert security services. Camera surveillance technology itself has been used for a long time, but combining it with artificial intelligence algorithms leads to new possibilities.

The scope of application of technology using artificial Intelligence in the everyday life of residents is most widely used, in a negative sense, in China. China actively uses technologies to track people's behavior. The analysis system creates reports about people who cross the street in the wrong place, who did not pay for a ticket, or about which part of the city riots began. The Chinese system provides penalties for people's inappropriate behavior. For example, a resident may be deprived of the right to start studies, the right to park his car, or the right to travel.

An example is the recognition and arrest of a criminal hiding in the crowd during a beer festival or being one of 60,000 guests at a concert in China. Due to their advantages, these systems are used in authoritarian and democratic countries. There are reports of their use in the United States, Germany, and Wales (Greser, 2022). It should be mentioned that technology based on artificial Intelligence is not limited to collecting facial images. It is also capable of managing other biometric data. These also include how you walk, the type of articulation, and the timbre of your voice. This also allows, for example, the identification of participants in telephone conversations in real-time. An ocean of emotional states is also possible. Such possibilities provide a wide range of side effects. They may be the basis for various discrimination - for example, people with a different skin color or gender.

In Poland, there are currently no systems in use that are being implemented to serve residents, making their everyday lives easier. An example is the city of Bydgoszcz, where the Dbamy o Bydgoszcz (DoB) application is available. The application is a tool thanks to which residents can report information about irregularities in the city and send suggestions regarding, among others, identifying architectural barriers for disabled people, illegal landfills, barriers to moving around the city on foot or by bike, improving the quality of life in the city. The implemented system comprises the website dobremy.bydgoszcz.pl and mobile applications. Thanks to DoB, city services can quickly and accurately take appropriate actions to solve the reported problem. Gołacz uses video monitoring, consisting of over 40 cameras throughout the city and the commune, operating 24 hours a day, seven days a week. This monitoring is being gradually expanded, and the appearance of cameras in public places that were not under its supervision has had a very positive impact on the residents' sense of security, reduced the number of crimes, and has often helped identify perpetrators of crimes, including those from outside the commune.

3.4. The Use of Artificial Intelligence in waste and natural resources management

Artificial Intelligence can have broad applications in waste and natural resource management and can be used to monitor, predict, and solve environmental problems.

AI can analyze waste generation data in different parts of the city, helping to optimize garbage collection routes and schedules. This can lead to reduced exhaust emissions from garbage vehicles and increased efficiency of the entire system. Advanced AI systems using image recognition can be used to automatically sort waste, which increases recycling efficiency and helps reduce waste going to landfills. AI can analyze water consumption patterns, predict demand, and identify leaks, allowing for more efficient water management and reduced waste.

The primary example of using artificial intelligence systems in environmental protection is AI solutions to monitor and improve Poland's natural environment constantly. They can analyze satellite data and process images, enabling monitoring of environmental changes, such as the development of city changes in water reservoirs or forest areas. Currently, there is an extensive ecological information system. They are included in various systems and databases, which are not necessarily interoperable but constitute a specific resource that artificial intelligence systems can use. There is a common concept of geoinformation to describe data presentation about objects in the surroundings, such as land development and utilities, using tools designed for this purpose. Sets of information about space can be divided into those whose creation is required by law and those created on their initiative by various institutions and individuals to achieve their goals. The potential possibilities of using geoinformation are determined by its subject scope, which is, by its very nature, very broad.

The city of Krakow prides itself on implementing intelligent solutions in urban space that directly improve the lives of residents. The concept of sustainable development and respect for the natural environment guides all activities. The latest investment of Krakowski Holding

Komunalny SA is the Thermal Waste Processing Plant. Currently, the Eco-combustion plant produces 65,000. MWH of electricity and 270 MWh of heat energy. Photovoltaic modules with a capacity of 60 kilowatts were installed on the roofs and facade of the Eco-incineration plant.

3.5. Services for Residents

A. Koriek and Joseph Stiglitz (Korinek 2019) distinguish two models of society's development in terms of access to information technology and, in the current reality, to artificial Intelligence. First, the wealthiest people will have access to the latest technology that will improve them and allow them to achieve superhuman Intelligence. Those unable to purchase the latest technology will be forced to rely on the public offering. Unfortunately, as the pace of innovation increases, the gap between best and public technology will increase. Enhanced humans through technology will be considered a better, separate species of AI humans. Secondly, the poorer part of the population will be marginalized and subordinated. Importantly, it will lose the fight for limited goods with artificial Intelligence - for example, it will lose the fight for electricity. In the second scenario, a world will be created for machines that will be wholly separated from humanity. The world will be created by machines, for machines. People in the second model will not be needed for this world to function.

It is assumed that a smart city is a city that not only uses intelligent technologies to generate sustainable economic growth and improve the quality of life of its inhabitants but also involves creating and using relationships and connections between human and social capital. A smart city is a set of interconnected sensors or technologies and a place where people should play the most crucial role. Smart cities are cities that should provide more space for citizens. A wide range of technology using artificial Intelligence means that smart technologies are becoming an essential part of the everyday life of city residents.

For example, Bydgoszcz introduced the Bydgoszcz Tourist Card and the Mobile Guide. Thanks to the Bydgoszcz Tourist Card, users receive several free services and attractive discounts in gastronomic, cultural, and entertainment facilities. Bydgoszcz - a mobile guide (since July 2015) helps tourists get to know the town on the Brda River. It provides information on current cultural and sports events (calendar of events) and encourages you to discover the city's secrets. Thanks to the city games included in the application, sightseeing can become even more interesting and exciting. Using the "tourist routes" module, guests can consciously explore both the Old Town and Śródmieście areas and plan a bicycle trip. Residents of the city of Bydgoszcz have also been equipped with the Dbamy o Bydgoszcz (DoB) application, which is a tool thanks to which residents can report information about irregularities, illegal landfills, barriers to moving around the city on foot or by bike, and improve the quality of life in the city[2].

[2] Based on: https://www.nist.gov.pl/rozwiazania-w-zakresie-smart-city-w-polsce

3.6. Spatial planning and urban development

Artificial Intelligence (AI) has enormous potential in spatial planning and urban development, offering new tools and methods to create more efficient, sustainable, and citizen-friendly cities.

AI can analyze data from various sources such as sensors, cameras, geospatial data, and social media to understand traffic patterns, resident preferences, and the use of urban space. This allows for better infrastructure planning, such as roads, parks, and residential and commercial areas. Using AI, it is possible to create advanced simulation models to predict the impact of various development strategies on the city. This allows for assessing the potential effects of urban plans before their implementation. AI can help manage urban resources such as water, energy, and waste more effectively by optimizing their distribution and consumption based on residents' needs and behavior.

The city of Łódź has implemented an application constituting a compendium of knowledge about the city's current spatial policy. The application always presents an up-to-date, uniform mosaic of local plan provisions. It also allows instant access to a preview extract and outline for a selected area.

4. Conclusions

The Smart Cities concept is becoming increasingly popular and essential in the operations of cities worldwide. The role of artificial Intelligence in shaping smart cities is comprehensive and dynamic. As AI technology evolves, new opportunities are opening up for more innovative, safer, and sustainable urban life. This article presented various AI applications, from traffic optimization and resource management to improving public safety and citizen health. However, it is equally important to recognize and address the challenges of implementing these technologies, including ethical, privacy, and data security issues.

The conclusions from our study emphasize that the success of smart cities depends not only on technological advancement but also on a responsible and sustainable approach to the use of AI. Policymakers, city planners and other stakeholders must work together to ensure that these technologies are implemented to serve all residents while maintaining their rights and privacy.

The future of smart cities with AI seems promising but requires continuous dialogue, research, and collaboration between disciplines and sectors. As we strive to build more intelligent and integrated cities, we must remember these technologies' human dimensions and put residents' well-being first.

Therefore, the paper takes a step towards a deeper understanding and better exploitation of the potential of AI in smart cities, encouraging further research and innovation in this exciting and rapidly developing field.

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EMPLOYEE INFORMATION IN THE FIELD OF CSR AND DIAGNOSIS AND RESOLUTION OF THE LABOUR CONFLICT[1]

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Purpose: The aim of the article is to present the disclosed non-financial information in the area of employees on the example of the examined company and the strategy used by the management to diagnose and remove the employee crisis. In order to achieve the adopted goal, a research question was posed: what determines the increased turnover of employees. The article is a research study. It presents a solution to a specific problem in the examined company. In order to gain a deeper understanding of the main causes of employee turnover, a survey was conducted among employees. The survey covered 1000 respondents.
The study is in line with the authors' scientific interests in reporting.
Design/methodology/approach: The applied research methods are based on the study of the literature in the field of study and the analysis of non-financial reports in order to identify the reported employee issues in the examined company and the conducted surveys in order to resolve the employee conflict.
Findings: The article presents a solution to a specific problem in the examined company. In order to gain a deeper understanding of the main causes of employee turnover, a survey was conducted among employees. The survey covered 1000 respondents.
Originality/value: The constant evolutionary processes taking place in the economy stimulate economic, as well as social and environmental development, thus requiring the adaptation of enterprises' communication channels with the market environment. Information presented in a traditional way by financial reporting no longer meets the expectations of potential investors and broadly understood stakeholders who want to base their decisions on the full picture of the situation affecting a given company. This possibility is provided by combining financial issues with non-financial information, and there are still no uniform patterns in the literature regarding non-financial reporting. The implementation of Corporate governance is to secure the interests of the owner and the capital invested in the company, as well as the interests of other stakeholders. A very important additional non-financial information from the point of view of corporate governance is information on the employee area, reporting of which in non-financial statements is still insufficient. There is also little information on resolving employee conflicts.

Key words: CSR, corporate governance, non-financial reports, employee issues.

Category of the paper: Research paper.

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1. Introduction

The globalization of financial markets has contributed to the on an international scale to undertake activities aimed at improving the process of creating and presenting information. Unrestricted access for investors to reliable comprehensible and comprehensibly provided material information relating to the issuer or financial instruments issued by it listed on an organised market is the basis for a well-functioning financial market.

Reports published by companies listed on the Warsaw Stock Exchange are the main source of information on the current condition and development prospects of companies. Therefore, they should support rational investor decisions. Therefore, it is important to create appropriate mechanisms and organizational solutions to increase the quality of published information.

Over the last decade, trust in reliable financial information has been significantly undermined, which has largely led to a change in the EU's disclosure arrangements. Due to the expectations of stakeholders, the scope of disclosures has been expanded. Additional disclosure obligations have been imposed on companies related to, m.in disclosure of non-financial information, including information on corporate governance, in particular information on social, employee, environmental and business model issues.

The aim of the article is to present the disclosed non-financial information in the area of employees on the example of the examined company and the strategy used by the management to diagnose and remove the employee crisis. In order to achieve the adopted goal, a research question was posed: what determines the increased turnover of employees. The article is a research study. It presents a solution to a specific problem in the examined company. In order to gain a deeper understanding of the main causes of employee turnover, a survey was conducted among employees. The survey covered 1000 respondents.

The study is in line with the authors' scientific interests in reporting. The applied research methods are based on the study of the literature in the field of study and the analysis of non-financial reports in order to identify the reported employee issues in the examined company and the conducted surveys in order to resolve the employee conflict.

2. CSR as a very important reporting area for stakeholders

"The principles of responsible business define how the company's relations with its stakeholders (shareholders, contractors, customers, employees and directly and indirectly related environment) should be structured. And entrepreneurs are not forced to incur expenditures without obtaining real benefits in return, which would be visible on the company's balance sheet. It is simply about companies being guided by CSR ideas to create a better image

of their brands, offer customers higher quality goods and services, and offer honest relations and settlements to contractors and employees. Corporate social responsibility, or CSR, is not just philanthropy, contrary to what many entrepreneurs believe. It is primarily an activity that is supposed to bring profits to the company. It's just that with respect for the whole environment" (Horodecki, 2015). The literature on the subject is increasingly describing corporate governance issues and employee problems.

The concept of corporate governance: "corporate governance", "corporate governance", "control in a corporation" Dunlop et al. (Dunlop, 1998; Szajkowski, 2005; Fijałkowska, Krasodomska, Macuda, Mućko, 2109; Aras, Crowdher, 2106; Bek-Gaik, 2015; Czubała, 2019; Śnieżek, 2016; Chłapek, Krajewska, Jonas, 2018; Eccles, Serafeim, Krzus, 2011). The term corporate governance is used interchangeably with the term corporate governance. The word governance derives from the Latin gubernare, and as a noun it comes from the English verb govern, which means "to govern, lead, control" (Jeżak, 2010). Good (proper) corporate governance is intended to improve the decision-making process and the effective allocation of power exercised by executives, managers and supervisory board members. It should facilitate effective tracking of results, thereby fostering more efficient use of resources by companies (Mesjasz, 2010).

The concept of corporate governance has evolved over the years, moving from an approach based mainly on agency theory to an approach that also takes into account other interest groups, including the external environment. And so, A. Berle and G. Means, in their definition, emphasize the role of both internal and external mechanisms in mitigating conflicts between the principal and the agent.

K. Keasey and M. Wright emphasize the roots of corporate governance already in ancient times (Keasey, Wright, 1997). According to the authors, Homer in the Odyssey already described the problems associated with the separation of property from control.

However, the issue of corporate governance became a real subject of interest much later. Since the beginning of the 1990s, the international debate on the application of corporate governance mechanisms has intensified. In particular, institutions such as the European Union, the World Bank, the OECD, as well as governments and institutions related to financial markets were involved in it (Jeżak, 2010).

Taking into account the social responsibility and the purpose of the company's operations, the following models of supervision have been distinguished in the literature on the subject:

- financial model (model ofhareholders),
- social model (Model Stakeholders).

In the financial model, the primary goal of a company's operations is, according to the agency's theory, to maximize value for the owners of capital – shareholders. This is related to the expectation of specific behaviors from the management that will appropriately shape the company's business results (Freeman,1983). Therefore, the Management Board undertakes such actions that bring quick positive effects as shown in the periodic reports submitted by the

company. The capital market is the main mechanism of control and supervision over the company's operations in this model. In contrast to the financial model, in the social model the company is seen as a joint venture and its purpose is to meet the needs of all parties involved. The model of supervision associated with this approach is based on the participation of representatives of various interest groups in the supervisory board (Koładkiewicz, 2000).

3. CSR and material issues of non-financial reporting

The obligation to report non-financial applies to large public-interest entities that meet the following criteria:- average annual employment of more than 500 people and- balance sheet total of more than EUR 20 million or net turnover of more than EUR 40 million.

Prior to the entry into force of Directive 2014/95/EU, few Polish companies voluntarily published reports on their CSR (Corporate Social Responsibility) policy (Samborski, 2011).

It enables reporting according to the rules chosen by the companies. As part of the new obligations, the company will provide a concise description of the business model, a description of the policies pursued in relation to the issues already mentioned and a description of the results of these policies, non-financial key performance indicators, and a description of the risk and how to manage risk in non-financial matters.

Table 2 presents the scope of disclosures included in the management report and the statement on non-financial information based on the provisions of the Accounting Act.

Table 1.
Disclosures in the management report and non-financial statement

The information contained in the management report	Information contained in the non-financial statement
– events significantly affecting the entity's operations in the financial year and after its end, until the date of approval of the financial statements – anticipated development of the unit – major R&D achievements – current and projected financial situation – own shares – branches owned by the entity – financial instruments	– a concise description of the entity's business model – key non-financial performance indicators related to the entity's operations – a description of the policies applied by the entity in relation to social, employee, environmental, respect for human rights, anti-corruption and a description of the results of the policies applied – a description of the due diligence procedures – a description of material risks related to the entity's operations

Source: Author's own elaboration based on Błażyńska, 2018, p. 13.

In principle, the content of both types of reports – the one prepared by companies voluntarily and the report imposed by the directive – is similar.

While entities are required to disclose information on matters of key importance to them, while requiring some flexibility in choosing matters relevant to their business, FEE[1] believes that efforts should be made to ensure the highest possible level of consistency in the information

disclosed and the implementation of EU rules in Europe. However, flexibility and consistency cannot always be reconciled. Therefore, it could be a good idea to create a single set of KPIs that would be used by all units.

Better access to information, including non-financial information, means easier, faster and more reliable analyses for investors, i.e. a higher level of comfort in making investment decisions, which may reduce the cost of raising capital.

4. Employee-related disclosures in the audited company

The audited company is an industrial and commercial establishment and an employer in Pomerania and employs over 1000 people. Its business and activities interfere directly or indirectly in the lives of almost all inhabitants of the region. In the long run, the company needs talented, educated and loyal employees to run its business. The job is demanding, and employees have to meet many more than just health requirements. The company strives to appreciate motivated employees by offering a wide range of financial and non-financial benefits, often exceeding the framework of statutory provisions. The company also places great emphasis on remunerating its employees fairly. The remuneration system is regulated individually for different jobs. Of course, the quantity and quality of the work performed are also taken into account when remunerating. Work continues on the unification and standardization of the remuneration system for all positions in the company. The company applies the principle of direct dependence on performance in combination with the achievement of individual and group goals. The Company's long-term goal is to ensure the safety and health of its employees as much as possible. Wages in the Company are determined either on the basis of the salary scale or, in the case of selected positions, employees are paid on an individual basis. The basic factors determining the amount of remuneration are, first of all, the employee's performance, the results achieved by the employee himself and the entire company (EBITDA). In terms of salaries, men and women have the same conditions. As part of improving cooperation and cooperation, employees are also involved in pro-social actions, i.e. collections for shelters, children in orphanages, cleaning the world or planting trees in city parks. The company also invests in the development of its employees through an employee training program, as well as equal opportunities and integration programs for employees.

In order to assess the company's compliance with the requirements for reporting non-financial disclosures in accordance with the GRI[2] Standards, financial reports from the last four years were examined. The employee area has been included in the reporting of employee issues (Furmańska-Maruszak, Sudolska, 2017).

[2] *GRI 101: Foundation 2016*, https://www.globalreporting.org, 23.09.2023.

In the audited company, information on employee issues is presented in Table 3.

Table 3.
Scope of non-financial information on employee issues in the audited company

Indicator No.	Description of the indicator	2019	2020	2021	2022
G4-LA1	Total number and rates of employment and employee turnover by age group, gender and region	Yes	Yes	Yes	Yes
G4-LA6	Rates of injuries, occupational diseases, days lost and absenteeism from work, and number of work-related fatalities, by region and gender	Yes	No	Yes	No
G4-LA9	Average number of training hours per year per employee by gender of the employment structure	Yes	Yes	Yes	Yes
G4-LA12	Composition of supervisory bodies and staff by category of employees by gender, age, minority membership	Yes	Yes	Yes	Yes
G4-LA13	Ratio of men's basic salary to women's salary by position	Yes	Yes	Yes	Yes

Source: Own elaboration based on data from reports.

Within four years, an entity generally applies a uniform set of non-financial information on employee matters, which it discloses to the public. In two years (2022, 2020), it does not provide information on occupational injuries and diseases, as well as absences from work and fatal accidents. However, it always discloses information on the number of employees, salaries for men and women, the composition of supervisory boards, and the hours of training conducted. The information it presents is prepared in accordance with the GRI guidelines.

5. Employment dispute resolution – case study

Employee issues are very important for the proper functioning of any company. A properly functioning team of employees contributes to the success of the company. At the time of entering the market, the surveyed trader did not have a problem with competitiveness and staff, so it was able to increase its turnover and strengthen its position on the market. All fluctuations in the staff were constantly monitored by the company's management. Maintaining it at the level of 6-9% was considered a safe fluctuation. In 2021, the number of employee departures per 1000 employees was 248. The redundancy rate was therefore around 25%. This contributed to a decrease in the company's turnover. In the first half of the following year, this figure rose to 32%, of which only 12 employees retired. At that time, the company implemented actions to identify and solve the problem. The aim of these activities was to return to turnover as well as to retain and employ new qualified staff. The following actions have been taken to identify current problems:

1. An exit interview was conducted,
2. Anonymous employee surveys were conducted,
3. An employee ideas program was launched.

The first exit interview was about an employee who had given immediate notice. The HR department interviewed the employee and invited him to a meeting after receiving information from the HR department about the employee's decision to leave. The purpose of the interview was to clarify the situation and make changes to the company's policy in order to retain qualified employees.

The next step was to conduct an anonymous survey by the HR department. Employees could identify more than one problem that affected the deterioration of their working conditions.

In an anonymous survey, employees responded to questions about the situation in the workplace. The result of the survey clearly indicated that the relationship with the supervisor of the Production Department is assessed negatively. According to the respondents, the Production Director is a person who causes conflicts at work and hinders the work of not only directly subordinate employees, but also other departments of the company. The problem is the lack of direct supervisors responsible for individual projects. All decisions are made directly by the Production Director.

The satisfaction survey indicated that several areas of the company's operation require improvement. The department that needs to be changed is primarily the Production Department, and in particular the resolution of the conflict with the Production Director. An in-depth analysis also showed that there is a lack of precisely defined competences and the flow of information between the management and other employees is limited, which results in bottlenecks in planning and production. The problem is a very complicated organizational chart, which makes the delegation of work chaotic and unclear and makes it difficult to perform the duties entrusted to it.

The problems indicated by employees cause the comfort and satisfaction of their daily work to be disturbed and this contributes to excessive turnover.

In the employee ideas program, the employees employed in the company proposed to improve the flow of information by updating the existing procedures, transparent division of competences and subordination. Among the submitted proposals to increase engagement, employees proposed the introduction of incentive allowances in the form of cinema and gym memberships and the introduction of integration events, e.g. a family picnic. There were proposals to change the Production Director. There have been proposals to promote an employee among the Managers who enjoys great respect among the staff due to his competence, professionalism and approach to co-workers. Problems reported by employees are shown in Figure 1.

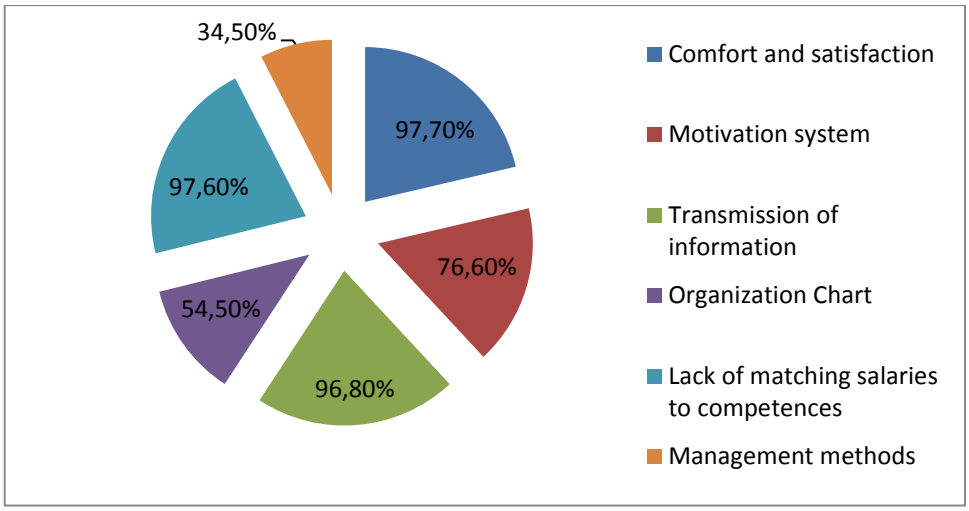

Figure 1. Problems reported by employees.

Source: Own analysis based on surveys.

According to a survey conducted for employees, the main problem in the workplace is the lack of job satisfaction and comfort in the workplace, as well as the lack of adjustment of salaries to the responsibilities of the position held. Such a problem was indicated by 97% of employees. Almost the same number, i.e. 96%, pointed to a bad transfer of information regarding the duties performed.

Table 4.
Problems identified by employees in surveys

Problems reported by employees	**Number of employees**
Comfort and satisfaction	977
Motivation system	766
Transmission of information	968
Organization Chart	545
Lack of matching salaries to competences	976
Governance	345

Source: Own analysis based on surveys.

After such diagnostic activities, radical corrective actions were carried out in the examined company. As part of these activities, the following actions were taken:

1. The employment relationship with the Production Manager was terminated due to the inability to resolve the conflict between the manager and the employees,
2. Creating a new recruitment and employment procedure adapted to the number of implemented projects,
3. Internal recruitment for the position of Production Manager,
4. Transformation and simplification of the organizational structure,
5. Taking action to reduce employment fluctuation by changing the remuneration method and introducing an incentive system,
6. Concentration of production on the most profitable projects,
7. Strict supervision of financial flows in the company and introduction of centres of responsibility with the assignment of managers responsible for individual projects.

6. Conclusion

The considerations carried out in the article are only a substitute for the problems concerning employee issues occurring in business units, but it should be stated that they are very important from the point of view of the interests of each enterprise. The aim of the article was to present the disclosed non-financial information in the area of employees on the example of the surveyed company. This goal was achieved through the analysis of non-financial reports published by the business entity from 2019-2022.

The article also presents the strategy used by the management to diagnose and remove the employee crisis. Planned and carried out corrective actions allowed for quick diagnosis and determination of which areas in the company are not working properly.

The conflict between the Production Manager and the employees was diagnosed and resolved by creating a new recruitment and employment procedure, the method of remuneration was adjusted to retain valuable employees and attract new employees, the focus was on more profitable tasks and the employees were motivated by giving them responsibility for the tasks performed. All these activities strengthened relations between employees and contributed to the development of new solutions. Thanks to the quick actions of the management board and the implementation of corrective actions in the area of employees, this crisis has been resolved and the company continues to strengthen its position on the market.

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ANALYSIS OF THE SHARE OF ENERGY OBTAINED FROM RENEWABLE ENERGY SOURCES IN THE EUROPEAN UNION COUNTRIES

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Purpose: The article aims to present the use of energy from sources by European Union countries in 2004-2021. The article contains statistical data on the share of energy from common sources and three sources of consumption (electricity, heating and cooling, and transport) in the European Union[1].
Design/methodology/approach: The data was analyzed regarding changes in the energy share in subsequent years of the European Union members, the smallest and largest claims concerning other countries, and the differences between the minimum and maximum percentages for individual countries.
Findings: Based on the data analysis, it is possible to determine the countries that use energy from renewable sources to the highest extent (for example Sweden, Finland) and those that use them to a minimum size to other European Union countries.
Research limitations/implications: The analysis covers data until 2021 due to the lack of data from all European Union countries for 2022.
Practical implications: The results of the data analysis can be used to assess the implementation of the assumptions of European Union directives regarding the use of energy from renewable sources, as well as the capabilities of individual countries, indicating the countries that have the most significant problems with the implementation of energy plans.
Social implications: Awareness of the entire European Union society about the need to take action to protect the environment, climate, and the use of natural energy sources.
Originality/value: Due to climate change, it seems necessary to monitor and analyze the implementation of the energy plans of European Union countries on an ongoing basis and to identify, in particular, those members of the European Union that should pay specific attention to their country's energy policy.

Keywords: renewable electricity in road transport, heating and cooling, final energy consumption, gross final consumption of energy from renewable.

[1] https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

1. Introduction

The European Union, striving to achieve ambitious sustainable development goals and reduce the impact of human activity on the natural environment, is consistently developing its approach to energy production and consumption[2]. One of the critical elements of this energy transformation is increasing the share of energy from renewable sources, which brings many potential benefits. Using power from renewable sources reduces greenhouse gas emissions, increases energy security, and creates conditions for innovation and sustainable economic growth. Energy from renewable sources is more environmentally friendly than traditional energy sources. Its acquisition and use generate significantly fewer CO2 emissions and other pollutants, which contributes to reducing climate change and improving air quality. In addition to environmental factors, using renewable sources reduces dependence on external energy sources and uncertain energy markets.

Gross final consumption of energy is defined in the Renewable Energy Directive 2009/28/EC (RED I) as energy goods supplied for energy purposes to industry, transport, households, services (including the public), agriculture, forestry, and fisheries, including the consumption of electricity and heat by the energy industry for the production of electricity and heat and taking into account losses of electricity and heat in distribution and transmission. The article presents the share of energy from renewable sources calculated for four indicators: transport, heating and cooling, electricity, and the total percentage of renewable energy sources based on data collected under Regulation (EC) No. 1099/2008 on energy statistics, which are transmitted Eurostat by national administrations. This dataset includes an indicator for monitoring progress towards the Europe 2020 renewable energy targets implemented under Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RED I) and the Fit for 55 strategies under the Green Governance implemented by Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II). The data analysis covers the years 2004-2021, divided into the four indicators mentioned above in terms of changes in the share of energy from renewable sources in individual EU countries in subsequent years, indicating the smallest and largest shares, specifying the period in which they occurred and due to differences in percentages in over the years 2004-2021. Countries with the most significant shares in energy from renewable sources and those with the most minor shares compared to other countries were indicated. Based on the analysis, it is possible to determine which countries can best implement European Union plans and directives.

[2] https://www.europarl.europa.eu/news/pl/headlines/society/20180208STO97442/ograniczanie-emisji-gazow-cieplarnianych-w-ue-krajowe-cele-na-2030-r

2. Share of energy from renewable sources

The table below presents the percentage gross final energy consumption data regarding the share of energy from renewable sources in European Union countries in 2004-2021.

Table 1.
Share of energy from renewable sources over the years 2004-2021

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	22,55	24,35	26,28	28,14	28,79	31,04	31,21	31,55	32,73	32,67	33,55	33,50	33,37	33,14	33,78	33,76	36,55	36,45
Belgium	1,92	2,33	2,66	3,14	3,61	4,75	6,00	6,30	7,09	7,67	8,04	8,06	8,74	9,14	9,47	9,93	13,00	13,01
Bulgaria	9,23	9,17	9,42	9,10	10,35	12,01	13,93	14,15	15,84	18,90	18,05	18,26	18,76	18,70	20,58	21,55	23,32	17,02
Croatia	23,40	23,69	22,67	22,16	21,99	23,60	25,10	25,39	26,76	28,04	27,82	28,97	28,27	27,28	28,05	28,47	31,02	31,33
Cyprus	3,07	3,13	3,26	4,00	5,13	5,92	6,16	6,25	7,11	8,43	9,14	9,90	9,83	10,48	13,87	13,78	16,88	18,42
Czechia	6,77	7,11	7,36	7,90	8,67	9,98	10,51	10,95	12,81	13,93	15,07	15,07	14,93	14,80	15,14	16,24	17,30	17,67
Denmark	14,84	15,96	16,33	17,75	18,54	19,95	21,89	23,39	25,47	27,17	29,31	30,47	31,72	34,39	35,16	37,02	31,68	34,72
Estonia	18,42	17,48	16,01	17,14	18,81	23,01	24,58	25,52	25,59	25,36	26,13	28,99	29,23	29,54	29,97	31,73	30,07	38,01
Finland	29,23	28,81	30,04	29,56	31,07	31,05	32,17	32,53	34,22	36,63	38,63	39,23	38,94	40,86	41,19	42,81	43,94	43,10
France	9,32	9,27	8,94	9,43	11,19	12,22	12,67	10,81	13,24	13,88	14,36	14,80	15,45	15,85	16,38	17,17	19,11	19,34
Germany	6,21	7,17	8,47	10,04	10,07	10,85	11,67	12,47	13,55	13,76	14,38	14,90	14,89	15,47	16,66	17,27	19,09	19,17
Greece	7,16	7,28	7,46	8,25	8,18	8,73	10,08	11,15	13,74	15,33	15,68	15,69	15,39	17,30	18,00	19,63	21,75	21,93
Hungary	4,36	6,93	7,43	8,58	8,56	11,67	12,74	13,97	15,53	16,21	14,62	14,50	14,38	13,56	12,55	12,63	13,85	14,12
Ireland	2,38	2,82	3,07	3,50	3,98	5,24	5,76	6,61	7,03	7,52	8,52	9,08	9,19	10,52	10,94	11,98	16,16	12,55
Italy	6,32	7,55	8,33	9,81	11,49	12,78	13,02	12,88	15,44	16,74	17,08	17,53	17,42	18,27	17,80	18,18	20,36	19,03
Latvia	32,79	32,26	31,14	29,62	29,81	34,32	30,38	33,48	35,71	37,04	38,63	37,54	37,14	39,01	40,02	40,93	42,13	42,11
Lithuania	17,22	16,77	16,89	16,48	17,82	19,80	19,64	19,94	21,44	22,69	23,59	25,75	25,61	26,04	24,70	25,47	26,77	28,23
Luxembourg	0,90	1,40	1,47	2,73	2,81	2,93	2,85	2,86	3,11	3,49	4,47	4,99	5,36	6,19	8,94	7,05	11,70	11,74
Malta	0,10	0,12	0,15	0,18	0,20	0,22	0,98	1,85	2,86	3,76	4,74	5,12	6,21	7,22	7,91	8,23	10,71	12,15
Netherlands	2,03	2,48	2,78	3,30	3,60	4,27	3,92	4,52	4,66	4,69	5,42	5,71	5,85	6,51	7,39	8,89	14,00	13,00
Poland	6,88	6,87	6,86	6,90	7,69	8,68	9,28	10,34	10,96	11,45	11,61	11,88	11,40	11,06	14,94	15,38	16,10	15,62
Portugal	19,21	19,52	20,79	21,91	22,93	24,41	24,15	24,60	24,57	25,70	29,51	30,51	30,86	30,61	30,20	30,62	33,98	33,98
Romania	16,81	17,57	17,10	18,20	20,20	22,16	22,83	21,74	22,83	23,89	24,85	24,79	25,03	24,45	23,88	24,29	24,48	23,60
Slovakia	6,39	6,36	6,58	7,77	7,72	9,37	9,10	10,35	10,45	10,13	11,71	12,88	12,03	11,47	11,90	16,89	17,35	17,41
Slovenia	18,40	19,81	18,42	19,68	18,65	20,77	21,08	20,94	21,55	23,16	22,46	22,88	21,98	21,66	21,38	21,97	25,00	25,00
Spain	8,35	8,44	9,16	9,67	10,74	12,96	13,78	13,18	14,24	15,08	15,88	16,22	17,02	17,12	17,02	17,85	21,22	20,73
Sweden	38,43	39,98	41,73	43,22	43,92	47,02	46,10	47,63	49,40	50,15	51,15	52,22	52,60	53,39	53,92	55,79	60,12	62,57

Source: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Based on the data presented, the lowest and highest values of energy shares were determined, as shown in Table 2.

Table 2.
Individual countries will give the highest and lowest value of shares of energy from renewable sources over the years 2004-2021

	The smallest value	Year of lowest value	The greatest value	Year of greatest value	Difference
Austria	22,55	2004	36,55	2020	13,99
Belgium	1,92	2004	13,01	2021	11,10
Bulgaria	9,10	2007	23,32	2020	14,22
Croatia	21,99	2008	31,33	2021	9,34
Cyprus	3,07	2004	18,42	2021	15,35
Czechia	6,77	2004	17,67	2021	10,89
Denmark	14,84	2004	37,02	2019	22,18
Estonia	16,01	2006	38,01	2021	22,00
Finland	28,81	2005	43,94	2020	15,13
France	8,94	2006	19,34	2021	10,41
Germany	6,21	2004	19,17	2021	12,96
Greece	7,16	2004	21,93	2021	14,77
Hungary	4,36	2004	16,21	2013	11,84
Ireland	2,38	2004	16,16	2020	13,78
Italy	6,32	2004	20,36	2020	14,04
Latvia	29,62	2007	42,13	2020	12,52
Lithuania	16,48	2007	28,23	2021	11,75
Luxembourg	0,90	2004	11,74	2021	10,84

Cont. table 2.

Malta	0,10	2004	12,15	2021	12,05
Netherlands	2,03	2004	14,00	2020	11,97
Poland	6,86	2006	16,10	2020	9,24
Portugal	19,21	2004	33,98	2021	14,78
Romania	16,81	2004	25,03	2016	8,22
Slovakia	6,36	2005	17,41	2021	11,05
Slovenia	18,40	2004	25,00	2021	6,60
Spain	8,35	2004	21,22	2020	12,88
Sweden	38,43	2004	62,57	2021	24,15

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Among the European Union member states, Malta had the smallest share of renewable energy from renewable sources – 0,10% in 2004, while Sweden had the largest – 62,57% in 2021. In terms of the minor difference between the maximum and minimum share of energy over the years 2004 -2021 was obtained by Slovenia – 6,60% (difference between 2004 and 2021), while Sweden received the highest value of the difference – 24,15% (difference between 2004 and 2021). Below, in Table 3, each country's energy share is presented in 2019, 2020 and 2021 in descending order.

Table 3.
Presentation of the share of energy from renewable sources in 2019, 2020 and 2021 in descending order

2019		**2020**		**2021**	
Sweden	55,785	Sweden	60,124	Sweden	62,573
Finland	42,807	Finland	43,939	Finland	43,096
Latvia	40,929	Latvia	42,132	Latvia	42,107
Denmark	37,02	Austria	36,545	Estonia	38,01
Austria	33,755	Portugal	33,982	Austria	36,445
Estonia	31,73	Denmark	31,681	Denmark	34,718
Portugal	30,623	Croatia	31,023	Portugal	33,982
Croatia	28,466	Estonia	30,069	Croatia	31,329
Lithuania	25,474	Lithuania	26,773	Lithuania	28,23
Romania	24,29	Slovenia	25	Slovenia	25
Slovenia	21,968	Romania	24,478	Romania	23,596
Bulgaria	21,545	Bulgaria	23,319	Greece	21,928
Greece	19,633	Greece	21,749	Spain	20,729
Italy	18,181	Spain	21,22	France	19,342
Spain	17,852	Italy	20,359	Germany	19,168
Germany	17,266	France	19,109	Italy	19,034
France	17,174	Germany	19,09	Cyprus	18,419
Slovakia	16,894	Slovakia	17,345	Czechia	17,667
Czechia	16,239	Czechia	17,303	Slovakia	17,412
Poland	15,377	Cyprus	16,879	Bulgaria	17,015
Cyprus	13,777	Ireland	16,16	Poland	15,624
Hungary	12,634	Poland	16,102	Hungary	14,115
Ireland	11,979	Netherlands	13,999	Belgium	13,014
Belgium	9,929	Hungary	13,85	Netherlands	13,003
Netherlands	8,886	Belgium	13	Ireland	12,546
Malta	8,23	Luxembourg	11,699	Malta	12,154
Luxembourg	7,046	Malta	10,714	Luxembourg	11,735

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

In the last three years of the analyzed period, Sweden was in first place in share of energy from renewable sources (55,785% - 2019, 60,12% - 2020, 62,57% - 2021), followed by Finland (42,81% - 2019, 43,94 - 2020, 43,096% - 2021) and Latvia (40,93% - 2019, 42,13 - 2020, 42,11 - 2021). The following countries changed in the following places: Austria, Estonia, Lithuania, Portugal, Croatia and Denmark. The countries with the lowest share in the last three years of the analyzed period are Malta (8,23% - 2019, 107,71% - 2020, 12,15% - 2021) and Luxembourg(7,05% - 2019, 11,699% - 2020, 11,735% - 2021). Analyzing the last year of reported data, Sweden had the largest share in energy from renewable sources (62,57%), ahead of Finland (43,10%) and Latvia (42,11%) by 19.48%. In comparison, the smallest share was achieved by Luxembourg (11,735%), Malta (12,154%), and Ireland (12,546%). The average share of European Union countries in energy from renewable sources in 2021 was 24,52%. Only ten countries had an above-average share of energy from renewable sources, with Slovenia having the most minor difference from the average - 25%. Below, Figure 1 presents the results of the share of energy from renewable sources in EU countries last three years from the period 2004-2021.

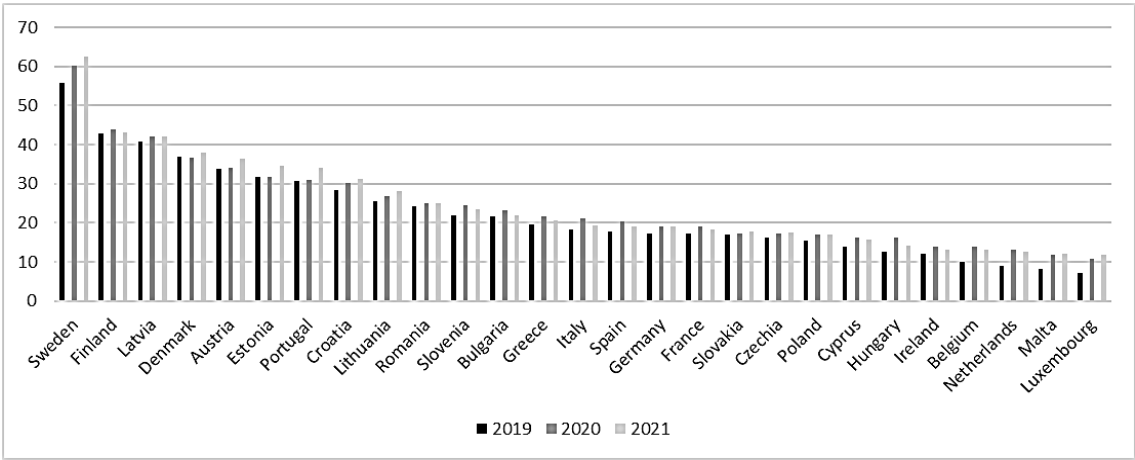

Figure 1. Presentation of the share of energy from renewable sources in EU countries in 2019, 2020 and 2021.

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Table 4 below shows the percentage change in the energy share in subsequent years compared to the year immediately preceding. Data analysis shows that Belgium is the only country that did not record any declines over 2004-2021 - the smallest increase was achieved in 2021 (0,11%) compared to 2020. Bulgaria showed The most significant share decrease - a decrease of 27,03% in 2021 compared to 2020. The most significant increase in the energy share can be observed in the case of Malta in 2010 compared to 2009 - a rise of 342,99%, while the smallest growth in the percentage change in the energy share was recorded by Finland in 2013 - an increase of 7,04%.

Table 4.
Percentage change from year to year in the share of energy from renewable sources in EU countries over the years 2004-2021

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	min	Max
Austria	8,0	7,9	7,1	2,3	7,8	0,5	1,1	3,7	-0,2	2,7	-0,2	-0,4	-0,7	2,0	-0,1	8,3	-0,3	-0,7	8,3
Belgium	21,3	14,3	18,1	15,0	31,4	26,5	5,0	12,4	8,3	4,8	0,3	8,5	4,5	3,7	4,8	30,9	0,1	0,1	31,4
Bulgaria	-0,6	2,6	-3,4	13,7	16,0	16,0	1,6	11,9	19,3	-4,5	1,2	2,7	-0,3	10,1	4,7	8,2	-27,0	-27,0	19,3
Croatia	1,2	-4,3	-2,2	-0,8	7,3	6,4	1,1	5,4	4,8	-0,8	4,1	-2,4	-3,5	2,8	1,5	9,0	1,0	-4,3	9,0
Cyprus	2,0	4,2	22,6	28,2	15,4	4,1	1,4	13,9	18,5	8,5	8,3	-0,7	6,6	32,4	-0,7	22,5	9,1	-0,7	32,4
Czechia	5,0	3,5	7,2	9,9	15,0	5,4	4,1	17,1	8,7	8,2	0,0	-1,0	-0,9	2,3	7,3	6,6	2,1	-1,0	17,1
Denmark	7,5	2,4	8,7	4,5	7,6	9,7	6,9	8,9	6,7	7,9	4,0	4,1	8,4	2,2	5,3	-14,4	9,6	-14,4	9,7
Estonia	-5,1	-8,4	7,0	9,8	22,3	6,8	3,8	0,3	-0,9	3,1	10,9	0,8	1,0	1,5	5,9	-5,2	26,4	-8,4	26,4
Finland	-1,4	4,3	-1,6	5,1	-0,1	3,6	1,1	5,2	7,0	5,5	1,5	-0,7	4,9	0,8	3,9	2,6	-1,9	-1,9	7,0
France	-0,5	-3,6	5,5	18,7	9,2	3,7	-14,7	22,4	4,8	3,5	3,1	4,4	2,6	3,4	4,8	11,3	1,2	-14,7	22,4
Germany	15,5	18,1	18,6	0,3	7,7	7,5	6,9	8,7	1,5	4,5	3,6	-0,1	3,9	7,7	3,6	10,6	0,4	-0,1	18,6
Greece	1,6	2,5	10,6	-0,8	6,7	15,4	10,7	23,2	11,5	2,3	0,0	-1,9	12,4	4,1	9,1	10,8	0,8	-1,9	23,2
Hungary	58,8	7,2	15,4	-0,1	36,3	9,2	9,7	11,2	4,3	-9,8	-0,8	-0,8	-5,7	-7,4	0,7	9,6	1,9	-9,8	58,8
Ireland	18,7	8,9	13,8	13,8	31,8	9,8	14,8	6,4	7,0	13,2	6,7	1,2	14,5	4,0	9,5	34,9	-22,4	-22,4	34,9
Italy	19,5	10,3	17,8	17,2	11,2	1,9	-1,1	19,9	8,4	2,0	2,6	-0,6	4,9	-2,6	2,2	12,0	-6,5	-6,5	19,9
Latvia	-1,6	-3,5	-4,9	0,7	15,1	-11,5	10,2	6,7	3,7	4,3	-2,8	-1,1	5,0	2,6	2,3	2,9	-0,1	-11,5	15,1
Lithuania	-2,6	0,7	-2,4	8,1	11,1	-0,8	1,5	7,5	5,8	4,0	9,1	-0,5	1,7	-5,2	3,2	5,1	5,4	-5,2	11,1
Luxembourg	56,0	4,8	85,5	3,1	4,3	-2,7	0,1	9,0	12,3	28,0	11,5	7,6	15,5	44,4	-21,2	66,0	0,3	-21,2	85,5
Malta	20,6	21,1	18,8	10,2	13,3	343,0	89,0	54,7	31,4	26,2	7,9	21,3	16,3	9,6	4,0	30,2	13,4	4,0	343,0
Netherlands	22,1	12,1	18,7	9,0	18,6	-8,2	15,5	3,0	0,7	15,4	5,5	2,3	11,3	13,6	20,2	57,5	-7,1	-8,2	57,5
Poland	-0,2	-0,1	0,6	11,3	12,9	7,0	11,4	6,0	4,5	1,3	2,4	-4,1	-3,0	35,1	3,0	4,7	-3,0	-4,1	35,1
Portugal	1,7	6,5	5,4	4,7	6,4	-1,0	1,9	-0,1	4,6	14,8	3,4	1,1	-0,8	-1,3	1,4	11,0	0,0	-1,3	14,8
Romania	4,5	-2,7	6,4	11,0	9,7	3,1	-4,8	5,0	4,6	4,0	-0,2	1,0	-2,3	-2,4	1,7	0,8	-3,6	-4,8	11,0
Slovakia	-0,5	3,5	18,0	-0,6	21,3	-2,9	13,7	1,0	-3,1	15,6	10,0	-6,6	-4,7	3,8	42,0	2,7	0,4	-6,6	42,0
Slovenia	7,7	-7,0	6,8	-5,2	11,4	1,5	-0,7	2,9	7,5	-3,0	1,9	-4,0	-1,4	-1,3	2,8	13,8	0,0	-7,0	13,8
Spain	1,2	8,4	5,6	11,1	20,6	6,4	-4,4	8,1	5,9	5,3	2,2	4,9	0,6	-0,6	4,9	18,9	-2,3	-4,4	20,6
Sweden	4,0	4,4	3,6	1,6	7,1	-2,0	3,3	3,7	1,5	2,0	2,1	0,7	1,5	1,0	3,5	7,8	4,1	-2,0	7,8

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

3. Share of energy from renewable sources in transport

The table below presents the percentage gross final energy consumption data regarding the allocation of energy from renewable sources in transport in European Union countries in 2004-2021.

Table 5.
Share of energy from renewable sources in transport over the years 2004-2021

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	4,53	5,07	7,53	8,24	9,56	11,18	10,71	10,08	10,03	9,70	10,98	11,41	10,58	9,70	9,93	10,05	10,28	9,36
Belgium	0,64	0,66	0,68	0,67	0,71	2,19	4,80	4,80	4,91	5,09	5,85	3,92	6,03	6,64	6,71	6,82	11,04	10,26
Bulgaria	0,97	0,88	1,05	0,96	0,94	1,09	1,50	0,90	0,65	5,89	5,74	6,49	7,20	7,27	8,08	7,89	9,10	7,61
Croatia	1,00	1,03	1,01	1,12	1,07	1,29	1,12	1,03	1,05	2,72	2,65	2,36	1,22	1,17	2,58	5,86	6,59	6,98
Cyprus	0,00	0,00	0,00	0,00	1,92	2,04	1,99	0,00	0,00	1,13	2,68	2,52	2,67	2,56	2,66	3,32	7,40	7,19
Czechia	1,20	1,10	1,07	1,05	2,84	4,31	5,22	1,29	6,25	6,45	7,00	6,54	6,50	6,62	6,56	7,84	9,38	7,49
Denmark	0,45	0,44	0,52	0,54	0,54	0,69	1,15	3,61	6,28	6,46	6,56	6,43	6,73	6,94	6,92	7,11	9,70	10,55
Estonia	0,20	0,24	0,18	0,17	0,19	0,44	0,43	0,45	0,45	0,45	0,42	0,41	0,43	0,42	3,32	6,24	12,17	11,24
Finland	1,01	0,91	0,96	1,03	2,91	4,56	4,39	1,00	1,05	10,67	24,12	24,57	8,82	18,68	14,77	14,85	14,31	20,51
France	0,78	0,78	0,79	0,83	6,25	6,65	6,58	0,99	7,41	7,60	8,25	8,37	8,41	8,77	8,96	9,25	9,21	8,21
Germany	2,14	3,95	6,70	7,53	6,32	5,88	6,41	6,46	7,32	7,30	6,90	6,57	7,01	7,03	7,94	7,63	10,01	7,97
Greece	0,09	0,06	0,74	1,27	1,06	1,10	1,92	0,60	0,90	0,98	1,33	1,10	1,62	4,00	4,11	4,05	5,34	4,31
Hungary	1,02	1,01	1,22	1,63	5,18	5,89	6,16	6,17	6,00	6,34	7,00	7,17	7,77	7,73	7,75	8,06	11,57	6,16
Ireland	0,04	0,08	0,10	0,50	1,31	1,96	2,49	3,84	4,04	4,90	5,20	5,94	5,16	7,44	7,19	8,92	10,19	4,30
Italy	1,21	1,05	1,00	0,96	2,62	4,00	4,92	5,06	6,16	5,41	5,02	6,51	7,41	6,48	7,66	9,05	10,74	10,00
Latvia	2,14	2,39	2,17	1,67	1,69	1,89	3,98	4,09	4,00	4,03	4,08	3,64	2,45	2,27	4,73	4,55	6,73	6,44
Lithuania	0,45	0,66	1,91	3,82	4,32	4,48	3,79	3,83	4,97	4,84	4,36	4,58	3,65	4,30	4,33	4,05	5,51	6,46
Luxembourg	0,14	0,16	0,19	2,20	2,17	2,23	2,09	2,36	2,83	4,07	5,55	6,70	5,97	6,48	6,60	7,71	12,58	7,96
Malta	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,02	3,22	3,48	4,67	4,68	5,27	6,83	8,02	8,90	10,59	10,58
Netherlands	0,52	0,50	0,85	3,18	2,98	4,57	3,40	5,07	5,22	5,34	6,56	5,60	4,76	5,84	9,48	12,33	12,63	8,99
Poland	1,58	1,75	1,82	1,75	4,14	5,41	6,64	6,92	6,53	6,67	6,32	5,69	3,97	4,23	5,72	6,20	6,58	5,67
Portugal	0,42	0,45	1,63	2,43	2,52	3,89	5,55	0,70	0,81	0,93	3,67	7,43	7,65	7,91	9,04	9,09	9,70	8,61

Cont. table 5.

Romania	1,82	1,87	1,54	1,64	1,35	1,30	1,37	5,54	4,96	5,45	4,68	5,49	6,17	6,56	6,34	7,85	8,54	7,67
Slovakia	1,50	1,66	3,30	3,99	4,28	5,36	5,29	5,73	5,60	6,21	7,95	8,63	7,77	6,95	6,99	8,31	9,26	8,75
Slovenia	0,85	0,83	1,06	1,47	1,77	2,25	3,12	2,48	3,25	3,77	2,88	2,24	1,60	2,57	5,48	7,98	10,91	10,64
Spain	1,04	1,27	0,84	1,38	2,17	3,71	5,02	0,77	0,87	0,95	1,02	1,09	5,17	5,80	6,94	7,61	9,53	9,19
Sweden	6,29	6,60	7,51	8,42	8,69	9,36	9,63	11,94	13,78	15,32	18,83	21,49	26,56	26,84	29,70	30,31	31,85	30,43

Source: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Table 6.

The largest and smallest share of energy from renewable sources in transport over the years 2004-2021

	The smallest value	Year of lowest value	The greatest value	Year of greatest value	Difference
Austria	4,53	2004	11,41	2015	6,88
Belgium	0,64	2004	11,04	2020	10,39
Bulgaria	0,65	2004	9,10	2020	8,45
Croatia	1,00	2004	6,98	2021	5,99
Cyprus	0,00	2004	7,40	2020	7,40
Czechia	1,05	2007	9,38	2020	8,34
Denmark	0,44	2005	10,55	2021	10,10
Estonia	0,17	2007	12,17	2020	12,00
Finland	0,91	2005	24,57	2021	23,66
France	0,78	2004	9,25	2019	8,47
Germany	2,14	2004	10,01	2020	7,87
Greece	0,06	2005	5,34	2020	5,28
Hungary	1,01	2005	11,57	2020	10,57
Ireland	0,04	2004	10,19	2020	10,14
Italy	0,96	2007	10,74	2020	9,77
Latvia	1,67	2007	6,73	2020	5,07
Lithuania	0,45	2004	6,46	2021	6,02
Luxembourg	0,14	2004	12,58	2020	12,44
Malta	0,00	2004-2010	10,59	2020	10,59
Netherlands	0,50	2005	12,63	2020	12,13
Poland	1,58	2004	6,92	2011	5,34
Portugal	0,42	2004	9,70	2020	9,28
Romania	1,30	2009	8,54	2020	7,24
Slovakia	1,50	2004	9,26	2020	7,76
Slovenia	0,83	2005	10,91	2020	10,08
Spain	0,77	2011	9,53	2020	8,76
Sweden	6,29	2004	31,85	2020	25,57

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Among the European Union member states, Malta had the smallest share of energy from renewable sources in transport - until 2010, the value shown was 0.00, while Sweden had the most significant – 31,85% in 2020. In terms of the minor difference obtained between the maximum and minimum energy share over the years 2004-2021 was achieved by Latvia – 5,07% (difference between 2007 and 2020), while Sweden achieved the highest value of the energy share difference – 25,57% (difference between 2004 and 2020). Below, in Table 7, each country's share of energy in transport is presented in 2019, 2020 and 2021 in descending order.

Table 7.
Presentation of the share of energy from renewable sources in transport in 2019, 2020 and 2021 in descending order

2019		2020		2021	
Sweden	30,309	Sweden	31,854	Sweden	30,426
Finland	14,845	Finland	14,31	Finland	20,512
Netherlands	12,326	Netherlands	12,631	Estonia	11,236
Austria	10,051	Luxembourg	12,581	Slovenia	10,641
France	9,248	Estonia	12,165	Malta	10,58
Portugal	9,089	Hungary	11,571	Denmark	10,546
Italy	9,047	Belgium	11,035	Belgium	10,262
Ireland	8,917	Slovenia	10,911	Italy	10,001
Malta	8,902	Italy	10,736	Austria	9,355
Slovakia	8,308	Malta	10,586	Spain	9,194
Hungary	8,057	Austria	10,283	Netherlands	8,991
Slovenia	7,983	Ireland	10,187	Slovakia	8,753
Bulgaria	7,893	Germany	10,008	Portugal	8,609
Romania	7,846	Denmark	9,701	France	8,209
Czechia	7,841	Portugal	9,701	Germany	7,972
Luxembourg	7,707	Spain	9,528	Luxembourg	7,962
Germany	7,63	Czechia	9,383	Romania	7,669
Spain	7,61	Slovakia	9,259	Bulgaria	7,613
Denmark	7,11	France	9,207	Czechia	7,492
Belgium	6,817	Bulgaria	9,101	Cyprus	7,188
Estonia	6,243	Romania	8,54	Croatia	6,983
Poland	6,2	Cyprus	7,401	Lithuania	6,462
Croatia	5,855	Latvia	6,733	Latvia	6,436
Latvia	4,554	Croatia	6,593	Hungary	6,159
Lithuania	4,049	Poland	6,575	Poland	5,665
Greece	4,049	Lithuania	5,511	Greece	4,31
Cyprus	3,316	Greece	5,341	Ireland	4,296

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

In the last three years of the analyzed period, Sweden was in first place (30,31% – 2019, 31,85% – 2020, 30,43% – 2021), followed by Finlandia (14,85% – 2019, 14,31% – 2020, 20,51% – 2021). The Netherlands was third in terms of energy from renewable sources in transport in 2019 (12,326%) and 2020 (12,631%). In 2021 on the third places was Estonia – 11,236%. Particular attention should be paid to the fact that Luxembourg was fourth in 2020 (12,58%), and Malta was fifth in 2021 (10,58%), i.e. countries that were last in the overall share of energy in those years. The countries with the lowest share in the last three years of the analyzed period are: Lithuania (4,05%), Greece (4,05%) and Cyprus (3,32%) in 2019, Poland (6,58%), Lithuania (5,51%) and Greece (5,34%) in 2020, Poland (5,67%), Greece (4,31%) and Ireland (4,23%) in 2021. Focusing on the last year reported data (2021), Sweden had the largest share in energy from renewable sources (30,43%), ahead of Finland (20,51%) by 9,91 % and Estonia by 19,19% (share 11,24%), while the smallest share was obtained by Ireland (4,30%), Greece (4,31%) and Poland (5,67%). The average percentage of European Union countries in energy from renewable sources in 2021 was 9,39%. Only ten countries have an above-average share of energy from renewable sources, with Italy having the most minor difference from the

average – 10%. Below, Figure 2 presents the results of the share of energy from renewable sources in transport of EU countries last three years from the period 2004-2021.

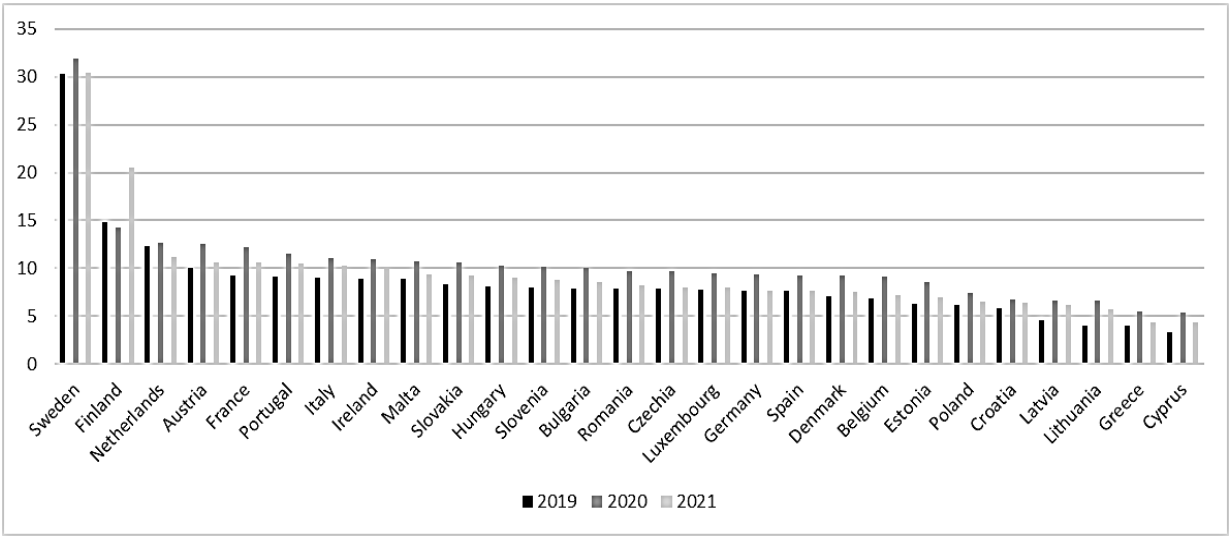

Figure 2. Presentation of the percentage share of energy from renewable sources in transport of EU countries last three years from the period 2004-2021.

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Table 8 below shows the percentage change in the share of energy from renewable sources in transport in subsequent years compared to the year immediately preceding. Malta and Cyprus are the critical points of concern. In the years 2004-2010, Malta's share of energy from renewable sources in transport was 0.00 in statistical reports, but in the following years, there were increases in the percentage of energy from year to year until 2020 - in 2021, there was a decrease of 0,06% compared to 2020. In turn, Malta has a 0,00 share of energy in the tables in the years 2004-2007 and 2011-2012, which, when determining percentage changes, resulted in a 100,00% decrease in the percentage change in 2011, defined to the immediately preceding year. Data analysis on the maximum percentage change shows that Greece achieved an increase of 1145,76% in 2006 compared to 2005, while Sweden achieved the most minor growth – 24,01% in 2011 compared to 2010.

Table 8.
Percentage change from year to year in the share of energy from renewable sources in the transport of EU countries over the years 2004-2021

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Min	Max
Austria	11,9	48,6	9,4	16,0	16,9	-4,2	-5,9	-0,5	-3,3	13,3	3,9	-7,2	-8,3	2,3	1,2	2,3	-9,0	-9,0	48,6
Belgium	3,3	2,0	-0,7	6,1	207,6	119,2	0,0	2,3	3,5	14,9	-32,9	53,8	10,1	1,1	1,6	61,9	-7,0	-32,9	207,6
Bulgaria	-9,0	18,7	-8,9	-1,9	16,4	37,2	-40,1	-27,6	805,5	-2,4	13,1	11,0	1,0	11,0	-2,3	15,3	-16,3	-40,1	805,5
Croatia	3,0	-2,0	11,5	-4,4	20,4	-13,0	-8,4	1,9	158,8	-2,3	-11,0	-48,4	-3,6	119,9	126,8	12,6	5,9	-48,4	158,8
Cyprus	-	-	-	-	6,0	-2,1	-100	-	-	137,8	-5,9	6,0	-4,1	3,9	24,6	123,2	-2,9	-100,0	137,8
Czechia	-8,6	-2,4	-2,3	171,3	51,7	21,1	-75,4	386,3	3,1	8,6	-6,6	-0,6	1,8	-0,9	19,6	19,7	-20,2	-75,4	386,3
Denmark	-0,4	17,6	2,7	0,9	28,3	65,9	213,8	74,0	2,8	1,5	-1,9	4,7	3,0	-0,2	2,7	36,4	8,7	-1,9	213,8
Estonia	17,5	-21,7	-8,7	10,1	136,8	-1,1	2,8	1,3	-0,7	-6,7	-1,2	4,4	-3,2	695,0	88,3	94,9	-7,6	-21,7	695,0
Finland	-9,9	5,1	7,2	183,8	56,6	-3,7	-77,1	4,5	916,7	126,2	1,8	-64,1	111,9	-20,9	0,5	-3,6	43,3	-77,1	916,7
France	0,1	1,0	4,5	654,2	6,5	-1,1	-85,0	651,2	2,5	8,5	1,4	0,5	4,3	2,3	3,2	-0,4	-10,8	-85,0	654,2
Germany	85,1	69,5	12,4	-16,1	-7,0	9,1	0,7	13,3	-0,3	-5,5	-4,8	6,8	0,2	13,0	-3,9	31,2	-20,3	-20,3	85,1
Greece	-32,2	1145,8	72,7	-16,3	3,8	73,8	-68,7	50,5	8,5	35,3	-17,0	47,6	146,4	2,7	-1,4	31,9	-19,3	-68,7	1145,8
Hungary	-1,0	21,0	34,2	217,4	13,6	4,7	0,2	-2,9	5,7	10,4	2,4	8,4	-0,5	0,2	4,0	43,6	-46,8	-46,8	217,4
Ireland	70,5	36,0	393,1	159,4	50,3	27,0	54,3	5,2	21,1	6,2	14,2	-13,2	44,3	-3,4	24,1	14,2	-57,8	-57,8	393,1
Italy	-13,6	-5,1	-3,1	171,4	52,9	22,9	2,9	21,6	-12,1	-7,2	29,6	14,0	-12,5	18,1	18,1	18,7	-6,8	-13,6	171,4
Latvia	11,7	-9,4	-23,0	1,3	11,8	110,7	2,8	-2,3	0,9	1,1	-10,7	-32,7	-7,3	108,3	-3,7	47,8	-4,4	-32,7	110,7
Lithuania	47,3	190,0	100,6	13,0	3,8	-15,3	0,9	29,9	-2,8	-9,9	5,2	-20,4	17,8	0,8	-6,6	36,1	17,3	-20,4	190,0

Cont, table 8.

Luxembourg	15,2	18,9	1065,6	-1,4	2,8	-6,3	12,8	19,8	44,1	36,2	20,7	-11,0	8,6	1,8	16,8	63,2	-36,7	-36,7	1065,6
Malta	-	-	-	-	-	-	-	59,5	8,3	34,0	0,3	12,6	29,6	17,5	11,0	18,9	-0,1	-0,1	59,5
Netherlands	-3,1	70,3	274,4	-6,3	53,3	-25,7	49,2	2,9	2,4	22,8	-14,7	-14,9	22,7	62,3	30,0	2,5	-28,8	-28,8	274,4
Poland	10,4	4,1	-3,9	137,3	30,5	22,8	4,2	-5,6	2,0	-5,2	-10,0	-30,1	6,5	35,2	8,4	6,0	-13,8	-30,1	137,3
Portugal	6,1	262,4	49,2	3,4	54,5	42,8	-87,5	16,1	14,6	296,4	102,6	2,9	3,5	14,2	0,6	6,7	-11,3	-87,5	296,4
Romania	2,9	-17,8	6,7	-18,0	-3,6	5,3	305,2	-10,4	9,7	-14,1	17,4	12,4	6,3	-3,3	23,7	8,8	-10,2	-18,0	305,2
Slovakia	10,7	98,5	21,2	7,1	25,4	-1,3	8,2	-2,3	11,0	28,0	8,6	-10,0	-10,5	0,5	18,9	11,4	-5,5	-10,5	98,5
Slovenia	-2,2	27,1	39,5	20,4	27,0	38,5	-20,6	31,3	15,9	-23,7	-22,0	-28,6	60,6	113,1	45,7	36,7	-2,5	-28,6	113,1
Spain	22,4	-33,9	64,3	57,5	71,4	35,3	-84,7	13,3	9,3	7,8	6,3	374,9	12,2	19,7	9,7	25,2	-3,5	-84,7	374,9
Sweden	4,9	13,8	12,1	3,2	7,6	2,9	24,0	15,4	11,2	23,0	14,1	23,6	1,1	10,6	2,1	5,1	-4,5	-4,5	24,0

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

4. Share of energy from renewable sources in electricity

The table below presents the percentage gross final energy consumption data regarding the allocation of power from renewable sources in electricity in European Union countries from 2004-2021.

Table 9.
Share of energy from renewable sources in electricity over the years 2004-2021

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Austria	61,63	62,90	63,53	65,67	65,88	68,63	66,36	66,78	67,44	68,91	71,06	71,49	72,52	71,63	74,19	75,07	78,20	76,19
Belgium	1,71	2,39	3,13	3,66	4,63	6,18	7,33	8,99	11,34	12,55	13,41	15,57	15,83	17,21	18,89	20,82	25,12	26,01
Bulgaria	8,36	8,67	8,73	8,90	9,54	10,91	12,36	12,62	15,82	18,68	18,69	18,98	19,15	19,02	22,36	23,51	23,59	18,79
Croatia	35,03	35,18	34,82	33,98	33,87	35,88	37,52	37,59	38,76	42,08	45,24	45,41	46,67	46,44	48,14	49,78	53,82	53,47
Cyprus	0,02	0,02	0,03	0,07	0,29	0,59	1,39	3,45	4,93	6,65	7,40	8,45	8,59	8,91	9,36	9,76	12,04	14,84
Czechia	3,69	3,78	4,10	4,62	5,18	6,38	7,52	10,61	11,67	12,78	13,89	14,07	13,62	13,65	13,71	14,05	14,81	14,54
Denmark	23,75	24,65	23,97	25,00	25,94	28,26	32,74	35,87	38,72	43,08	48,49	51,29	53,72	59,94	62,39	65,35	65,32	62,65
Estonia	0,55	1,13	1,43	1,43	1,97	5,97	10,29	12,20	15,67	12,95	14,02	16,15	16,19	17,58	19,68	22,00	28,29	29,34
Finland	26,71	26,92	26,42	25,47	26,75	26,82	27,22	28,96	29,11	30,54	31,11	32,21	32,72	35,04	36,54	37,97	39,56	39,53
France	13,78	13,74	14,06	14,29	14,36	15,09	14,82	16,18	16,55	16,98	18,47	18,82	19,21	19,93	21,13	22,39	24,82	25,02
Germany	9,44	10,58	11,94	13,73	15,14	17,52	18,24	20,93	23,61	25,28	28,17	30,88	32,27	34,61	37,59	40,60	44,22	43,68
Greece	7,84	8,21	8,92	9,33	9,65	11,02	12,31	13,81	16,36	21,24	21,92	22,09	22,66	24,46	26,00	31,30	35,86	35,93
Hungary	2,22	4,42	3,45	4,19	5,32	6,96	7,10	6,38	6,06	6,60	7,31	7,34	7,29	7,51	8,31	9,97	11,90	13,66
Ireland	6,03	7,20	8,51	9,53	10,82	14,06	15,64	18,25	19,84	20,96	23,32	25,73	27,07	30,32	33,32	36,46	39,06	36,40
Italy	16,09	16,29	15,93	15,95	16,65	18,81	20,09	23,55	27,42	31,30	33,42	33,46	34,01	34,10	33,93	34,97	38,08	36,00
Latvia	45,96	43,02	40,41	38,62	38,73	41,94	42,05	44,69	44,88	48,69	51,04	52,21	51,25	54,35	53,50	53,42	53,36	51,40
Lithuania	3,59	3,83	4,02	4,65	4,91	5,87	7,40	9,02	10,88	13,15	13,71	15,54	16,87	18,26	18,41	18,79	20,17	21,28
Luxembourg	2,77	3,18	3,17	3,31	3,58	4,11	3,79	4,08	4,66	5,33	5,96	6,20	6,67	8,06	9,12	10,86	13,89	14,22
Malta	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,45	1,12	1,57	3,33	4,31	5,71	6,85	7,70	7,49	9,49	9,66
Netherlands	4,45	6,30	6,54	5,96	7,46	9,07	9,60	9,74	10,35	9,91	9,92	11,04	12,55	13,81	15,17	18,23	26,41	30,39
Poland	2,05	2,51	2,86	3,32	4,25	5,71	6,55	8,08	10,61	10,68	12,36	13,40	13,34	13,08	13,03	14,36	16,24	17,17
Portugal	27,39	27,70	29,31	32,29	34,06	37,56	40,61	45,78	47,51	49,10	52,05	52,62	53,99	54,17	52,19	53,77	58,03	58,43
Romania	28,43	28,78	28,05	28,11	28,08	30,89	30,38	31,13	33,57	37,52	41,68	43,16	42,71	41,97	41,79	42,62	43,37	42,49
Slovakia	15,40	15,74	16,57	16,47	17,01	17,77	17,77	19,31	20,05	20,80	22,87	22,66	22,51	21,34	21,50	22,10	23,07	22,37
Slovenia	29,27	28,65	28,23	27,70	29,96	33,76	32,20	31,05	31,64	33,08	33,94	32,72	32,06	32,43	32,31	32,63	35,10	34,98
Spain	19,02	19,17	20,03	21,72	23,78	27,88	29,75	31,53	33,44	36,03	37,13	36,97	36,68	36,47	35,24	37,13	42,94	45,96
Sweden	51,20	50,90	51,78	53,21	53,69	58,25	55,77	59,62	59,78	61,74	63,21	65,73	64,87	65,91	66,23	71,23	74,50	75,70

Source: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

The smallest and largest values were determined based on the data presented in Table 10.

Table 10.
The largest and smallest share of energy from renewable sources in electricity over the years 2004-2021

	The smallest value	Year of lowest value	The greatest value	Year of greatest value	Difference
Austria	61,63	2004	78,20	2020	16,58
Belgium	1,71	2004	26,01	2021	24,30
Bulgaria	8,36	2004	23,59	2020	15,23
Croatia	33,87	2008	53,82	2020	19,95
Cyprus	0,02	2004	14,84	2021	14,82
Czechia	3,69	2004	14,81	2020	11,12
Denmark	23,75	2004	65,35	2019	41,59
Estonia	0,55	2004	29,34	2021	28,79
Finland	25,47	2007	39,56	2021	14,10
France	13,74	2004	25,02	2021	11,28
Germany	9,44	2004	44,22	2020	34,78
Greece	7,84	2004	35,93	2021	28,09
Hungary	2,22	2004	13,66	2021	11,44
Ireland	6,03	2004	39,06	2020	33,02
Italy	15,93	2006	38,08	2020	22,16
Latvia	38,62	2007	54,35	2017	15,73
Lithuania	3,59	2004	21,28	2021	17,69
Luxembourg	2,77	2004	14,22	2021	11,45
Malta	0,00	2004-2009	9,66	2021	9,66
Netherlands	4,45	2004	30,39	2021	25,95
Poland	2,05	2004	17,17	2021	15,12
Portugal	27,39	2004	58,43	2021	31,04
Romania	28,05	2006	43,37	2020	15,32
Slovakia	15,40	2004	23,07	2020	7,66
Slovenia	27,70	2007	35,10	2020	7,40
Spain	19,02	2004	45,96	2021	26,94
Sweden	50,90	2004	75,70	2021	24,81

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Among the European Union Member States, Malta had the smallest share of energy from renewable sources in electricity – 0,00 in 2004-2009, while Austria had the largest – 78,20% in 2020. In terms of the minor difference obtained between the maximum and minimum share of energy over the years 2004-2021, Slovenia achieved – 7,40% (difference between 2007 and 2020), while Denmark achieved the highest difference value – 41,59% (difference between 2004 and 2019). Below, in Table 11, each country's share of energy in electricity is presented in 2019, 2020 and 2021 in descending order.

Table 11.
Presentation of the share of energy from renewable sources in electricity in 2019, 2020 and 2021 in descending order

2019		2020		2021	
Austria	75,067	Austria	78,204	Austria	76,185
Sweden	71,234	Sweden	74,495	Sweden	75,704
Denmark	65,347	Denmark	65,323	Denmark	62,647
Portugal	53,774	Portugal	58,032	Portugal	58,433
Latvia	53,423	Croatia	53,816	Croatia	53,471
Croatia	49,783	Latvia	53,357	Latvia	51,397
Romania	42,616	Germany	44,215	Spain	45,962
Germany	40,604	Romania	43,374	Germany	43,681
Finland	37,969	Spain	42,944	Romania	42,489

Cont. table 11.

Spain	37,131	Finland	39,564	Finland	39,531
Ireland	36,46	Ireland	39,055	Ireland	36,403
Italy	34,969	Italy	38,081	Italy	35,996
Slovenia	32,632	Greece	35,856	Greece	35,934
Greece	31,295	Slovenia	35,095	Slovenia	34,976
Bulgaria	23,509	Estonia	28,293	Netherlands	30,394
France	22,389	Netherlands	26,407	Estonia	29,34
Slovakia	22,103	Belgium	25,122	Belgium	26,013
Estonia	21,998	France	24,819	France	25,016
Belgium	20,817	Bulgaria	23,586	Slovakia	22,369
Lithuania	18,79	Slovakia	23,066	Lithuania	21,278
Netherlands	18,23	Lithuania	20,166	Bulgaria	18,79
Poland	14,356	Poland	16,237	Poland	17,166
Czechia	14,046	Czechia	14,81	Cyprus	14,84
Luxembourg	10,863	Luxembourg	13,887	Czechia	14,544
Hungary	9,969	Cyprus	12,041	Luxembourg	14,217
Cyprus	9,756	Hungary	11,904	Hungary	13,66
Malta	7,485	Malta	9,489	Malta	9,655

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

In the last three years of the analyzed period, Austria was in first place in share of energy from renewable sources in electricity (75,07% – 2019, 78,2% – 2020, 76,185% – 2021), followed by Sweden (71,23% – 2019, 74,495% – 2020, 75,704% – 2021) and Denmark (65,35%-2019, 65,32-2020, 62,65-2021). The countries with the lowest share in the last three years of the analyzed period are: Hungary (9,969%), Cyprus (9,756%) and Malta (7,485%) in 2019, Cyprus (12,04%), Hungary (11,9%) and Malta (9,49%) in 2020, Luxemburg (14,217%), Hungary (13,66%) and Malta (9,655%) in 2021. Analysis of the last year of reported data, the largest share in energy from renewable sources was recorded by Austria (76,19%), followed by Sweden (75,70%) and Denmark (62,65%). In comparison, Malta obtained the smallest share (9,655%), then Hungary (13,66%) and Luxembourg (14,217%). The average percentage of European Union countries in energy from renewable sources in 2021 was 35,19%. The share of energy from renewable sources was above average in 13 countries, with the most minor difference from the average being Greece – 35,93%. Below, Figure 3 presents the results of the share of energy from renewable sources in electricity of EU countries last three years from the period 2004-2021.

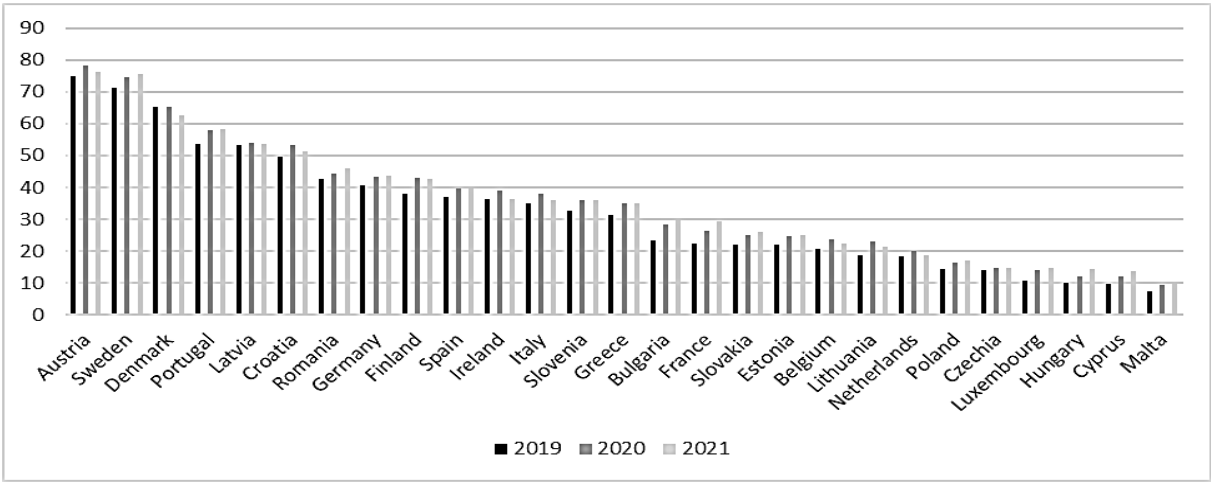

Figure 3. Presentation of the percentage share of energy from renewable sources in electricity of EU countries in 2021.

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

The table below shows the percentage change in the share of energy from renewable sources in electricity in subsequent years compared to the immediately preceding year. In the years 2004-2009, Malta in the statistical reports of the share of energy from renewable sources in electricity has 0.00, taking into account the percentage of 0,03% in 2010 and 0,45% in 2011, which indicates an increase in 2011 by 1318,75% compared to 2010. Over 2004-2021, only four countries did not record a decrease in the percentage change compared to the preceding year: Greece 0,22%, Lithuania 0.84%, Belgium 1,676% and Cyprus 1,681%. Of the remaining countries, Hungary experienced the most significant decline in 2006 (21,96%), and Germany had the smallest drop – 1,21% in 2021. In an analysis of the data on the maximum percentage change, it can be visible that Malta achieved an increase of 1318,75% in 2011 compared to 2010, while the smallest increase was achieved by Austria by 4,18% in 2020 compared to 2019.

Table 12.
Percentage change from year to year in the share of energy from renewable sources in electricity in EU countries over the years 2004-2021

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Min	Max
Austria	2,1	1,0	3,4	0,3	4,2	-3,3	0,6	1,0	2,2	3,1	0,6	1,4	-1,2	3,6	1,2	4,2	-2,6	-3,3	4,2
Belgium	39,2	31,2	17,0	26,3	33,5	18,7	22,6	26,1	10,7	6,9	16,1	1,7	8,7	9,7	10,2	20,7	3,5	1,7	39,2
Bulgaria	3,7	0,7	1,9	7,2	14,3	13,3	2,1	25,3	18,1	0,0	1,5	0,9	-0,7	17,5	5,2	0,3	-20,3	-20,3	25,3
Croatia	0,4	-1,0	-2,4	-0,3	5,9	4,6	0,2	3,1	8,5	7,5	0,4	2,8	-0,5	3,7	3,4	8,1	-0,6	-2,4	8,5
Cyprus	26,3	41,7	117,6	285,1	106,7	136,0	147,8	43,0	35,1	11,2	14,1	1,7	3,8	5,0	4,3	23,4	23,2	1,7	285,1
Czechia	2,4	8,3	12,8	12,1	23,1	17,8	41,2	10,0	9,5	8,7	1,3	-3,2	0,3	0,4	2,4	5,4	-1,8	-3,2	41,2
Denmark	3,8	-2,8	4,3	3,7	8,9	15,8	9,6	7,9	11,3	12,6	5,8	4,7	11,6	4,1	4,7	0,0	-4,1	-4,1	15,8
Estonia	106,4	26,7	0,3	37,7	202,5	72,5	18,5	28,5	-17,4	8,3	15,2	0,3	8,6	11,9	11,8	28,6	3,7	-17,4	202,5
Finland	0,8	-1,9	-3,6	5,0	0,3	1,5	6,4	0,5	4,9	1,9	3,5	1,6	7,1	4,3	3,9	4,2	-0,1	-3,6	7,1
France	-0,3	2,3	1,6	0,5	5,1	-1,8	9,2	2,3	2,6	8,8	1,9	2,1	3,8	6,0	6,0	10,9	0,8	-1,8	10,9
Germany	12,1	12,9	14,9	10,3	15,7	4,1	14,7	12,8	7,1	11,4	9,6	4,5	7,2	8,6	8,0	8,9	-1,2	-1,2	15,7
Greece	4,7	8,7	4,5	3,4	14,2	11,7	12,2	18,5	29,8	3,2	0,8	2,6	8,0	6,3	20,4	14,6	0,2	0,2	29,8
Hungary	99,1	-21,9	21,4	26,8	30,9	2,1	-10,2	-5,0	9,0	10,7	0,5	-0,7	3,0	10,6	20,0	19,4	14,8	-21,9	99,1
Ireland	19,3	18,2	12,1	13,5	29,9	11,2	16,7	8,7	5,7	11,3	10,3	5,2	12,0	9,9	9,4	7,1	-6,8	-6,8	29,9
Italy	1,3	-2,3	0,2	4,3	13,0	6,8	17,2	16,5	14,2	6,8	0,1	1,7	0,3	-0,5	3,1	8,9	-5,5	-5,5	17,2
Latvia	-6,4	-6,1	-4,4	0,3	8,3	0,3	6,3	0,4	8,5	4,8	2,3	-1,8	6,1	-1,6	-0,1	-0,1	-3,7	-6,4	8,5
Lithuania	6,8	4,8	15,8	5,6	19,4	26,1	21,9	20,6	20,9	4,2	13,4	8,6	8,2	0,8	2,1	7,3	5,5	0,8	26,1
Luxembourg	15,0	-0,2	4,2	8,4	14,6	-7,8	7,6	14,4	14,4	11,8	4,0	7,7	20,7	13,2	19,2	27,8	2,4	-7,8	27,8
Malta	-	-	-	-	-	-	1318,8	145,6	40,9	112,2	29,4	32,5	19,8	12,5	-2,8	26,8	1,7	-2,8	1318,8
Netherlands	41,6	3,9	-8,8	25,2	21,5	5,9	1,4	6,3	-4,2	0,1	11,2	13,7	10,1	9,8	20,2	44,9	15,1	-8,8	44,9
Poland	22,6	13,9	15,9	28,1	34,5	14,6	23,3	31,3	0,6	15,8	8,4	-0,4	-1,9	-0,4	10,2	13,1	5,7	-1,9	34,5
Portugal	1,1	5,8	10,2	5,5	10,3	8,1	12,7	3,8	3,4	6,0	1,1	2,6	0,3	-3,7	3,0	7,9	0,7	-3,7	12,7
Romania	1,2	-2,5	0,2	-0,1	10,0	-1,7	2,5	7,8	11,8	11,1	3,6	-1,0	-1,7	-0,4	2,0	1,8	-2,0	-2,5	11,8

Cont. table 12.

Slovakia	2,2	5,3	-0,6	3,3	4,4	0,1	8,6	3,9	3,7	10,0	-0,9	-0,6	-5,2	0,7	2,8	4,4	-3,0	-5,2	10,0
Slovenia	-2,1	-1,5	-1,9	8,2	12,7	-4,6	-3,6	1,9	4,6	2,6	-3,6	-2,0	1,2	-0,4	1,0	7,5	-0,3	-4,6	12,7
Spain	0,8	4,5	8,4	9,5	17,3	6,7	6,0	6,1	7,7	3,1	-0,4	-0,8	-0,6	-3,4	5,4	15,7	7,0	-3,4	17,3
Sweden	-0,6	1,7	2,8	0,9	8,5	-4,3	6,9	0,3	3,3	2,4	4,0	-1,3	1,6	0,5	7,6	4,6	1,6	-4,3	8,5

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

5. Share of energy from renewable sources in heating and cooling

The table below presents the percentage gross final energy consumption data regarding energy allocation from renewable sources in heating and cooling in European Union countries in 2004-2021.

Table 13.
Share of energy from renewable sources in heating and cooling over the years 2004-2021

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Austria	20,17	22,82	24,49	27,14	27,20	29,63	30,96	31,52	33,08	33,22	33,38	33,23	33,48	33,67	34,18	33,93	35,00	35,48
Belgium	2,93	3,42	3,81	4,71	5,12	6,09	6,71	6,72	7,11	7,64	7,75	7,94	8,25	8,20	8,29	8,32	8,45	9,24
Bulgaria	14,06	14,26	14,79	13,86	17,26	21,64	24,33	24,77	27,24	29,23	28,52	28,90	29,99	29,85	33,25	35,42	37,18	25,63
Croatia	29,41	30,00	29,07	29,30	28,82	31,30	32,88	33,82	36,55	37,31	36,22	38,62	37,64	36,63	36,65	36,79	36,93	38,03
Cyprus	9,26	9,97	10,43	13,06	14,47	17,31	18,81	19,98	21,76	22,54	22,19	24,07	24,69	26,42	37,16	35,05	37,12	41,34
Czechia	9,92	10,84	11,23	12,37	12,92	14,26	14,10	15,39	16,25	17,71	19,53	19,79	19,88	19,73	20,64	22,63	23,54	24,18
Denmark	20,50	22,61	23,66	26,71	27,96	29,40	30,37	31,89	33,20	34,68	38,01	39,54	41,08	44,06	44,97	47,30	51,07	41,53
Estonia	33,36	32,37	30,84	33,04	36,00	42,03	43,16	44,55	43,22	43,11	44,93	50,03	51,77	52,22	53,67	52,19	58,83	61,32
Finland	39,50	39,12	41,41	41,43	43,08	42,89	43,97	45,73	48,23	50,77	51,96	52,62	53,70	54,59	54,91	56,88	57,62	52,59
France	12,53	12,36	11,70	12,79	13,28	15,04	16,16	15,26	16,59	17,61	18,05	18,88	20,12	20,60	21,22	22,36	23,37	24,21
Germany	7,20	7,71	8,41	10,25	10,33	11,16	12,06	12,61	13,42	13,41	13,41	13,43	13,03	13,37	14,22	14,50	14,48	15,44
Greece	13,47	13,38	13,10	14,68	14,72	17,25	18,66	20,11	24,12	27,42	27,87	26,56	25,42	28,25	30,12	30,05	31,94	31,15
Hungary	6,45	9,94	11,38	13,54	11,97	17,02	18,08	20,04	23,31	23,70	21,28	21,34	21,03	19,90	18,20	18,16	17,72	17,93
Ireland	2,87	3,44	3,59	3,79	3,51	4,18	4,28	4,66	4,85	5,19	6,26	6,18	6,24	6,62	6,38	6,34	6,26	5,17
Italy	5,71	8,22	10,09	13,33	15,31	16,43	15,64	13,82	16,98	18,09	18,91	19,26	18,89	20,08	19,28	19,70	19,95	19,71
Latvia	42,49	42,68	42,59	42,36	42,94	47,89	40,75	44,71	47,27	49,65	52,15	51,74	51,81	54,58	55,41	57,75	57,09	57,38
Lithuania	30,44	29,32	29,23	29,09	31,99	33,72	32,53	32,79	34,54	36,87	40,63	46,08	46,56	46,50	46,02	47,37	50,35	48,63
Luxembourg	1,82	3,61	3,63	4,35	4,57	4,63	4,70	4,74	4,93	5,33	7,07	6,86	7,06	7,45	8,36	8,69	12,61	12,92
Malta	1,04	1,03	1,36	1,51	1,70	2,01	7,28	12,03	13,40	15,40	15,03	14,64	16,85	19,31	22,83	23,60	23,03	31,36
Netherlands	2,18	2,38	2,70	2,91	3,02	3,37	3,10	3,69	3,77	4,00	4,93	5,28	5,19	5,75	6,16	7,22	8,05	7,72
Poland	10,21	10,16	10,17	10,46	10,85	11,61	11,81	13,24	13,50	14,27	14,24	14,80	14,92	14,78	21,47	22,01	22,14	21,03
Portugal	32,49	32,08	34,23	34,95	37,45	37,93	33,81	35,18	33,15	34,63	40,45	40,10	41,61	41,02	40,92	41,66	41,55	42,68
Romania	17,34	17,93	17,58	19,47	23,17	26,43	27,23	24,31	25,75	26,20	26,74	25,89	26,87	26,58	25,43	25,74	25,33	24,48
Slovakia	5,06	5,03	4,45	6,23	6,10	8,18	7,90	9,26	8,80	7,88	8,87	10,79	9,88	9,84	10,60	19,70	19,43	19,52
Slovenia	22,82	26,40	24,35	29,31	27,53	28,87	29,54	31,79	33,15	35,12	34,64	36,15	35,56	34,64	32,34	32,13	32,14	35,22
Spain	9,55	9,41	11,38	11,25	11,62	13,22	12,50	13,47	13,97	13,97	15,56	16,85	15,90	16,21	16,14	17,20	17,97	17,40
Sweden	45,93	49,02	52,50	54,47	55,78	59,20	57,07	58,52	60,64	61,71	62,57	63,24	63,41	63,62	63,30	64,39	66,38	68,64

Source: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

The smallest and largest values were determined based on the presented data, as shown in Table 14.

Table 14.
The largest and smallest share of energy from renewable energy sources in heating and cooling over the years 2004-2021

	The smallest value	**Year of lowest value**	**The greatest value**	**Year of greatest value**	**Difference**
Austria	20,17	2004	35,48	2021	15,32
Belgium	2,93	2004	9,24	2021	6,31
Bulgaria	13,86	2007	37,18	2020	23,32
Croatia	28,82	2008	38,62	2015	9,80
Cyprus	9,26	2004	41,34	2021	32,08
Czechia	9,92	2004	24,18	2021	14,27
Denmark	20,50	2004	51,07	2020	30,57

Cont. table 14.

Estonia	30,84	2006	61,32	2021	30,49
Finland	39,12	2005	57,62	2021	18,51
France	11,70	2006	24,21	2021	12,52
Germany	7,20	2004	15,44	2021	8,24
Greece	13,10	2006	31,94	2021	18,85
Hungary	6,45	2004	23,70	2013	17,25
Ireland	2,87	2004	6,62	2020	3,75
Italy	5,71	2004	20,08	2021	14,37
Latvia	40,75	2010	57,75	2021	17,00
Lithuania	29,09	2007	50,35	2020	21,26
Luxembourg	1,82	2004	12,92	2021	11,10
Malta	1,03	2005	31,36	2021	30,33
Netherlands	2,18	2004	8,05	2020	5,88
Poland	10,16	2005	22,14	2020	11,98
Portugal	32,08	2005	42,68	2021	10,61
Romania	17,34	2004	27,23	2021	9,89
Slovakia	4,45	2006	19,70	2019	15,25
Slovenia	22,82	2004	36,15	2015	13,33
Spain	9,41	2005	17,97	2020	8,56
Sweden	45,93	2004	68,64	2021	22,71

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

Among the European Union member states, Malta had the smallest share of energy from renewable sources in heating and cooling – 1,03% in 2005, while Sweden had the largest – 68,64% in 2021. In terms of the minor difference obtained between the maximum and minimum share of energy over the years 2004-2021, Ireland achieved – 3,75% (difference between 2004 and 2020), while Cyprus achieved the highest value of the difference – 32,08% (difference between 2004 and 2021).

Table 15.

Presentation of the share of energy from renewable sources in heating and cooling in 2019, 2020 and 2021 in descending order

2019		**2020**		**2021**	
Sweden	64,394	Sweden	66,381	Sweden	68,642
Latvia	57,749	Estonia	58,834	Estonia	61,323
Finland	56,884	Finland	57,622	Latvia	57,378
Estonia	52,193	Latvia	57,094	Finland	52,589
Lithuania	47,372	Denmark	51,073	Lithuania	48,627
Denmark	47,302	Lithuania	50,35	Portugal	42,681
Portugal	41,657	Portugal	41,546	Denmark	41,53
Croatia	36,791	Bulgaria	37,178	Cyprus	41,343
Bulgaria	35,423	Cyprus	37,117	Croatia	38,028
Cyprus	35,051	Croatia	36,928	Austria	35,481
Austria	33,929	Austria	34,995	Slovenia	35,215
Slovenia	32,132	Slovenia	32,141	Malta	31,356
Greece	30,048	Greece	31,941	Greece	31,146
Romania	25,739	Romania	25,327	Bulgaria	25,625
Malta	23,602	Czechia	23,535	Romania	24,483
Czechia	22,632	France	23,368	France	24,212
France	22,36	Malta	23,027	Czechia	24,183
Poland	22,005	Poland	22,143	Poland	21,031
Italy	19,699	Italy	19,949	Italy	19,713
Slovakia	19,696	Slovakia	19,427	Slovakia	19,521
Hungary	18,16	Spain	17,966	Hungary	17,929

Cont. table 15.

Spain	17,203	Hungary	17,72	Spain	17,398
Germany	14,504	Germany	14,481	Germany	15,438
Luxembourg	8,687	Luxembourg	12,614	Luxembourg	12,918
Belgium	8,319	Belgium	8,447	Belgium	9,241
Netherlands	7,217	Netherlands	8,053	Netherlands	7,72
Ireland	6,344	Ireland	6,264	Ireland	5,174

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

In the last three years of the analyzed period, Sweden was in first place in share of energy from renewable sources in heating and cooling (64,394% - 2019, 66,381% – 2020, 68,642% – 2021), followed by Latvia (57,749% in 2019 and 57,378% in 2021) and Finlandia (56,884% in 2019 and 57,622% in 2020). Estonia was in second place wn 2020 (58,834%) and in 2021 (61,323%). The countries with the lowest share in the last three years of the analyzed period are Belgium, Netherlands and Ireland. In these countries share of energy from renewable sources in heating and cooling was as follows: in 2019 – Belgium 8,319%, Netherlands 7,217%, Ireland 6,344%, in 2020 – Belgium 8,447%, Netherlands 8,053, Ireland 6,264%, in 2021 – Belgium 9,241%, Netherlands 7,72%, Ireland 5,174%. Analysis of the last year of reported data, the largest share in energy from renewable sources was recorded by Sweden (68,642%), followed by Estonia (61,32%) and Latvia (57,38). In contrast, the smallest share was recorded by Ireland (5,174%), then the Netherlands (7,72%) and Belgium (9,241%). The average percentage of European Union countries in energy from renewable sources in 2021 was 30.74%. The share of energy from renewable sources was above average in 13 countries, with the most minor difference from the average being Greece – 31,15%. Below, Figure 4 presents the results of the share of energy from renewable sources in heating and cooling of EU countries last three years from the period 2004-2021.

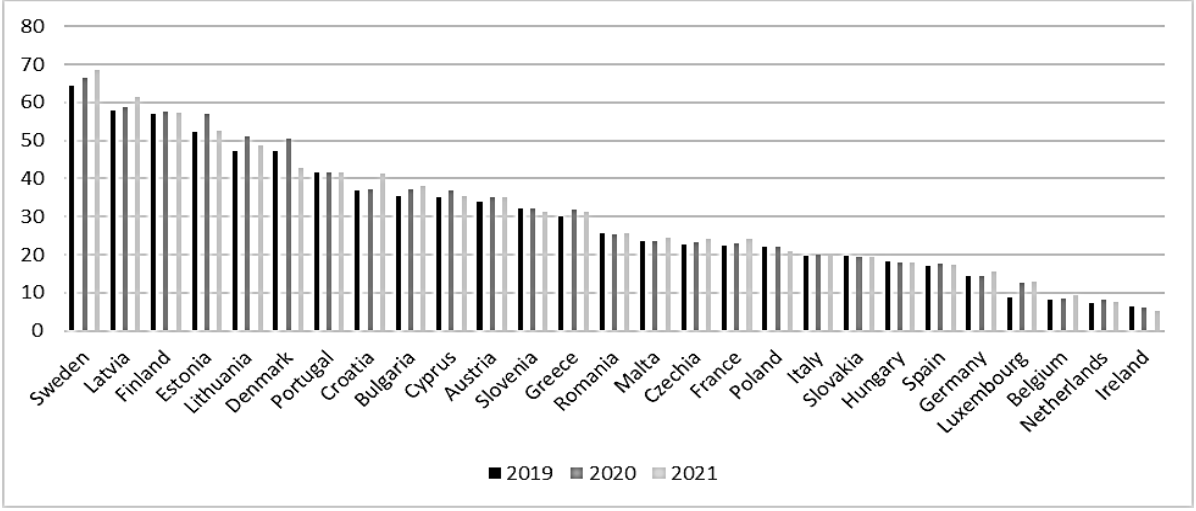

Figure 4. Presentation of the percentage share of energy from renewable sources in heating and cooling of EU countries in 2019, 2020 and 2021.

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

The table below shows the percentage change in the share of energy from renewable sources in heating and cooling in subsequent years compared to the year immediately preceding. Over the years 2004-2021, all countries recorded a decline. The most significant decrease was achieved by Bulgaria in 2021 (31,07%), and the most minor drop by Belgium was 0,57% in 2017. Analysis of the data on the maximum increase in percentage change, Malta achieved a rise of 262,11% in 2010 compared to 2009, while the smallest increase was achieved by Finland by 5,86% in 2006 compared to 2005.

Table 16.
Percentage change from year to year in the share of energy from renewable sources in heating and cooling in EU countries over the years 2004-2021

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	MIN	MAX
Austria	13,2	7,3	10,8	0,2	8,9	4,5	1,8	4,9	0,4	0,5	-0,4	0,7	0,6	1,5	-0,7	3,1	1,4	-0,7	13,2
Belgium	16,8	11,5	23,6	8,7	18,9	10,2	0,1	5,8	7,5	1,5	2,5	3,8	-0,6	1,1	0,3	1,5	9,4	-0,6	23,6
Bulgaria	1,4	3,7	-6,3	24,5	25,4	12,5	1,8	10,0	7,3	-2,4	1,4	3,8	-0,5	11,4	6,5	5,0	-31,1	-31,1	25,4
Croatia	2,0	-3,1	0,8	-1,6	8,6	5,1	2,9	8,1	2,1	-2,9	6,6	-2,5	-2,7	0,1	0,4	0,4	3,0	-3,1	8,6
Cyprus	7,6	4,7	25,2	10,8	19,7	8,7	6,2	8,9	3,6	-1,6	8,5	2,6	7,0	40,7	-5,7	5,9	11,4	-5,7	40,7
Czechia	9,2	3,7	10,1	4,4	10,4	-1,2	9,2	5,6	9,0	10,3	1,3	0,5	-0,8	4,6	9,6	4,0	2,8	-1,2	10,4
Denmark	10,3	4,6	12,9	4,7	5,1	3,3	5,0	4,1	4,5	9,6	4,0	3,9	7,3	2,1	5,2	8,0	-18,7	-18,7	12,9
Estonia	-3,0	-4,7	7,1	9,0	16,8	2,7	3,2	-3,0	-0,2	4,2	11,3	3,5	0,9	2,8	-2,8	12,7	4,2	-4,7	16,8
Finland	-1,0	5,9	0,1	4,0	-0,4	2,5	4,0	5,5	5,3	2,3	1,3	2,1	1,7	0,6	3,6	1,3	-8,7	-8,7	5,9
France	-1,3	-5,4	9,3	3,9	13,2	7,5	-5,6	8,7	6,1	2,5	4,6	6,6	2,4	3,0	5,4	4,5	3,6	-5,6	13,2
Germany	7,1	9,1	21,9	0,8	8,0	8,1	4,6	6,5	-0,1	0,0	0,2	-3,0	2,6	6,4	2,0	-0,2	6,6	-3,0	21,9
Greece	-0,6	-2,2	12,1	0,3	17,2	8,2	7,8	19,9	13,7	1,6	-4,7	-4,3	11,1	6,6	-0,2	6,3	-2,5	-4,7	19,9
Hungary	54,0	14,5	19,0	-11,6	42,2	6,2	10,9	16,3	1,7	-10,2	0,2	-1,4	-5,4	-8,5	-0,2	-2,4	1,2	-11,6	54,0
Ireland	19,8	4,4	5,4	-7,2	19,0	2,4	8,8	4,1	6,9	20,8	-1,2	1,0	6,1	-3,7	-0,6	-1,3	-17,4	-17,4	20,8
Italy	43,9	22,8	32,1	14,8	7,3	-4,8	-11,7	22,9	6,5	4,5	1,8	-1,9	6,3	-4,0	2,2	1,3	-1,2	-11,7	43,9
Latvia	0,4	-0,2	-0,5	1,4	11,5	-14,9	9,7	5,7	5,0	5,0	-0,8	0,1	5,3	1,5	4,2	-1,1	0,5	-14,9	11,5
Lithuania	-3,7	-0,3	-0,5	10,0	5,4	-3,5	0,8	5,3	6,8	10,2	13,4	1,0	-0,1	-1,0	2,9	6,3	-3,4	-3,7	13,4
Luxembourg	98,2	0,5	19,9	5,0	1,3	1,6	0,7	4,1	8,1	32,6	-3,0	2,9	5,6	12,2	3,9	45,2	2,4	-3,0	98,2
Malta	-0,7	32,6	10,6	12,5	18,6	262,1	65,1	11,4	14,9	-2,4	-2,6	15,1	14,6	18,2	3,4	-2,4	36,2	-2,6	262,1
Netherlands	9,2	13,5	7,9	3,8	11,4	-8,0	19,0	2,2	6,2	23,1	7,2	-1,6	10,7	7,1	17,2	11,6	-4,1	-8,0	23,1
Poland	-0,5	0,1	2,9	3,7	7,0	1,8	12,1	1,9	5,7	-0,2	3,9	0,8	-0,9	45,3	2,5	0,6	-5,0	-5,0	45,3
Portugal	-1,3	6,7	2,1	7,2	1,3	-10,9	4,1	-5,8	4,4	16,8	-0,9	3,8	-1,4	-0,2	1,8	-0,3	2,7	-10,9	16,8
Romania	3,4	-1,9	10,7	19,0	14,1	3,0	-10,7	5,9	1,7	2,1	-3,2	3,8	-1,1	-4,3	1,2	-1,6	-3,3	-10,7	19,0
Slovakia	-0,6	-11,5	40,0	-2,2	34,1	-3,4	17,2	-4,9	-10,5	12,6	21,7	-8,5	-0,4	7,7	85,8	-1,4	0,5	-11,5	85,8
Slovenia	15,7	-7,8	20,4	-6,1	4,9	2,3	7,6	4,3	5,9	-1,4	4,4	-1,6	-2,6	-6,6	-0,6	0,0	9,6	-7,8	20,4
Spain	-1,5	20,9	-1,1	3,3	13,8	-5,4	7,8	3,7	0,0	11,4	8,3	-5,6	1,9	-0,4	6,6	4,4	-3,2	-5,6	20,9
Sweden	6,7	7,1	3,8	2,4	6,1	-3,6	2,5	3,6	1,8	1,4	1,1	0,3	0,3	-0,5	1,7	3,1	3,4	-3,6	7,1

Source: own study based on
https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

6. Summary

The EU share in the gross final energy consumption from renewable sources in 2021 amounted to 21,775%, compared to 2020, and the energy share of 22,038%, gives a decrease of 0,263%. This change may have been influenced by the lifting of restrictions related to the Covid-19 pandemic, as well as a difference in the legal basis and accounting methodology: data for 2020 were calculated based on the RED I directive, while data for 2021 were based on the RED II directive. This article focuses on analyzing available energy share data from 2004-2021. Still, it seems reasonable to explore in more detail the data from these two periods (2020 and 2021) and the impact of the differences between the RED I and RED II directives.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

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THE ROLE OF PROCESS MANAGEMENT IN THE IMPLEMENTATION OF AN ERP CLASS IT SYSTEM

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Purpose: The purpose of the study was to identify the importance of process management in the success of ERP information system implementation.
Design/methodology/approach: The main sources of analyzed information are: the results of participant observation of the author of the article, a case study based on a face-to-face interview with the manufacturer and, at the same time, an expert making implementations of an ERP class information system. A literature review was also performed.
Findings: Based on a survey conducted at a company implementing an ERP Work Manager information system, it can be concluded that there is a need for organizational knowledge of business processes, which has a strong impact on individual calculation of the benefits and effort of implementing integrated information systems.
Research limitations/implications: In the future, it is suggested to conduct similar surveys on a wider scale. Surveys should be conducted among representatives of organizations in which such solutions are not yet in place, i.e. among users. There are lasso intentions to conduct research in the analyzed area in organizations belonging to the micro, small and medium-sized enterprise sector. In the case study, the expert in the case study referred only to medium-sized companies. Surveys in the environment of companies belonging to the SME sector are planned for the second quarter of 2024.
Practical implications: Polish business owners should continue to look for ways to effectively use the assumptions of process management in the implementation of ERP systems. Learning in detail about the organization's business processes, will have an impact on eliminating or reducing the barriers associated with such action.
Originality/value: The analysis performed in the article is a response to reduce the risk of failure of the implementation of an information system of the ERP class of thinking in Polish enterprises, especially in the small and medium-sized sector. The value of this article is also to make entrepreneurs aware of the virtues of process management, which supports the adaptation of organizations to the ongoing digital transformation.

Keywords: process management, Enterprise Resource Planning (ERP), business processes.

Category of the paper: Research paper.

1. Introduction

Today's organizations face the need to adapt their structures and processes to the demands of a changing market. Process management in an organization has been identified for many years as a particularly important management concept. Nowadays, both in the literature and in business practice, there is an increasing emphasis on the importance of knowledge and the use of knowledge to optimize the company's used resources. Therefore, process management is a fundamental mechanism to prepare an organization for the successful implementation of an ERP information system. For today's enterprises, implementing an integrated information system is both a big challenge and an opportunity to reduce bad business decisions in a changing market environment. The success of the implementation is undoubtedly determined by the awareness of the processes taking place in the organization, but also by the maturity of the companies' employees in process thinking.

2. Method

The materials collected and presented in the article provide a synthetic description of the various stages of the importance of process management in the implementation of ERP information systems. The research activities, which were Cartier out in 2022, resulted from the available ERP system implementation reports of the company producing the WORK MANAGER system (participant observation), as well as a personal interview conducted with the developer of the WORK MANAGER ERP system and at the same time an expert in the implementation of information systems supporting the management process (case study). For the case study using a personal interview, the expert identified 15 medium-sized enterprises among those served in his own business. The selection of the group of 15 enterprises for the study was done using the purposive method, and the selected research subjects were enterprises where management representatives had adequate knowledge of process management initiatives.

3. The concept of process management in a modern enterprise

Process management creates a rationale for building a system based on the ongoing processes of the organization, which is a combination of strategy and goals in line with customer expectations (Grajewski, 2012). Strategies are established through a process of research, design, and ultimately, execution to improve an organization's business processes (Zaini, Saad, 2019).

In this view, the concept is regarded as classic process management. It assumes identification, modeling, automation, control, measurement and optimization of business processes taking into account the implemented strategy, thus increasing the efficiency of the entire organization (Hermkens, Buuren, Kort, 2022).

Contemporary studies point to the need for companies to evolve towards comprehensive business process management. This means the need to integrate and coordinate the process in modern organizations towards integrated process management. Thus, classical process management becomes one of the main directions of solutions not only of theoretical concepts, but also of practical solutions of integrated process management (Łukaszczuk, 2016). Under these conditions, the evolution from classical to integrated process management becomes one of the main directions of practical solutions and theoretical concepts. It is also the basis for the successful implementation of ERP information systems.

Integrated process management, based on the consistency of the process-project-knowledge triad and the synergy occurring between them, is realized through a structured combination, alignment of concepts and methods based on the process approach (Nowosielski, 2018). It encompasses the dynamic and comprehensive impact on the organization's processes, in line with the strategic goals of building value for customers and other stakeholders. Integrated process management builds on classic process management while ensuring higher efficiency and adaptation to changing environmental conditions (Badakhshan, Conboy, Grisold, vom Brocke, 2019).

Process management is about optimising the structure of organisational elements because of their impact on the value creation of the final outcome of separated processes (Ryzhakova, Ryzhakov, Petrukha, Ishchenko, Honcharenko, 2019). It is worth mentioning here that the main advantage of the process view is to break down organisational rigidity, in which functions or units are often isolated from each other and perform mutually exclusive functions (Sliż, 2022). This will have the effect of increasing the importance of attitudes such as genuine creativity and innovation, courage, openness and empathy in dealing with customers, direct communication (Szmidt, Sidor-Rządkowska, 2021).

When building a process management system, the organisation should be guided by the following guidelines (Harmon, 2019):

- identify process maps and optimise the company's activities to meet its strategic objectives based on individual and group employee processes,
- communicate strategic objectives and gain acceptance of planned activities,
- define and confirm the knowledge, skills and competences of the members of the organisation necessary to achieve its objectives,
- carry out a valuation of the actions undertaken so that their results can be monitored and, if necessary, corrected at the implementation stage in terms of compliance with legal and ethical standards.

Building a process management system in organisations is a quantitative and qualitative challenge. This process requires the construction of a coherent process management system based on field-proven systems, models and tools, supplemented, extended or modified as a result of expert support (Nian, Liu, Huang, 2020). It is necessary to segment the processes into those that are associated with significant implementation costs and those that do not have a significant impact on the resources consumed and the associated costs. Identifying processes at this stage allows the most effective solutions to be implemented in the future to evaluate and optimise them for efficiency. In this situation, it is possible to mention optimisation in relation to the effectiveness of the implementation of the chosen ERP IT system.

The evolution of process management is a response to the increasing turbulence of the environment and the changes taking place within the company, the increasing complexity of internal and external processes, as well as the individualisation of customer needs and expectations (Lizano-Mora, Palos-Sanchez, Aguayo-Camacho, 2021).

The demands of today's macro and micro-environment of organisations do not allow process and knowledge issues to be treated separately. Companies that choose to do so are condemning themselves to market failure as a result of losing the possible synergies that could be created if a holistic approach integrating these management concepts were taken. The use of knowledge makes it possible to achieve significant benefits in terms of structuring the way a company operates, the processes it carries out, reducing costs, increasing flexibility and transparency, identifying processes, customer orientation and improving its competitive position (Kosieradzka, Rostek, 2021).

Building such a market position requires an organisation to be constantly engaged in knowledge management processes. It is not enough just to have knowledge, but it must be „in motion". Knowledge becomes meaningful when it is used (Wąchol, 2020). The mere fact of having it and storing it does not create value; on the contrary, using old and outdated knowledge results in „negative value" for the organisation (Chopra, Saini, Kumar, Varma, Mangla, Lim, 2021). For this reason, knowledge management cannot be a one-off activity; it must become an ongoing process within the organisation. The knowledge management process consists of three sub-processes (Śmiałek, 2016):

- knowledge distribution, whereby members of the organisation are guaranteed access to the knowledge contained in the organisation's resources,
- organisational learning, which means acquiring knowledge and developing existing resources,
- knowledge production, whereby information is transformed into useful „here and now" knowledge, from the organisation's perspective.

Knowledge management is a process that should have been in place for as long as the organisation has been operating (Corrêa, Ziviani, Carvalho, Faria, Parreiras, 2022). In their daily work, managers should keep in mind a regularity that reminds them of the cyclical nature of the different processes carried out in the knowledge management structure (Nwankpa,

Roumani, Datta, 2022). Combining knowledge management with process thinking has the effect of creating awareness of constantly changing processes. As a consequence of such views, there is full conviction for continuous improvement of ERP systems which ultimately translates into the quality of reported company data.

Knowledge management processes in the organisation interact and intertwine (Zwierzchowski, 2022). While it is possible to detail the stages in the knowledge management cycle and their consequences, each of these elements can (and should) influence the shape of other stages in the cycle (Di Vaio, Palladino, Pezzi, Kalisz, 2021).

Process models must be integrated with the implemented workflow models and the process data generated during process execution. In addition, process models must be designed to use resources more efficiently. One way to accelerate the response to the organisation's changing environment is to use best practices related to process knowledge, especially the knowledge of process participants (Avila, dos Santos, Mendling, Thom, 2020).

A key strategic challenge for organisations is the need to continually adapt processes to the increasing speed of business in order to keep up with ever-changing technology. This means that organisations need an acceleration of the process life cycle, a greater frequency of analysis and change of the indicated processes, perhaps even continuously (Satyal, Weber, Paik, Di Ciccio, Mendling, 2019).

4. Process approach as a stage in the implementation of an ERP information system

The considerations presented in the theoretical part are reflected in the implemented research part. In the case of process management based on knowledge resources, we are dealing with the acquisition of knowledge, its consolidation in the processes taking place and the dissemination of knowledge within the organisation. All these activities, undertaken by organisations, are aimed at achieving tangible benefits that respond to the challenges posed by the contemporary market. One of the challenges is to build awareness of the need for process management resulting from the gap that exists in many companies between the organisation's processes and the ERP information system implemented (Rotchanakitumnuai, Speece, Swierczek, 2019).

Organisations identified by the expert interviewed declared that incorporating process thinking into their ERP implementation activities brings significant benefits (Figure 1). They included among these benefits: the ability to have an up to date assessment of the situation in the organisation (33.33%), support in finding the business needs served by ERP (53.33%), and an indication of the ERP vendor's capabilities when selecting a supplier (13.33%). The main benefits identified in this way have a strong impact on the customisation of the

integrated IT system to the specifics of the enterprise. Adapting the system to the specifics of the enterprise significantly increases implementation success and efficiency.

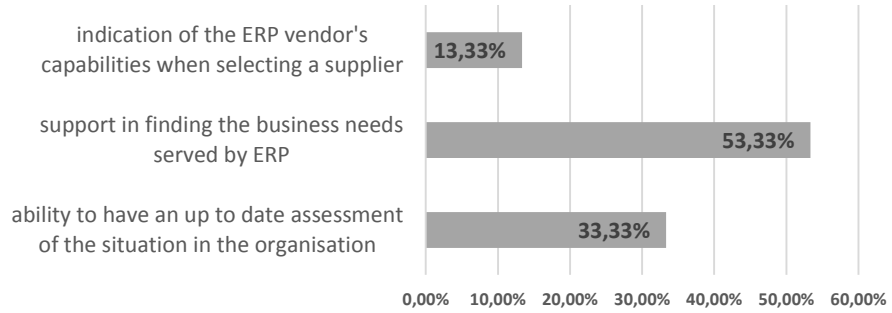

Figure 1. Main benefits of using process management in the ERP implementation process.
Source: Personal analysis of the data gathered in the study.

At the beginning of the article, a statement was made: the need to know the business processes has a strong influence on the individual calculation of the benefits and effort of implementing integrated IT systems. Therefore, conscious modelling of business processes plays an important role, especially in the first stages of an ERP class information system implementation (Rajaratnam, Sunmola, 2020). This state of affairs, provides answers to a set of questions:

- How to close the gap between business requirements and business process design and ERP IT system implementation?
- How do you ensure that your ERP information system is compatible with your company's end-to-end business processes?
- How do you make sure that the plan documentation reflects the actual implementation?
- How to improve communication between IT experts and end users during and after implementation?

In the case of organisational management, which also includes the implementation of IT systems, conscious process management is a necessary element. This is a significant element of operation, as only a defined, described process can be further analysed, simulated and improved, optimised. Once such a detailed analysis of all the processes occurring in an enterprise has been performed, it is safe to proceed with the creation of an ERP implementation plan. The 15 companies surveyed by the expert in the interview were asked whether the identification of processes in their business has an impact on the success of the implementation of an ERP IT system. Consequently, whether this is an action that should be taken. The answers in this case were almost unequivocal (Figure 2). Only 13.33% of businesses found it hard to comment.

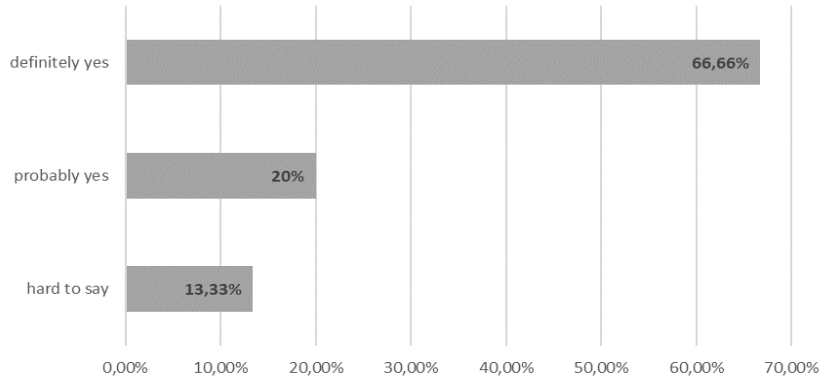

Figure 2. Does the identification of processes in a company's operations affect the success of an ERP implementation?

Source: Personal analysis of the data gathered in the study.

Simulation activities are undertaken on the basis of models of processes occurring in the organisation and the results of their optimisation. This is due to the fact that before implementing a process, it is necessary to check how the process will run and what effects it will have on the organisation, the functioning of the ERP system or its environment (with system functionalities extending beyond the organisation). In this case, opinions are not as clear cut as they were in the previous question (Figure 3). A significant proportion of organisations fail to determine whether the simulation of activities carried out has a beneficial effect on the organisation. This is explained by the fact that the direct benefits of running a simulation are not actually quantifiable. The potential of simulation, on the other hand, is seen by managers indicating a „probably yes" answer, as these activities make it possible to avoid future, sometimes costly errors in processes and, consequently, in the implementation of an ERP system. It enables better process design and verification in a secure test environment.

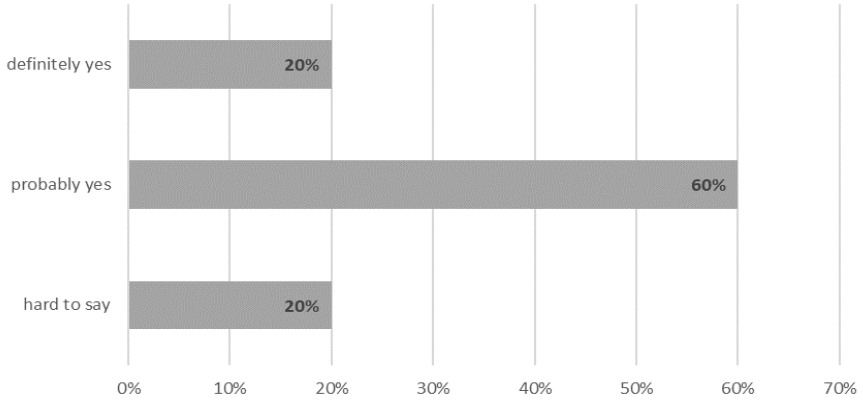

Figure 3. Benefits of implementing process management in an ERP information system implementation - process simulation.

Source: Personal analysis of the data gathered in the study.

Analysing the results of the research conducted, it can be concluded that undoubtedly companies see an opportunity to improve their effectiveness of the implementation and use of an ERP-class information system, by performing the identification and analysis of business

processes in advance. This is clearly visible in the structure of the responses to the research questions. The organisations invited to participate in the study belong to the group of those that are aware of the processes taking place in them and at the same time realise their importance for their current and future functioning. These are organisations that have implemented process management in their operations, and the vast majority of them consciously use this way of thinking in the use of the implemented ERP class IT system. This is an unmistakable sign of the changes taking place in the market, and given the significant need to increase the effectiveness of ERP class information systems implementations, we can speak of the necessity of implementing process management before introducing integrated information systems into the organisation. Companies that have chosen to use process management prior to implementing an ERP information system must be ready to embrace change. The very fact of using knowledge resources means that organisations must be ready to continuously identify, model, optimise, simulate, monitor, report and improve their processes.

5. Conclusion

The article cites 2022's own research, which was a case study and literature research. The case study was based on an analysis of 15 Polish medium-sized process managed companies. They clearly indicate that Polish enterprises are also becoming aware of the need not only to take care of their current processes, but also to adapt them to changes both dictated by the environment and resulting from the organisation's internal conditions. These changes increasingly include the implementation of ERP class IT systems. For the implementation of the indicated tasks, it is absolutely necessary to reach for process management in order to reduce the level of risk of implementing changes.

The research is also a source of knowledge for managers implementing ERP implementation projects. The considerations presented in the article have both cognitive and applied value.

The changes taking place in a dynamic environment, the lack of clearly defined processes, the operating management standards adopted in a modern company and the growing competition have forced the decision to look for solutions that will increase the effectiveness of the implementation of an ERP class information system (Grochowski, 2022). One important mechanism, unnoticed .by entrepreneurs, is the inculcation of process thinking and, at a later stage, process management. Therefore, entrepreneurs mainly highlighted such benefits: the possibility of an up-to-date assessment of the situation in the organisation, support in finding the business needs supported by the ERP, learning about the capabilities of the ERP vendor when selecting a supplier.

Despite the long standing existence of Enterprise Resource Planning class systems on the Polish and international market, 25% of implementation projects fail and 50% fail to meet customer expectations. One of the fundamental factors increasing the level of effectiveness of an ERP implementation is the need for organisational knowledge of business processes, which has a strong influence on the individual calculation of the benefits and effort of implementing integrated IT systems.

The maturity of an organisation, understood as an appropriate level of development of the processes, structures, people and systems that make up the organisation, is one of the factors involved in the process of implementing an ERP class information system.

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EXPLORING THE ROLE OF SOCIAL MEDIA IN ACADEMIC TEACHING

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Purpose: The main aim of this article is to determine the usage of social media in university teachers' educational activities, along with identifying the primary obstacles.
Design/methodology/approach: The study was carried out using the CAWI (Computer Assisted Web Interview) method. The data was gathered in June 2023 by surveying a sample of academic instructors at the Faculty of Organisation and Management at Silesian University of Technology.
Findings: The findings indicate that social media is scarcely used by the academic staff for teaching purposes, but rather for communication with students. Remarkable differences were observed between generations. Younger academic educators appear to demonstrate a greater willingness to use social media tools in their work, both in communication with students and during lectures.
Research limitations/implications: A limitation of the study is the size of the research sample. This may indicate the direction of future research concentrating on using social media in different activity areas by academics.
Practical implications: Students, who are one of the main users of social media, use these online platforms to enhance their learning in a variety of subjects. Teachers should also use these tools to improve their teaching process by making it more attractive.
Originality/value: This paper addresses knowledge gaps regarding the use of social media in working with students. Its findings can aid academics in developing strategies for using social media in the classroom.

Keywords: social media, academic teachers, teaching.

Category of the paper: research paper**.**

1. Introduction

Social media (SM) is becoming more and more integrated into many different aspects of the academic world, including teaching, research and professional networking (Chawinga, 2017; Purwanto et al., 2023; Rowan-Kenyon et al., 2016).

Using social media by academic teachers can have a positive impact on the didactic process, in particular by providing a new platform to engage and motivate young students (Cooke, 2017). It is very important, especially for the growth of generations Y and Z, who have spent their entire lives in the digital environment (Briggs, 2020; Deloitte Insights, 2021; Karasek, Hysa, 2020; Moczydłowska, 2020; Wolfinger, McCrindle, 2014). The use of social media in the educational process is inevitable, although it requires the acquisition of new skills (Kumar, Nanda, 2019; Purwanto et al., 2023). Social media allows teachers to break the routine, makes teaching more attractive and also removes the feeling of burnout, which occurs especially after 20-30 years of work (Anderson, 2019; Keenan et al., 2018; Manca, Ranieri, 2016). Although increasingly adopted by Polish academics, social media remains less prevalent than in other countries (Mazurek, 2018; Sobaih et al., 2016). This is due to many barriers that appear during the use of social media in the wider academic sphere (Manca, Ranieri, 2016). The most common barriers are privacy concerns, plagiarism, and a negative impact on students' productivity (Wąsek, 2019). The development of technology makes it possible to precisely track internet user activity, leading to legitimate privacy concerns. Additionally, teachers may refrain from implementing social media as an educational tool to prevent students from gaining access to their personal lives. Another noteworthy issue is students' lack of independence in using social media, which leads to plagiarism. In particular, GPT artificial intelligence has been over-used by students recently (Steele, 2023; Yu, 2023). However, there is a lack of deep research on this subject in Poland.

Therefore, the primary aim of this article is to determine the level of utilisation of social media in university teachers' educational activities, along with identifying the primary obstacles. Following an introduction, the article is divided into three chapters. The first chapter presents the literature review on the use of social media in the didactic process at universities. The second chapter is a presentation of the research methodology. The third chapter contains an analysis of the results of a study and discussion. The material for the analysis was collected through an online survey of academic teachers. Finally, the article concludes.

2. Literature review

Today, information technology, the internet and social media are inescapable. Therefore, it is reasonable to assume that they can impact all aspects of our lives, both in private and professional spheres. Social media's popularity has made it a widely studied subject in various disciplines (Anderson, 2019; Boahene et al., 2019), including its usage in higher education. With the emergence of internet technology, social media has become an essential component of every student's life. Social networking makes it easier and more convenient to share information, communicate and stay connected (Doğan et al., 2018). Teachers and students can use social platforms to stay connected and use them for educational purposes. As Romero

(2015, pp. 1-15) points out, the use of social media in education can translate into higher quality education; improving communication between lecturers and students and between students themselves, shaping and developing their 'digital competencies' (Romero, 2015). Mazurek (2018) points out that the use of social media in teaching encourages students to actively participate in class, and supports critical thinking and collaboration (Mazurek, 2018).

Au, Lam and Chan (2015) found that the inclusion of social media in the teaching process makes the role of lecturers change. They then become not 'teachers' but rather 'coordinators' or 'mentors' who set the tone and encourage students to discuss and work. Therefore, the big challenge of using social media as an educational tool is that it requires a new pedagogical approach. Age is important in terms of the decision to use social media for teaching Several studies indicate that social media are increasingly utilised as educational resources by younger scholars (Anderson, 2019; Au et al., 2015; Horzum, 2016; Kumar, Nanda, 2019; Mazurek, 2018). Keenan et al. (2018) reveal three values for social media: engagement: reaching students inside and outside of the classroom, utility: familiarity and immediacy, sharing: collaboration and dissemination (Keenan et al., 2018).

However, some factors discourage academic teachers from using social media. One of the most commonly cited is privacy concerns (Au et al., 2015; Mazurek, 2018). Academics are afraid of using social media because of loss of privacy, cyberbullying, and stalking (Korzynski, Protsiuk, 2022; Tandon et al., 2021). Moreover, lecturers may not wish students to have insight into their personal lives (Sobaih et al., 2016). Another issue identified is the fear of losing influence over the teaching process (Au et al., 2015). Although universities aim to improve educational outcomes by promoting teamwork among students and members of the research and teaching staff, there is still concern about losing control over the quality of teaching and learning processes. Moreover, social media can also have a negative influence on students' productivity (Chawinga, 2017; Manca, Ranieri, 2016; Rowan-Kenyon et al., 2016; Wushe, Shenje, Jacob, 2019). It can be potentially time-wasting, distract and overwhelm other information that students receive (Boahene et al., 2019; Chakraborty et al., 2013). Plagiarism is also another concern including misuse of social media in a didactic process. In communication with students, teachers also complained about students' expectation of instant, quick answers (on e-mails, blogs, tweets, posts, etc) (Cooke, 2017; Manca, Ranieri, 2016).

Despite the vast number of studies published on social media adoption for didactic purposes in higher education, there is a lack of research regarding teachers' perspectives on how to implement social media and the impact it has on learning outcomes within this adoption. Hence, the following research questions have been developed:

1. How do academic teachers in Poland use social media in the didactic process?
2. What are the main concerns of teachers regarding the use of social media in working with students?
3. What are the main perspectives related to the use of social media by academic teachers?

3. Methods

Data were collected in June 2023 through a survey conducted on a sample of academic teachers of the Faculty of Organization and Management at Silesian University of Technology using the CAWI (Computer Assisted Web Interview) method. This was a preliminary study to verify the research assumptions and evaluation of the measurement tool. In this article, only research related to the didactic work of academic teachers is presented. The study used a purposive sample as it aimed to interview all teachers working at the Silesian University of Technology in the field of Management Science and Quality (n = 118).

The questionnaire consisted of three parts. The first part concerned the use of social media by teachers in didactic and research work, the second part contained questions about concerns and opportunities related to the use of social media. The last part included questions about teachers' work performance. The questionnaire included also questions about sociodemographic data.

The survey was dominated by closed questions with a 5-point Likert scale, where 1 represented *strongly disagree* and 5, *strongly agree*. However, there were several open questions where respondents could explain their previous choices or enter comments. After an initial selection of the collected questionnaires, sixty-nine were qualified for further analysis, which is 58% of all teachers working at the Faculty of Organization and Management at The Silesian University of Technology and in the field of Management Science and Quality.

The structure of the survey sample is shown in Table 1.

Table 1.
Structure of the survey sample

Item		%
Sex	male	55.1
	female	44.9
Age	up to 28	16.2
	29-42	29.3
	43-59	49.2
	60-67	5.3
	above 67	0
Position	research and teaching	69.6
	only research	11.6
	only teaching	18.8

N = 69.

Source: own study.

Both women (44,9%) and men (55.1%) took part in the study. Almost half of the respondents (49.2%) were between 43 and 59 years old. They represent the X generation. One-third of respondents (29.3%) were between 29 and 42 years old. It is the Millennium generation. People from the Z generation, under 28 years of age, constituted 16% of the respondents. The rest of the respondents were more than 60 years old. They represent the oldest

generation, Baby Boomers. Most people participating in the study worked in research and teaching positions (69.6%). Respondents who held only research positions constituted only 11.6% and only teaching positions 18.8%.

4. Results and Discussion

The first question was about using social media (SM) for professional work (both didactic and research work[1]) by academics. Every fifth respondent stated that they did not use social media at all (21.7%). 7.2% of academics have been using SM for less than one year, 18.8% from two to three years, 14.5% from four to five years, 20.3% from six to ten years and 17.4% over ten years (Figure 1). However, the answers were significantly dependent on age. Most of the academics who didn't use SM at all for professional work were over 43 years old. All younger respondents (from generations Y and Z) used SM for their work for more than six to ten years. These responses support other established research (Manca, Ranieri, 2016), but in opposite to the research (Keenan et al., 2018).

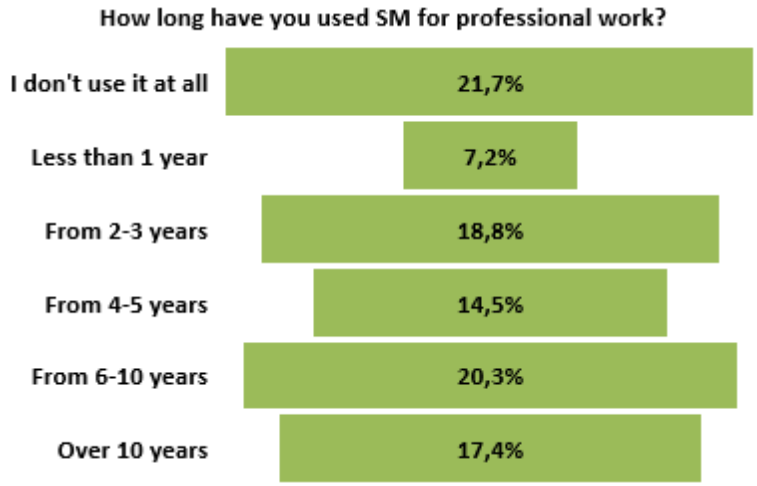

Figure 1. Academic teachers' use of social media in their professional work.
Source: Own work.

It is worth noting that almost one-fifth of teachers started using social media at work for 2-3 years, which was certainly contributed to by the Covid-19 pandemic, which began in the world 3 years ago (Charina et al., 2022; Podgórska, Zdonek, 2022; Zdonek, Król, 2021).

The results confirm many other studies that education systems and educators have been forced to adopt "emergency education," shifting from traditional face-to-face learning pedagogies to remote virtual platforms. This forced distance teaching and learning contributed to the increase in teachers' digital competencies (Godber, Atkins, 2021; Selvaraj et al., 2021).

[1] For editorial reasons, not all aspects of the research are presented in this article.

Analysis of answers, regarding different SM platforms/portals in didactic work, showed that academic teachers use typical SM platforms. As shown in Figure 2 the most popular SM platforms/portals in a teaching process were video platforms e.g. Zoom, Teams, Skype (66.7%), data clouds e.g. OneDrive, Google Drive, Dropbox (51.9%), YouTube (38.9%). This is in line with other research (Boahene et al., 2019; Godber, Atkins, 2021; Romero, 2015). This is not surprising because video platforms were essential in teaching during the COVID-19 pandemic. Clouds improve the process of storing and transmitting information. Many YouTube videos are academic and professional, and if used properly, can enhance classroom discussions and engage students through images and sounds.

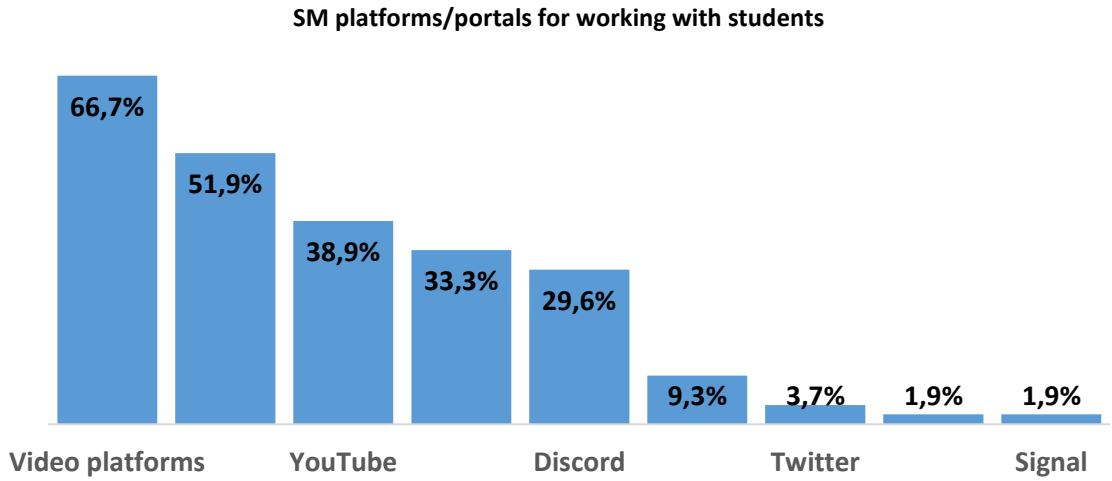

Figure 2. Used platforms/portals for working with students.

Source: Own work.

Academic teachers used Messenger or WhatsApp (33.3%) only in communication with students. However, significant differences were observed in the use of social media by the various generations. Younger academic teachers are more willing to use social media tools in their work both in communication with students and during lectures. Compared to other countries (Boahene et al., 2019; Chawinga, 2017) Polish academics rarely use Instagram (9.3%) Twitter[2] (3.7%) and Facebook (1.9%) in their teaching process.

The respondents who admitted they didn't use social media at all were also asked why. Preference for other forms of cooperation and communication (66.7%) was the main reason for not using social media by respondents. Interaction between a student and a teacher is still based on face-to-face contact during designated consultations at a specific time and place. Older generations of teachers in particular prefer this form of contact or via email.

At present, every academic teacher is obliged to have an email address. After the lockdown, because of the Covid pandemic they also much more often use remote education platforms to contact students, send the necessary materials for classes and solve problems that arise regularly.

[2] 23 July 2023 Twitter's name and logo were changed to X platform.

Privacy concerns were the second most common reason given by respondents for not using social media (46.7%). These results confirmed previous findings ((Mazurek, 2018) where 51% of respondents were concerned about privacy. Surprisingly, 40% of teachers stated that SM was not necessary for their work, which was contrary to Mazurek's (2018) study where 17% stated this. Other reasons given by respondents for not using social media for teaching purposes include: *I'm not interested in posting on SM* (33.3%), *I think the service takes too much time* 6.7%.

Respondents were also asked about their attitudes to using social media in a didactic process and how social media and new technologies (e.g. IA) have changed and will change their work with students. There were several statements to agree or disagree with (Figure 3).

According to the results, thirty percent of respondents (33.3%) (answers *I strongly agree / I rather agree* -57.4%) admitted that *SM has significantly changed the way they teach.* 37% percent of respondents answered *that SM has significantly changed the way they communicate with students.* It is worth paying attention to the neutral answers of the respondents because almost thirty percent of the academic teachers said so. This may mean they are not sure or don't want to admit it. Additionally, almost forty respondents (38.9%) claimed that *the use of SM for professional purposes would not have developed so much if there had been no COVID-19 pandemic.* This shows the positive side of the pandemic: teachers of all ages have had to make an effort to improve their digital skills.

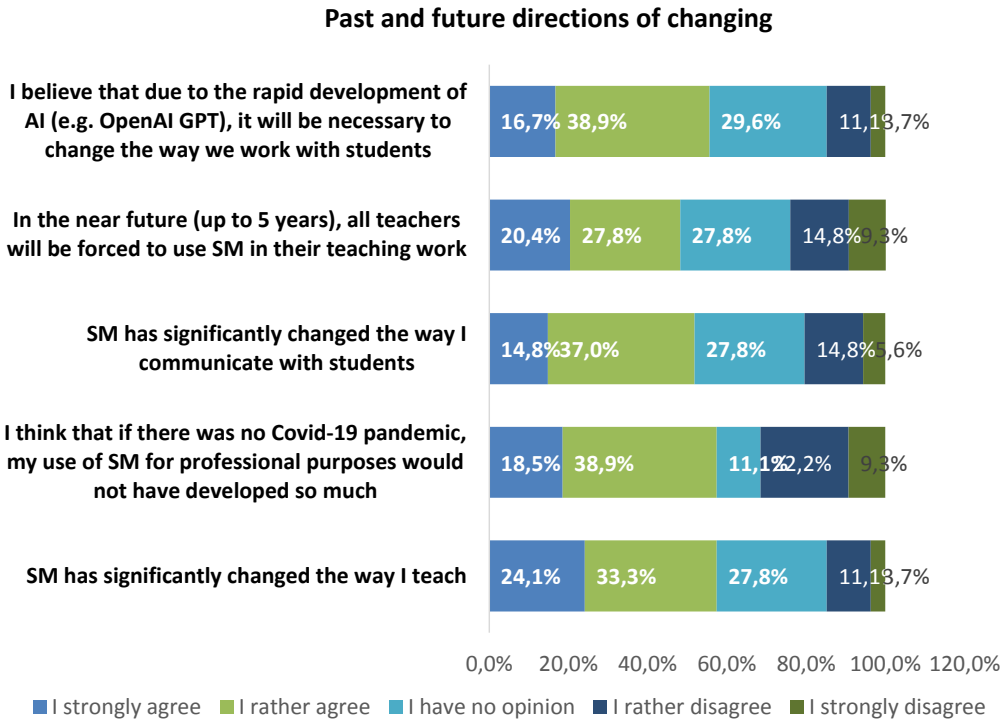

Figure 3. Past and future directions of changing in the didactic process.

Source: Own work.

Looking for the future directions of social media in the context of the teaching process, academics had diverse opinions. Almost forty percent of respondents (38.9%) (answers I strongly agree / I rather agree -55.6%) *believe that due to the rapid development of AI (e.g. Open AI), it will be necessary to change the way they work with students* but also 29.6% of respondents indicated neutral option and 19.8% disagree with this statement (they indicated options *I rather disagree/ I rather disagree*. Similarly, 27.8% of academic teachers admitted that *in the near future (up to 5 years), all teachers will be forced to use SM in their teaching work, and* the same percent of respondents indicated a neutral option (27.8%) This may indicate that those surveyed feel uncertain about the direction of social media in teaching.

5. Summary

Social media has dramatically changed the educational process in recent years. Especially since the spread of the COVID-19 pandemic, the universities have transformed teaching and learning and the lecturers have been conducting online classes.

Academic teachers in Poland are increasingly integrating social media into their teaching and professional activities, recognizing its potential to engage and motivate students, particularly those from younger generations like Gen Y and Gen Z. However, there are several concerns related to the use of social media in academia. Privacy concerns, plagiarism, and negative impacts on student productivity are common barriers. Teachers are concerned that students' reliance on social media may result in immediate responses.

Research on this topic in Poland is limited, prompting a study to assess the utilization of social media among university teachers and identify primary obstacles. The survey revealed that while many teachers have adopted social media for professional use, there are age-related differences in their adoption. Younger teachers are more inclined to use social media tools in their teaching. Video platforms, data clouds, and YouTube are the most popular platforms used for teaching, likely due to the COVID-19 pandemic.

Privacy concerns and a preference for other forms of communication were the main reasons cited for not using social media in teaching. A significant percentage of teachers also indicated that they didn't believe social media was necessary for their work. Nevertheless, a considerable portion of respondents acknowledged the positive impact of social media on their teaching methods and communication with students.

Teachers expressed varying opinions on the future of social media in education, with some believing that the rapid development of AI, such as OpenAI, will necessitate changes in their work with students, while others remained uncertain about the direction of social media in teaching.

In summary, while Polish academic teachers are increasingly using social media in their teaching and professional work, there are concerns and uncertainties regarding its long-term impact and the need for new pedagogical approaches to fully harness its potential.

As this study was not representative of the population as a whole, the results cannot be generalised to society as a whole. They can only be treated as tendencies, which require deeper research. Looking at the future directions of social media in the higher education process in Poland, the use of social media tools for academic teachers will be inevitable. As technology GPT and the world continue to develop, academic teachers must also develop to meet the new challenges that arise.

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A STUDY ON THE DISTANCES BETWEEN COMPANIES IN POLAND AND IN SELECTED COUNTRIES OF THE EUROPEAN UNION WITH RESPECT TO THE USE OF ICT RESOURCES AND COMPETENCIES

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Purpose: The aim of the paper is to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.
Design/methodology/approach: The study examines the use of the Internet and information and communication technologies by enterprises of the selected country, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from Eurostat, taking into account the thematic scope of the study and data availability. The study covered the years 2013-2020, including the time of the Covid-19 pandemic. Selected taxonomic methods were used in the analysis. In the first step of the study, a synthetic variable was determined. The synthetic variable made it possible to compare the level of development of the phenomenon for selected countries. Then the distance matrix was determined. The distance of the level of development of the phenomenon that separates Poland from the studied countries has been determined.
Findings: The study analyzes internet and ICT usage by enterprises in the selected country in the years 2013-2020, with special focus on the COVID-19 pandemic period. To sum up, comparative analysis performed by means of taxonomic methods can be an effective tool to study the elements of a complex process, can provide a broad picture of this process.
Research limitations/implications: The main limitation is that it is not possible to collect a comparable data set over a long period of years. The final set of diagnostic data included only 11 variables.
Originality/value: The concept of comparative analysis of the phenomenon under consideration presented and implemented in this study can be applied to compare other countries, using relevant measures, or to perform comparative analysis of other aspects of the issue, and the findings of these studies will contribute to further research in this area. The results of the proposed research methodology applied to explore the selected research problem and the set of data the study was based on can be used in the analyses of economic and socio-economic policies.

Keywords: taxonomic methods, Internet and ICT usage, COVID-19.

Category of the paper: Research paper.

1. Introduction

Recent years have seen dynamic development and transformation of ICT resources and competencies. Socio-economic processes are becoming increasingly reliant on new technologies and so is the information society, which we have turned into, both in the public and private spheres. The coronavirus pandemic also brought about significant changes that contributed to the transformation of economies in numerous countries. Enterprises, public administration units, educational institutions, health care facilities, citizens, etc. faced both challenges and opportunities arising from the rapid introduction of remote work and remote communication, digitization of internal processes, acceleration of operations due to the use of the internet, etc. (Goban-Klas, Sienkiewicz, 1999).

These developments have not only catapulted digital transformation but also provided employees with new convenient solutions, e.g. electronic document signing, electronic document circulation, video verification, biometric technologies, remote work management and remote task monitoring tools and software, data analysis systems, etc. Of course, the scope and the nature of changes made by various enterprises and organizations was and is dependent on their type and size as well as their ability to adopt technological innovation and maintain optimum competitiveness at the same time (Śledziewska, Włoch, 2020).

Some of the most common technologies include e-commerce - a subset of e-business gaining increasing popularity over recent years, virtual reality, artificial intelligence, cloud computing, blockchain, mainframe technology, etc. The Internet of Things is becoming an integral part of our daily lives, with new technologies employed not only in households, but also in workplaces. Artificial intelligence is growing in importance, as it can replace humans in many situations and support decision-making. Chatbots and voicebots are being adopted by companies to provide customer service 24 hours a day (Gajewski et al., 2016).

The current digital revolution requires continuous education and training of young people so that they can learn to use various IT tools and develop digital skills, which i.a. prevents digital exclusion. Digital reality forces us to acquire, process and manage information and apply new technologies. However, when using modern technologies, we mustn't forget about potential threats they pose, which is why new cybersecurity measures are being introduced.

To sum up, the COVID-19 pandemic threatened the global economy, including the economy of the European Union. The measures taken by the EU countries in response to the pandemic such as restrictions on social contact, quarantine, travel restrictions or bans for certain countries, shutdown of commercial and cultural facilities, restrictions imposed on tourism, transport, etc., had a significant impact on the functioning of public administration, as well as large, small and medium-sized enterprises in the European Union.

The study analyzes internet and ICT usage by enterprises in the selected country in the years 2020-2013 with special focus on the COVID-19 pandemic period.

The aim of the paper is to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.

2. The set of diagnostic characteristics of the problems under study

The study examines the use of the internet and information and communication technologies by enterprises of the selected country, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from Eurostat, taking into account the thematic scope of the study and data availability. The diagnostic variables selected for the study had to be measurable and best describe the level of development of the examined phenomenon. Based on the calculated values of the coefficients of variation and the results of verifying correlation analysis conducted by means of an inverted correlation matrix, the final set of diagnostic characteristics which describes the phenomenon for a given country was adopted (Młodak, 2006; Panek, 2009; Zeliaś, 2004; Narayan, 2004; Fisher, 1978; Hartigan, 1985; Jardine, Sibson, 1971). Due to the lack of statistical data, it was necessary to reduce the thematic scope of the dataset. The final set of diagnostic variables was the basis for the analysis (due to the construction of the synthetic variable, x_6 was added) (Bolch, Huang, 1974; Anderberg, 1973; Cole, 1969; Gordon, 1981; Greenacre, 1984; Harrison, 1968). The following set of variables was adopted in years: 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020.

x_1 - Number of enterprises having received orders online – [%] of enterprises (S).

x_2 - Share of enterprises' turnover on e-commerce – [%] (S).

x_3 - Percentage of the ICT sector on GDP [%] (S).

x_4 - Digital single market - promoting e-commerce for individuals [%] (S).

x_5 - High-tech exports [%] (S).

x_6 - Population on 1 January (S).

x_7 - Number of individuals using the internet for selling goods or services [%] (S).

x_8 - E-banking and e-commerce [%] (S).

x_9 - Individuals using the internet for interacting with public authorities [%] (S).

x_{10} - High-tech trade by high-tech group of products in million euro (S).

x_{11} - E-government activities of individuals via websites [%] (S).

In describing the variables, the determination S – stimulant was introduced (Mika, 1995). The table 1 includes descriptive characteristics of the variables.

Table 1.
Basic descriptive characteristics of variables

Variable		Years							
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
X1	**Vx [%]**	45,30	44,09	40,12	41,22	35,19	36,38	36,43	31,73
	$\bar{x}$	13,15	13,58	14,41	15,14	15,98	16,12	17,55	18,28
	min	4,8	5,3	5,8	5,4	7,3	5,7	7,4	8,3
	max	25,7	26,5	24,6	26,6	24,3	28,8	29,6	29,6
X2	**Vx [%]**	43,14	49,50	44,07	45,08	42,43	44,08	45,46	36,32
	$\bar{x}$	12,28	13,19	14,94	15,	16,67	16,37	16,96	17,86
	min	2,7	3,1	5,2	3,9	5,4	5,2	4,5	6,1
	max	25,7	29,3	29,8	30,5	31,4	32,5	32,6	31,4
X3	**Vx [%]**	24,13	24,77	23,24	23,27	26,44	24,72	26,42	26,28
	$\bar{x}$	4,08	4,09	4,19	4,28	4,47	4,52	4,74	5,04
	min	2,41	2,56	2,97	2,99	3,03	3,13	3,35	3,4
	max	6,55	6,9	6,86	6,94	7,77	7,43	8	8,02
X4	**Vx [%]**	39,49	34,87	33,46	31,97	30,18	26,37	25,79	18,41
	$\bar{x}$	42,21	45,34	48,28	49,58	52,55	55,09	58,38	65,00
	min	14,05	16,68	16,46	17,68	22,09	26,91	26,83	38,81
	max	72,72	73,08	75,02	75,87	77,27	78,43	80,57	83,99
X5	**Vx [%]**	56,75	53,92	45,88	40,98	42,66	43,88	43,49	44,84
	$\bar{x}$	11,21	11,57	11,76	11,45	11,62	11,81	12,06	12,99
	min	4	3,9	4,4	5,1	5,4	5,8	6,3	6,8
	max	28,5	28,7	24,1	21,7	22,5	24,1	23,7	29,6
X6	**Vx [%]**	126,5	126,8	127,0	127,4	127,6	127,7	127,8	127,8
	$\bar{x}$	19460352,1	19566108,9	19609629,5	19668161,3	19689361,5	19707839,8	19689380,0	19698716,1
	min	422509	429424	439691	450415	460297	475701	493559	514564
	max	80523746	80767463	81197537	82175684	82521653	82792351	83019213	83166711
X7	**Vx [%]**	60,7	56,9	54,4	51,9	54,2	48,8	51,9	49,2
	$\bar{x}$	15,2	15,3	15,0	14,1	15,4	16,7	16,6	18,6
	min	9,24941835	8,738795773	8,133485699	7,318490305	8,329110164	8,169300665	8,602895224	9,177714857
	max	35,05	28,98	31,47	29,39	31,02	32,05	31,71	33,14
X8	**Vx [%]**	42,4	41,8	41,3	39,6	37,7	35,7	34,8	30,1
	$\bar{x}$	47,5	49,2	50,2	52,8	54,3	57,1	59,6	62,8
	min	8,07	7,6	8,8	6,73	8,56	10,86	12,34	19,44
	max	89,9	91,02	91,4	91,12	92,05	92,69	94,85	94,34
X9	**Vx [%]**	37,1	32,9	36,2	35,0	34,6	33,2	31,7	28,8
	$\bar{x}$	45,0	51,7	51,4	54,8	55,3	57,4	60,2	64,3
	min	8,66	18,82	16,47	15,66	13,78	13,44	17,92	21,68
	max	80,02	86,71	86,74	88,17	90,73	88,8	92,63	92,51
X10	**Vx [%]**	71,99	72,61	72,73	71,56	71,53	70,75	71,18	74,22
	$\bar{x}$	4894,26	5056,97	5802,45	6065,23	6640,76	7021,47	7501,41	7518,16
	min	449,87	310,17	304,92	265,43	254,86	461,69	541,91	555,67
	max	65918,79	71091,27	75514,21	76279,64	78517,53	80291,39	83973,62	83421,35
X11	**Vx [%]**	40,7	36,9	43,0	42,4	39,2	36,5	36,3	33,7
	$\bar{x}$	45,4	53,9	52,1	55,0	57,4	60,9	62,1	65,7
	min	5,06	10,74	10,98	8,68	8,22	8,44	11,11	14,76
	max	77,06	90,85	94,3	93,23	91,72	92,6	94,57	93,95

Source: based on own research (https://ec.europa.eu/eurostat).

In addition, for the selected data set, a graphical presentation of data from the Eurostat website has been added to compare the years 2013 and 2020 and to identify possible similarities or differences. The diagrams are shown below.

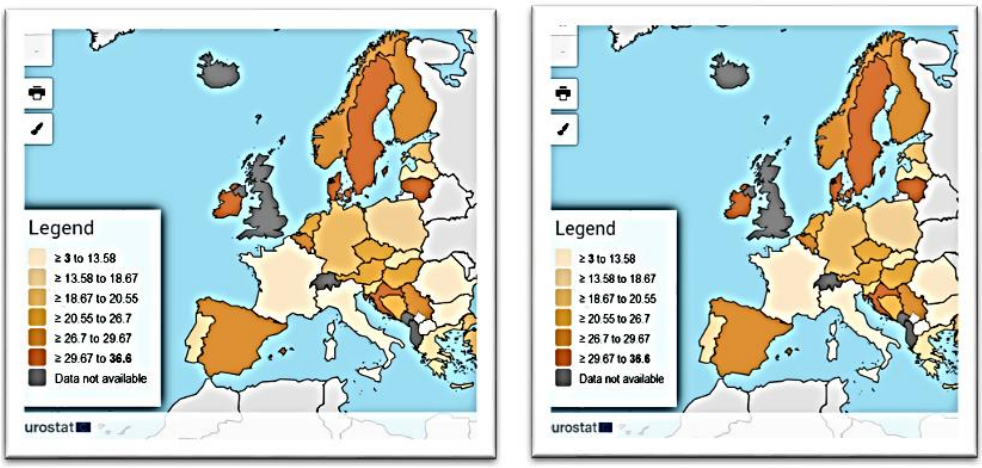

Figure 1. - Number of enterprises having received orders online – [%] of enterprises – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

The second variable was then taken into account - Share of enterprises' turnover on e-commerce – [%] – 2013 and 2020.

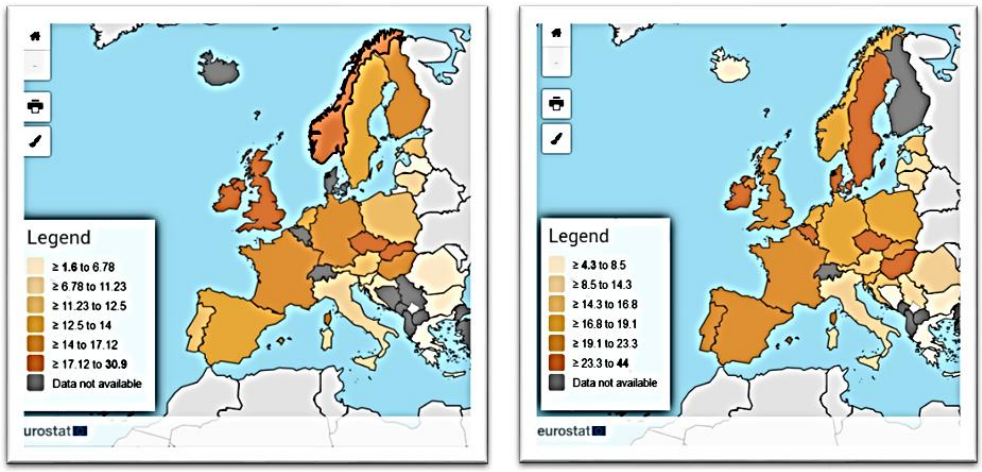

Figure 2. Share of enterprises' turnover on e-commerce – [%] – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

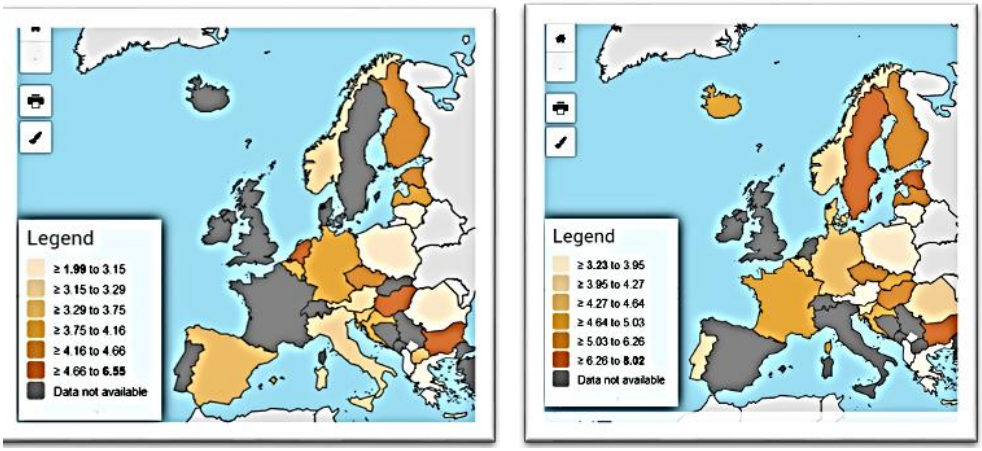

Figure 3. Percentage of the ICT sector on GDP [%] – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

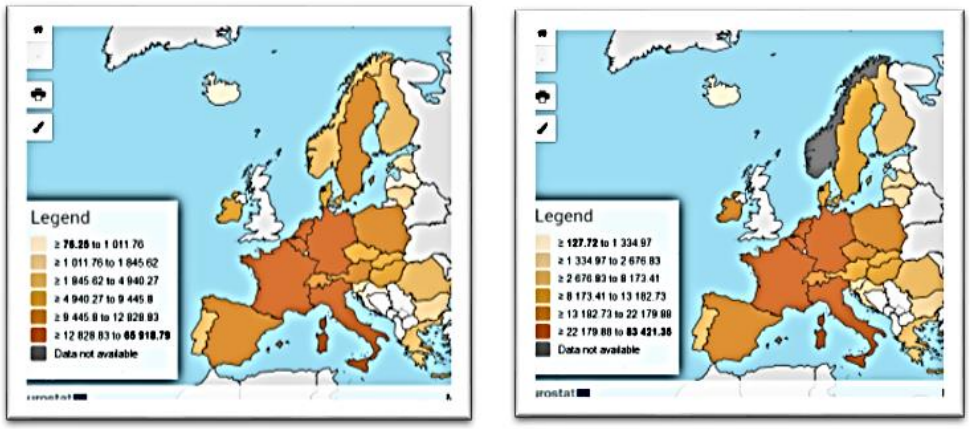

Figure 4. High-tech trade by high-tech group of products in million euro – 2013 and 2020.
Source: https://ec.europa.eu/eurostat.

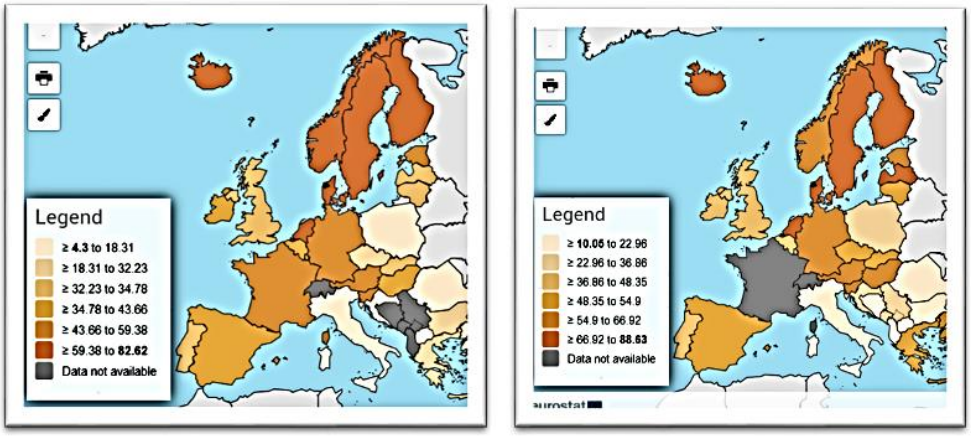

Figure 5. E-government activities of individuals via websites [%] – 2013 and 2020.
Source: https://ec.europa.eu/eurostat.

3. The synthetic variable

The first information about the synthetic variable can be found in the works of Z. Hellwig, who developed a method for presenting a complex phenomenon by means of one synthetic variable (Edwards, Cavalli-Sforza, 1963; Hellwig, 1972). Variables which describe a particular phenomenon are usually diverse in character, as there are both stimulants and destimulants among them (Mika, 1995; Wishart, 1969). The aim of the synthetic variable is to aggregate all the structure features of the variables that are used for its construction (Chomątowski, Sokołowski, 1978; Zeliaś, 2004; Strahl, 1990; Malina, 2008; Hartigan, 1975; Sneath, Sokal, 1973; Szczotka, 1972; Ward, 1963; Everitt, 1974; Johnson, 1967).

The analyzed set of diagnostic variables includes stimulants and destimulants, which have to be converted into stimulants according to formula (Zeliaś, 2004; Strahl, 1990; Tryon, Bailey, 1970):

$$x_{ijt}^{S} = 2\overline{\boldsymbol{x}} - x_{ijt}^{D},\ i = 1, \ldots, m;\ j = 1, \ldots, k;\ t = 1, \ldots, n, \quad (1)$$

where:

x_{ijt}^{D} - the value of the destimulant for the object *i* in time unit *t,*

x_{ijt}^{S} - the value of the stimulant for the object *i* in time unit *t,*

$\overline{\boldsymbol{x}}$ **-** weighted average of selected variable for countries,

k - the number of variables that make up the final set of variables,

m - the number of objects,

n - the number of time units.

A negative value of the stimulant for a given object indicates its unfavorable state. The next step involves normalizing variables by means of formula (Chomątowski, Sokołowski, 1978; Pociecha et al., 1988; Młodak, 2006; Panek, 2009; Zeliaś, 2004; Strahl, 1998; Malina, 2008):

$$S_{ijt} = \frac{x_{ijt}}{\sum_{i=1}^{m} x_{ijt}}, \quad (2)$$

S_{ijt} - the value of the normalized *j*-th variable for object *i* in unit time *t,*

$I = 1, \ldots, m;\ j = 1, \ldots, k;\ t = 1, \ldots, n.$

The transformation preserves the volatility of the variable and the measurement scale. Once the variables are normalized, we synthesize each of the selected groups of measures and calculate a synthetic variable (the arithmetic mean of the normalized variables).

4. Determination of a synthetic variable - an empirical example

Once the variables are normalized, we synthesize each of the selected groups of measures and calculate a synthetic variable. The values of the synthetic variable for the i-th country in time t are: $\boldsymbol{z_{it}}$ ($t = 1, \ldots, n$, $I = 1, \ldots, m$). The analysis covered 17 countries ($m = 17$, Belgium, Bulgaria, Czechia, Germany, Estonia, France, Italy, Latvia, Lithuania, Hungary, Malta, Austria, Poland, Romania, Slovenia, Slovakia, Finland), the time frame was 8 years ($n = 8$, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020) and the number of variables was 11 ($k = 15$, variables listed in the previous chapter). Table 2 shows the calculated values of the synthetic variable for selected countries in the years analysed.

Table 2.
Determined values of the synthetic variable

Country	Years							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Belgium	0,0679	0,0697	0,0685	0,0692	0,0677	0,0696	0,0720	0,0700
Bulgaria	0,0286	0,0260	0,0268	0,0254	0,0261	0,0276	0,0279	0,0301
Czechia	0,0647	0,0677	0,0619	0,0623	0,0645	0,0674	0,0696	0,0665
Germany	0,1159	0,1136	0,1165	0,1153	0,1134	0,1088	0,1061	0,1051
Estonia	0,0539	0,0605	0,0639	0,0640	0,0600	0,0598	0,0573	0,0556
France	0,1047	0,1010	0,1012	0,0984	0,0965	0,0932	0,0928	0,0874
Italy	0,0515	0,0514	0,0533	0,0523	0,0536	0,0547	0,0539	0,0554
Latvia	0,0386	0,0411	0,0426	0,0460	0,0465	0,0452	0,0443	0,0470
Lithuania	0,0410	0,0405	0,0420	0,0438	0,0460	0,0456	0,0472	0,0483
Hungary	0,0563	0,0579	0,0563	0,0551	0,0546	0,0566	0,0565	0,0614
Malta	0,0590	0,0583	0,0585	0,0571	0,0592	0,0606	0,0605	0,0623
Austria	0,0598	0,0569	0,0578	0,0582	0,0583	0,0556	0,0564	0,0570
Poland	0,0511	0,0528	0,0532	0,0567	0,0554	0,0560	0,0574	0,0553
Romania	0,0255	0,0264	0,0273	0,0273	0,0274	0,0285	0,0292	0,0350
Slovenia	0,0564	0,0517	0,0465	0,0463	0,0477	0,0480	0,0458	0,0468
Slovakia	0,0558	0,0546	0,0537	0,0534	0,0542	0,0561	0,0548	0,0543
Finland	0,0691	0,0700	0,0701	0,0691	0,0690	0,0666	0,0682	0,0624

Source: based on own research (https://ec.europa.eu/eurostat)

For the determined values of the synthetic variables, a graph is presented below.

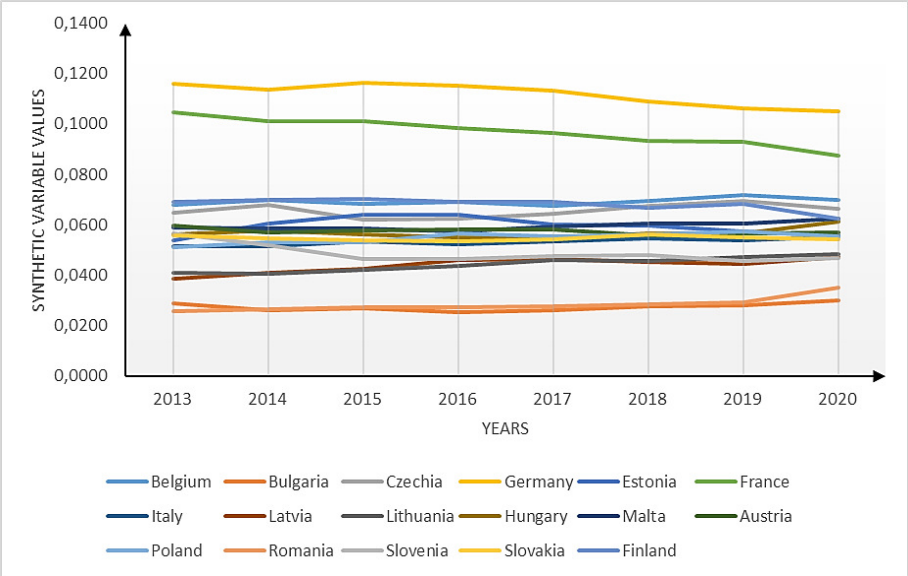

Figure 6. Synthetic variable values in 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 for selected countries.

Source: based on own research.

The determined values of the synthetic variable describing the level of the analyzed phenomenon allow the countries to be ranked from the best to the worst. Table 3 shows the rank values assigned to the surveyed countries for the subsequent years analyzed.

Table 3.
Positions of selected countries by the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods

Country	Years							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Austria	6	9	8	7	8	11	10	8
Belgium	4	4	4	3	4	3	3	3
Bulgaria	16	17	17	17	17	17	17	17
Czechia	5	5	6	6	5	4	4	4
Estonia	11	6	5	5	6	7	8	9
Finland	3	3	3	4	3	5	5	5
France	2	2	2	2	2	2	2	2
Germany	1	1	1	1	1	1	1	1
Hungary	9	8	9	10	10	8	9	7
Italy	12	13	11	12	12	12	12	10
Latvia	15	14	14	14	14	15	15	14
Lithuania	14	15	15	15	15	14	13	13
Malta	7	7	7	8	7	6	6	6
Poland	13	11	12	9	9	10	7	11
Romania	17	16	16	16	16	16	16	16
Slovakia	10	10	10	11	11	9	11	12
Slovenia	8	12	13	13	13	13	14	15

Source: based on own research (https://ec.europa.eu/eurostat)

Analyzing the results, we can conclude that:

- the countries with the highest level of the phenomenon at the time studied are: Germany, France, Finland, Belgium,
- Poland maintained the highest level in 2019 (7), and the lowest in 2013 (13),
- countries with the lowest level are: Bulgaria, Romania, Latvia, Lithuania.

5. A distance matrix of the countries under study with respect to the problems examined in the paper

A multivariate comparative analysis is closely related to the quantitative disciplines. Taxonomic methods, which involve ordering a set of objects, are often employed to investigate research problems and research areas for which other tools cannot be applied.

Determining the distance between pairs of analyzed objects is a key element of the taxonomic analysis of multidimensional objects. A distance matrix provides a basis for comparing objects (countries). It is of the following form (Zeliaś, 2004; Malina, 2008; Malina, Zeliaś, 1998):

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1m} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mm} \end{bmatrix}, \tag{3}$$

where d_{ij} – the distance between *i*-th and *j*-th object, (*i,j* = 1, …,*m*) (Matrix D is determined for the relevant year in the analyzed time interval, t = 1,…,n), respectively: d_{ij} = 0 - the compared objects are identical, d_{ij}≠0 - the greater the value, the more dissimilar the objects are.

Matrix D allows for individual analysis of objects. The mutual position of objects can be described by means of a similarity or dissimilarity function (Zeliaś, 2004). The subject literature offers various distance measures, and this study applies – Chomątowski-Sokołowski measure (Młodak, 2006; Panek, 2009; Zeliaś, 2004).

6. A distance matrix of the countries under study with respect to the problems examined in the paper - an empirical example

We start the taxonomic analysis by constructing a three-dimensional data matrix $\boldsymbol{X} = [\boldsymbol{x_{ijt}}]$, *k* - the number of variables that make up the final set of variables (k = 11), *m* - the number of objects (*m* = 17), *n* - the number of time units (*n* = 8). Then we determine the normalized matrix according to the previously discussed theory. For each year, we calculate the distance matrix between the surveyed countries. Table 4 presents the distance matrices between the analyzed countries for the years: 2013, 2018, 2019, 2020.

Table 4.
Distance matrix - for the year 2013

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,026537	0,014061	0,033637	0,018108	0,030361	0,027865	0,019453	0,017801	0,015186	0,023287	0,012579	0,020441	0,0306	0,01999	0,010365	0,016491
Bulgaria	0,026537	0	0,024824	0,05751	0,018617	0,050423	0,050423	0,012754	0,016245	0,017895	0,022963	0,022651	0,019788	0,013373	0,021924	0,018555	0,027505
Czechia	0,014061	0,024824	0	0,042315	0,031284	0,040469	0,040469	0,022696	0,021221	0,012435	0,020824	0,016899	0,020293	0,028774	0,025808	0,01242	0,023754
Germany	0,033637	0,05751	0,042315	0	0,046085	0,018166	0,041659	0,051268	0,049616	0,04349	0,049798	0,038671	0,041924	0,058499	0,046726	0,041639	0,045509
Estonia	0,018108	0,018617	0,019841	0,046085	0	0,03651	0,03651	0,011182	0,014344	0,01107	0,015091	0,010559	0,022217	0,026593	0,015134	0,014137	0,015722
France	0,030361	0,050423	0,040469	0,018166	0,03651	0	0,034436	0,042822	0,045557	0,035168	0,038943	0,029658	0,034701	0,051276	0,033996	0,037547	0,036979
Italy	0,027865	0,021058	0,031284	0,041659	0,032086	0,034436	0	0,02462	0,027458	0,02796	0,036279	0,02862	0,012817	0,01905	0,034378	0,028798	0,039191
Latvia	0,019453	0,012754	0,022696	0,051268	0,011182	0,042822	0,02462	0	0,00597	0,015608	0,018211	0,01526	0,01617	0,017698	0,016065	0,013058	0,020899
Lithuania	0,017801	0,016245	0,021221	0,049616	0,014344	0,045557	0,027458	0,00597	0	0,018836	0,02203	0,016461	0,01835	0,019133	0,017541	0,012687	0,02026
Hungary	0,015186	0,017895	0,012435	0,04349	0,01107	0,035168	0,02796	0,015608	0,018836	0	0,012495	0,012433	0,01845	0,023516	0,018602	0,011253	0,019701
Malta	0,023287	0,022963	0,020539	0,049798	0,015091	0,038943	0,036279	0,018211	0,02203	0,012495	0	0,019812	0,025348	0,030785	0,019009	0,018037	0,025933
Austria	0,012579	0,022651	0,016899	0,038671	0,010559	0,029658	0,02862	0,01526	0,016461	0,012433	0,019812	0	0,016755	0,02631	0,016138	0,010662	0,015281
Poland	0,020441	0,019788	0,020293	0,041924	0,022217	0,034701	0,012817	0,01617	0,01835	0,01845	0,025348	0,016755	0	0,016781	0,023313	0,016949	0,027405
Romania	0,0306	0,013373	0,028774	0,058499	0,026593	0,051276	0,01905	0,017698	0,019133	0,023516	0,030785	0,02631	0,016781	0	0,028267	0,024786	0,03345
Slovenia	0,01999	0,021924	0,025808	0,046726	0,015134	0,033996	0,034378	0,016065	0,017541	0,018602	0,019009	0,016138	0,023313	0,028267	0	0,019354	0,016535
Slovakia	0,010365	0,018555	0,01242	0,041639	0,014137	0,037547	0,028798	0,013058	0,012687	0,011253	0,018037	0,010662	0,016949	0,024786	0,019354	0	0,014186
Finland	0,016491	0,027505	0,023754	0,045509	0,015722	0,036979	0,039191	0,020899	0,02026	0,019701	0,025933	0,015281	0,027405	0,03345	0,016535	0,014186	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 5.
Distance matrix - for the year 2018

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,030353	0,008763	0,03766	0,020688	0,025452	0,02781	0,021987	0,017047	0,015784	0,024592	0,015084	0,018077	0,029406	0,016346	0,012912	0,019909
Bulgaria	0,030353	0	0,028044	0,055101	0,024133	0,045116	0,045116	0,015293	0,017744	0,018964	0,024313	0,021935	0,022206	0,01047	0,018954	0,021977	0,027639
Czechia	0,008763	0,028044	0	0,037962	0,031035	0,023849	0,023849	0,017628	0,01484	0,009963	0,019338	0,010125	0,017615	0,028277	0,015378	0,01174	0,017499
Germany	0,03766	0,055101	0,037962	0	0,0419	0,019761	0,035	0,045568	0,043034	0,041111	0,042856	0,03735	0,0346	0,05194	0,042617	0,037966	0,041656
Estonia	0,020688	0,024133	0,017575	0,0419	0	0,028897	0,028897	0,009895	0,012275	0,0153	0,014338	0,011369	0,022229	0,029081	0,009754	0,010038	0,008554
France	0,025452	0,045116	0,023849	0,019761	0,028897	0	0,024893	0,032908	0,033871	0,026743	0,033123	0,024464	0,024028	0,041833	0,029926	0,024812	0,030225
Italy	0,02781	0,02226	0,031035	0,035	0,035732	0,024893	0	0,028132	0,026132	0,026932	0,036953	0,025712	0,013503	0,017993	0,028794	0,028256	0,037686
Latvia	0,021987	0,015293	0,017628	0,045568	0,009895	0,032908	0,028132	0	0,008382	0,0114	0,016768	0,009851	0,019907	0,020762	0,010895	0,013368	0,017404
Lithuania	0,017047	0,017744	0,01484	0,043034	0,012275	0,033871	0,026132	0,008382	0	0,01362	0,016398	0,010635	0,01702	0,020247	0,00725	0,012103	0,015074
Hungary	0,015784	0,018964	0,009963	0,041111	0,0153	0,026743	0,026932	0,0114	0,01362	0	0,017991	0,008234	0,016095	0,021618	0,013141	0,010077	0,017983
Malta	0,024592	0,024313	0,019082	0,042856	0,014338	0,033123	0,036953	0,016768	0,016398	0,017991	0	0,017914	0,02566	0,030302	0,014664	0,016707	0,019466
Austria	0,015084	0,021935	0,010125	0,03735	0,011369	0,024464	0,025712	0,009851	0,010635	0,008234	0,017914	0	0,012856	0,021494	0,009631	0,008619	0,01555
Poland	0,018077	0,022206	0,017615	0,0346	0,022229	0,024028	0,013503	0,019907	0,01702	0,016095	0,02566	0,012856	0	0,018063	0,016396	0,014753	0,024534
Romania	0,029406	0,01047	0,028277	0,05194	0,029081	0,041833	0,017993	0,020762	0,020247	0,021618	0,030302	0,021494	0,018063	0	0,022736	0,022771	0,031445
Slovenia	0,016346	0,018954	0,015378	0,042617	0,009754	0,029926	0,028794	0,010895	0,00725	0,013141	0,014664	0,009631	0,016396	0,022736	0	0,009123	0,012049
Slovakia	0,012912	0,021977	0,01174	0,037966	0,010038	0,024812	0,028256	0,013368	0,012103	0,010077	0,016707	0,008619	0,014753	0,022771	0,009123	0	0,010669
Finland	0,019909	0,027639	0,017499	0,041656	0,008554	0,030225	0,037686	0,017404	0,015074	0,017983	0,019466	0,01555	0,024534	0,031445	0,012049	0,010669	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 6.
Distance matrix - for the year 2019

	Belgium	**Bulgaria**	**Czechia**	**Germany**	**Estonia**	**France**	**Italy**	**Latvia**	**Lithuania**	**Hungary**	**Malta**	**Austria**	**Poland**	**Romania**	**Slovenia**	**Slovakia**	**Finland**
Belgium	0	0,032049	0,009621	0,034237	0,021529	0,023748	0,028654	0,0239	0,019033	0,01587	0,023278	0,015597	0,018755	0,030448	0,017338	0,014267	0,019931
Bulgaria	0,032049	0	0,029761	0,053914	0,022414	0,04524	0,04524	0,014667	0,018576	0,019269	0,02406	0,022751	0,023486	0,010828	0,017646	0,021361	0,029128
Czechia	0,009621	0,029761	0	0,039234	0,032394	0,025374	0,025374	0,019837	0,01538	0,011066	0,021021	0,011325	0,018527	0,029174	0,017791	0,014749	0,018921
Germany	0,034237	0,053914	0,039234	0	0,041479	0,018318	0,033769	0,045332	0,043158	0,038458	0,04273	0,036285	0,032585	0,049764	0,040014	0,037247	0,041828
Estonia	0,021529	0,022414	0,018224	0,041479	0	0,029917	0,029917	0,008653	0,010012	0,014878	0,015425	0,010447	0,021499	0,027209	0,009587	0,010955	0,011331
France	0,023748	0,04524	0,025374	0,018318	0,029917	0	0,025139	0,033641	0,033581	0,026624	0,033679	0,025858	0,022893	0,041133	0,031221	0,024584	0,031252
Italy	0,028654	0,02324	0,032394	0,033769	0,034345	0,025139	0	0,027488	0,026896	0,026671	0,03697	0,026458	0,014397	0,017894	0,027108	0,027865	0,039007
Latvia	0,0239	0,014667	0,019837	0,045332	0,008653	0,033641	0,027488	0	0,007344	0,013467	0,017913	0,011049	0,019742	0,018836	0,011114	0,011102	0,018127
Lithuania	0,019033	0,018576	0,01538	0,043158	0,010012	0,033581	0,026896	0,007344	0	0,015024	0,016	0,008864	0,01748	0,020612	0,007341	0,011187	0,015068
Hungary	0,01587	0,019269	0,011066	0,038458	0,014878	0,026624	0,026671	0,013467	0,015024	0	0,017454	0,009419	0,013778	0,021065	0,012431	0,009334	0,019263
Malta	0,023278	0,02406	0,02077	0,04273	0,015425	0,033679	0,03697	0,017913	0,016	0,017454	0	0,018349	0,026969	0,029834	0,014725	0,017912	0,019564
Austria	0,015597	0,022751	0,011325	0,036285	0,010447	0,025858	0,026458	0,011049	0,008864	0,009419	0,018349	0	0,014079	0,021347	0,010686	0,008902	0,015991
Poland	0,018755	0,023486	0,018527	0,032585	0,021499	0,022893	0,014397	0,019742	0,01748	0,013778	0,026969	0,014079	0	0,018601	0,014528	0,01402	0,025069
Romania	0,030448	0,010828	0,029174	0,049764	0,027209	0,041133	0,017894	0,018836	0,020612	0,021065	0,029834	0,021347	0,018601	0	0,020674	0,021457	0,032559
Slovenia	0,017338	0,017646	0,017791	0,040014	0,009587	0,031221	0,027108	0,011114	0,007341	0,012431	0,014725	0,010686	0,014528	0,020674	0	0,008096	0,014645
Slovakia	0,014267	0,021361	0,014749	0,037247	0,010955	0,024584	0,027865	0,011102	0,011187	0,009334	0,017912	0,008902	0,01402	0,021457	0,008096	0	0,011854
Finland	0,019931	0,029128	0,018921	0,041828	0,011331	0,031252	0,039007	0,018127	0,015068	0,019263	0,019564	0,015991	0,025069	0,032559	0,014645	0,011854	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 7.
Distance matrix - for the year 2020

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,02998	0,010934	0,031367	0,019634	0,021134	0,026315	0,022467	0,017447	0,012494	0,021909	0,013662	0,018799	0,025395	0,018505	0,013799	0,018268
Bulgaria	0,02998	0	0,026717	0,052523	0,019668	0,040692	0,040692	0,015318	0,01815	0,02212	0,023742	0,022515	0,021223	0,012344	0,017127	0,019855	0,023573
Czechia	0,010934	0,026717	0	0,03836	0,029439	0,024629	0,024629	0,018208	0,013807	0,011888	0,020104	0,010854	0,018502	0,023425	0,017462	0,014996	0,018404
Germany	0,031367	0,052523	0,03836	0	0,040498	0,017358	0,032118	0,043619	0,041998	0,033684	0,043156	0,035703	0,032219	0,04536	0,039422	0,035998	0,039611
Estonia	0,019634	0,019668	0,0182	0,040498	0	0,028234	0,028234	0,005901	0,009909	0,011138	0,013266	0,009837	0,02191	0,022737	0,008216	0,010147	0,009362
France	0,021134	0,040692	0,024629	0,017358	0,028234	0	0,020671	0,030144	0,031758	0,020623	0,03439	0,024202	0,020962	0,035428	0,02844	0,02421	0,028495
Italy	0,026315	0,022719	0,029439	0,032118	0,032354	0,020671	0	0,027577	0,026573	0,02916	0,037225	0,026184	0,011413	0,017571	0,026397	0,026902	0,034295
Latvia	0,022467	0,015318	0,018208	0,043619	0,005901	0,030144	0,027577	0	0,008255	0,01355	0,017386	0,010695	0,019514	0,019775	0,008733	0,011284	0,012602
Lithuania	0,017447	0,01815	0,013807	0,041998	0,009909	0,031758	0,026573	0,008255	0	0,015284	0,015343	0,00858	0,017109	0,017962	0,006156	0,009392	0,013368
Hungary	0,012494	0,02212	0,011888	0,033684	0,011138	0,020623	0,02916	0,01355	0,015284	0	0,015035	0,009208	0,017823	0,021858	0,012273	0,007164	0,010454
Malta	0,021909	0,023742	0,019859	0,043156	0,013266	0,03439	0,037225	0,017386	0,015343	0,015035	0	0,017864	0,02724	0,027305	0,015784	0,015808	0,018825
Austria	0,013662	0,022515	0,010854	0,035703	0,009837	0,024202	0,026184	0,010695	0,00858	0,009208	0,017864	0	0,015002	0,018755	0,008674	0,008821	0,012785
Poland	0,018799	0,021223	0,018502	0,032219	0,02191	0,020962	0,011413	0,019514	0,017109	0,017823	0,02724	0,015002	0	0,015604	0,016261	0,016092	0,023255
Romania	0,025395	0,012344	0,023425	0,04536	0,022737	0,035428	0,017571	0,019775	0,017962	0,021858	0,027305	0,018755	0,015604	0	0,017631	0,017791	0,025227
Slovenia	0,018505	0,017127	0,017462	0,039422	0,008216	0,02844	0,026397	0,008733	0,006156	0,012273	0,015784	0,008674	0,016261	0,017631	0	0,005858	0,010538
Slovakia	0,013799	0,019855	0,014996	0,035998	0,010147	0,02421	0,026902	0,011284	0,009392	0,007164	0,015808	0,008821	0,016092	0,017791	0,005858	0	0,007896
Finland	0,018268	0,023573	0,018404	0,039611	0,009362	0,028495	0,034295	0,012602	0,013368	0,010454	0,018825	0,012785	0,023255	0,025227	0,010538	0,007896	0

Source: based on own research (https://ec.europa.eu/eurostat)

Tables 4-7 present the determined distance matrices between the analyzed countries for selected years from 2013-2020. Analyzing the results obtained, we can conclude that in 2013 for Poland and the countries studied:

- the largest distance in terms of the level of the phenomenon analysed was between Poland and Germany, followed by Malta, France and Finland.
- the smallest distances are between Poland and Italy, also Lithuania, Austria, Romania.

In 2018:

- the largest distance separates Poland from: Germany, Malta, Finland, France.
- Poland was the closest to the level of development of the phenomenon to Austria, Italy, Slovakia.

Then in 2019 the largest distance for Poland occurs between Germany, followed by Malta and Finland. A similar level of development of the phenomenon studied for Poland is also observed for Hungary, Italy and Slovakia. The year 2020 was included in the study, which includes the beginning of the covid pandemic. During this period of time, we notice the greatest distance between Poland and Germany, Malta and Finland. The countries with the most similar level of the phenomenon to Poland are: Italy, Austria, Romania.

The analysis of the distances between Poland and the other countries allowed identifying the fields where Poland lags far behind as well as the countries in relation to which it managed to shorten the distance in the years under study.

7. Conclusion

The aim of the paper was to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.

The study covered the years 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, including the time of the Covid-19 pandemic. Selected taxonomic methods were used in the analysis. In the first step of the study, a synthetic variable was determined.

In 2013, the value of the synthetic variable for Poland was 0. 0511. In the years 2014-2016, the value of the synthetic variable increased to 0.0567. In 2020, it was 0.0553. The level of the phenomenon analysed for Poland is not increasing rapidly. The distance to countries with a higher level of development of the phenomenon is not diminishing rapidly. The analyzed countries can be divided into two groups. The first group consists of countries that have a higher value of the synthetic variable in 2020 (the beginning of the Covid-19 pandemic) than in 2013. The second group consists of countries presenting the opposite situation (the value of the variable decreased). Poland belongs to the second group. The values of the synthetic variable additionally allowed for ranking the countries from the best to the worst in terms of the studied phenomenon. Germany had the highest level throughout the period under study. This country has a highly developed IT sector. The IT sector is one of the basic industries of the German economy and constitutes the basis for the assumptions of Industry 4.0. The last places of Romania and Bulgaria are due, among other things, to their late accession to the European Union.

Then the distance matrix was determined. The distance of the level of development of the phenomenon that separates Poland from the studied countries has been determined. The analysis of the distance matrix for Poland confirmed that the greatest distance separates Poland from Germany in terms of the level of the phenomenon under study.

The distance matrices also contain information on the distances between each of the selected European countries in the analysis. For example, we can check the distance between Germany and other countries in the analyzed years. In 2013, 2018, 2019, 2020, Germany is very far away from countries such as Romagna and Bulgaria. However, the level of development of the phenomenon was closest to: France.

To sum up, it can be said that digital transformation is implemented by enterprises, public administration, society and the national economy. Digitization has a significant impact on consumer behavior, changes the rules of competition in the market and creates new economic models.

In summary, today's organizations, businesses, society and economy must respond quickly to the changing environment and implement appropriate, effective solutions to survive.

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PRINCIPLES OF SOFTWARE DIAGNOSIS AND TESTING USING TEST AUTOMATION TOOLS

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Purpose: The aim of the article is to provide an in-depth discussion of traditional and modern methods of software diagnostics and testing. The basic ways of implementing these processes will be discussed. We will also discuss the concept of automation of the testing process and its impact on modern software development with usage of Artificial Intelligence.
Design/methodology/approach: The analysis of the article's topic is based on the analysis of sources discussing methods of software diagnostics and testing.
Findings: The importance of analytical thinking and predictive skills.
Originality/value: Presentation of various factors influencing the quality of software production with a particular focus on software test automation.

Keywords: software engineering, testing, diagnostics, automation.

Category of the paper: General review.

1. Introduction

A person responsible for preparing and conducting various tests on applications provided by programmers is referred to as a software tester. This process is mainly based on the technical specification provided by the client. It's important for the tester to identify potential areas of defects based on the specification before software production begins (Cińcio-Pętlicka, 2023). This is a commonly used programming approach known as Test Driven Development (TDD).

There are two main approaches to software testing: manual testing and automated testing. The work of a manual tester involves physically diagnosing the software to verify its functionality. On the other hand, an automated tester designs and implements a system that

checks the correctness of the tested software's operation (Praca testera..., 2023). Therefore, high requirements in terms of both hard and soft skills are placed on a software tester.

In recent years, there has been a strong trend towards full test automation, which is not only a result of optimizing software production costs but also becomes a necessary requirement in a world focused on frequent releases of new application versions. The goal is to achieve a situation in which, according to DevOps methodology, every change made by a developer is deployed to production as quickly as possible (Kim et al., 2016). This is, of course, an ideal state but very challenging to attain. It requires having highly specialized teams of programmers and testers capable of implementing full automation of software production processes at every stage. Research indicates that software testing consumes up to 50% of resources, with costs accounting for 50%-60% of all expenses (Myers, 2011; Ramler, 2006). Given the above, achieving full automation of software production processes is not easy and often results in failure or prolonged DevOps implementation processes. According to Statista reports, the adoption of DevOps methodology led to an increase from 33% of companies in 2017 to 63% in 2020 (Statista, 2023).

2. Principles for test development

The International Software Testing Qualifications Board (ISTQB) (2018) has developed and introduced 7 fundamental principles of software testing (Podraza, 2023; Stelmach, 2023; 7 Principles, 2023). The following set establishes basic principles for test development (ISTQB, 2018; ISTQB Syllabus, 2011), even in the case of their automation:

1. Software testing diagnoses defects, not their absence.

Software testing is not intended to prove the absence of defects in the software. The purpose of software testing is to identify the presence of defects. There is a fundamental difference in the approach to testing and test planning. Testing significantly helps reduce the number of undiscovered defects hidden in the software. Finding and resolving these issues is not in itself proof that the software or system is completely free from them (Podraza, 2023).

2. Achieving complete testing of software is impossible.

A crucial aspect of conducting software testing is to be guided by risk analysis and task prioritization. This stems from the fact that time constraints often prevent comprehensive and exhaustive testing of all possible scenarios. Hence, priorities need to be established, strategies devised, and tests well-designed to avoid delaying the system deployment or the intended application.

3. Early initiation of software testing.

Early initiation of software testing increases the likelihood of detecting errors and reduces the cost of their correction. It's best to begin testing during the planning and analysis stage. Finding errors at this point and rectifying them is much less costly than when developers have already started writing code. At that stage, rectifying an error might require revising parts or even the entire application (Stelmach, 2023).

4. Accumulation of software errors.

"The 80% of errors in software are found in 20% of modules." This statement highlights that if an error is detected in a certain part of the software (in a specific module), it's worthwhile to focus on testing the entire module. This is due to the higher logical complexity of specific modules, leading to a domino effect in case of defects. The principle number 3 mentioned earlier is helpful in this context, as such error-prone "hotspots" can be identified during the earliest testing stages.

5. The paradox of continuous software testing updates.

Repeatedly conducting the same tests becomes ineffective. You cannot keep using the exact same tests for the same parts of the software. Tests need to be updated to cover different test cases concerning specific parts of the software or system. This allows for the discovery of new software errors (Syllabus, 2023).

6. Context-dependent software testing.

The approach to testing largely depends on the purpose of the software. Testing is carried out in different ways in different contexts (Syllabus, 2023).

7. Misconception of software being error-free.

It's not enough for software testing to merely pass without errors. It's also crucial to verify whether performance and functionality are appropriate for the client's requirements and capabilities. This means that meeting customer expectations and requirements is just as important as the reliable operation of the program (Podraza, 2023). After all, software that is error-free but too complex to efficiently perform its intended task would be of no use (Stelmach, 2023).

3. The application of process models in an IT project

One of the factors that significantly enhances the effectiveness and ease of work for software testers is the increased efficiency of project teams. This is because the higher the quality of the code, the lower the risk of software errors. Quality, in this context, refers to the accuracy and performance of the program. Therefore, well-organized teamwork among testers, programmers, and architects has a significant impact on the overall software quality as a product. Cockburn (2006) presented a chart that visualizes the path that can be achieved by increasing the efficiency of project teams. The chart outlined in Cockburn's work shows that

increased tolerance for uncertainty allows for the implementation and adoption of agile methodologies, incremental development, and iterative methods with greater ease. This leads to improved software performance.

Cockburn (2006) also presents seven principles that are helpful in designing and evaluating software production methodologies:

1. The fastest and cheapest way to communicate is face-to-face interaction.
2. A methodology with too broad a scope incurs costs.
3. The larger the project team, the greater the need for a comprehensive software production methodology.
4. Increased "ceremony" (formality) is only necessary in projects with high criticality.
5. Frequent feedback reduces the need for compromises in software production.
6. Discipline, skills, and understanding are necessary attributes for executing processes, formalizing, and documenting software creation.
7. Efficiency is not the most important factor in software creation activities.

Hence, one might ask why testing, or rather its techniques, works. The answer can be traced back to the fact that in the 1980s, Boehm (Boehm, 1981) demonstrated that the cost of fixing a software error increases exponentially depending on the time of its discovery. For instance, finding a software error within, let's say, 3 minutes of its introduction into the system might not cost us much. However, if the problem is only discovered three months after its introduction, the cost of rectification could be substantial. At that point, not only does the software itself need to be fixed, but also the consequences of the software functioning with the error need to be addressed.

4. Automation of tests depending on their application method

Over the years, various software testing methods have been developed. In this chapter, they will be described in the context of automation capabilities.

The automation of tests depending on their application method is a strategy that aims to optimize the testing process by selectively automating certain types of tests based on their characteristics and requirements. This approach acknowledges that not all tests are equally suitable for automation and that the decision to automate should be made considering the specific context and goals of the testing effort.

Tests can vary widely in terms of their scope, complexity, and objectives. Some tests, such as unit tests, focus on isolating and verifying small units of code in isolation, while others, like end-to-end tests, aim to validate the entire software system's functionality.

The following testing techniques differ in scope and the approach in which they are applied. As a result, by utilizing the testing techniques listed below, various types of software errors can be detected.

4.1. Ad-hoc (exploratory) testing

Ad-hoc tests, also known as exploratory tests, serve both as a means of learning about the software and verifying its functionality. This leads to the proper design of further tests of this type. Such ad-hoc tests are most useful in projects with limited documentation (What is Exploratory Testing, 2023). Unfortunately, due to their nature, this type of testing is not suitable for automation. Automation requires complete knowledge of the subject under test. Each test acts as a contract describing how a specific part of the software should function. If we don't have prior knowledge of the system's behavior, exploratory tests can be used as a preliminary step in creating documentation.

4.2. Unit tests

Unit testing involves testing individual modules, their functions, to verify their proper operation for specific input data. A key characteristic of this type of testing is breaking down the program into distinct unit tests (Unit test, 2023). It's the most common type of testing generated within automation environments like Continuous Integration and Continuous Delivery (CI/CD). It holds fundamental importance as it often develops in parallel with implemented functionalities. Unit tests focus on testing small sections of code and serve as a valuable source of software documentation, succinctly and systematically describing the functionality of individual parts within the whole system. The significance of these tests is reflected even in integrated development environments like IntelliJ or Visual Studio Code, which integrate their user interfaces to facilitate the direct execution of unit tests from the programming environment, making it easier for developers to run tests multiple times.

In practice, unit tests are written in the same programming language as the specific part of the application. Unit tests utilize a set of pre-existing libraries that aid in the testing process, allowing programmers to write concise testing procedures that examine small portions, often a single procedure or function in the code. An issue in unit testing is isolating a small code fragment from its connections to the rest of the system. An example of this is accessing a database. However, libraries that support unit testing often provide the necessary functionalities for simulating other systems, referred to as Mocks.

Unit tests are generally executed in two scenarios. The first is the manual execution of unit tests by the programmer, which checks whether introduced implementation changes have adversely affected the entire system. Only after the programmer successfully passes local verification can they submit their changes to the central code repository. In software development teams that employ agile methodologies or DevOps (Kim et al., 2016) for work organization, the moment code changes are uploaded to the central repository automatically

triggers what's called a Pipeline. In the initial step, this Pipeline involves compiling the code with the latest changes, followed by executing a suite of tests. The most commonly used tool for supporting the CI/CD process is Jenkins. However, suitable support for building CI/CD automation can essentially be found in any major code repository tool with automation mechanisms. Examples of such tools include GitHub Actions, GitLab, and AWS CodeBuild.

4.3. Integration tests

Integration tests aim to verify the correctness of the interaction between different modules of the tested software, particularly the interactions of various interfaces that are often closely linked through data exchange. In large systems, there is a significant number of connections between system components, which poses a challenge in implementing integration tests.

There are several types of integration tests that are recognized (Kitakabe, 2023):

- **Big-bang integration testing**: This integration testing involves integrating all the components at once and testing them as a complete system. The method is typically used when the components are relatively independent and can be tested individually.
- **Top-down integration testing**: You can use top-down integration testing when the components are integrated and tested from the highest level to the lowest level. The approach is used when the higher-level components depend on the lower-level components.
- **Bottom-up** integration testing: The integration testing type involves integrating and testing the components from the lowest level to the highest level.
- **Sandwich/hybrid integration testing**: This integration testing involves combining elements of both top-down and bottom-up integration testing. The components are tested from both the top and bottom levels, with stubs and drivers used to simulate the missing components.
- **Continuous integration testing**: It involves continuously integrating and testing the components as they are developed. The method helps to catch and resolve problems early in the development process, improving the overall quality of the system.

The selection of the appropriate type of integration test is linked to the development process and the specific requirements of the system itself. Unfortunately, not all types of integration tests are easily automatable. While automated testing of a system's APIs can be implemented using contract tests, such as Pact, testing the user interface is more challenging to execute. However, this does not mean it's impossible, and one can utilize tools like Selenium for UI testing. Integration tests, in general, require a significant amount of human and machine resources for their implementation and execution.

4.4. Regression tests

Regression testing involves testing after changes, such as bug fixes, software modifications, or the addition of new features. Its purpose is to ensure that the changes introduced to the software have not introduced new errors. These tests also significantly increase the likelihood of identifying issues that were not visible before the changes were made. It's important to emphasize that such tests must be conducted in the same environment and scope as the tests mentioned earlier (Wydmański, 2023).

Automating regression tests, similar to integration tests, is a complex task. Regression tests often appear in later stages of implementation or may even be absent from the technological stack of a given team. As mentioned in the work by Sutapa et al. (2020), some of the most commonly used tools for assisting with the automation of regression tests include Selenium, SAHI, and Robot Framework. However, implementing effective automated regression tests requires careful planning, design, and integration into the development process to ensure that code changes do not inadvertently introduce new issues into the software.

4.5. Performance tests

Performance testing of software is typically conducted as the last phase of testing, following the resolution of defects detected in previous testing stages. Its purpose is to examine the behavior of an application or system under various load conditions. There are different types of performance tests that can be applied to projects with different characteristics. The following types of performance tests are distinguished: load tests, stress tests, scalability tests, spike tests, endurance tests, concurrency tests, and throughput tests (Performance Testing, 2023). The challenge in implementing performance tests lies primarily in selecting the areas that need to be tested. Performance testing can encompass the overall performance of the software, as well as specific aspects like network throughput or data flow. The nature of a specific application guides the choice of the most suitable type of performance tests. Performance testing may involve subjecting the server, database, or the application itself to various types of loads and conditions to evaluate its performance.

To conduct performance testing of software, commonly used tools include JMeter, LoadUI, Gatling, Fiddler, and LoadRunner. These tools assist in simulating various load conditions and scenarios to evaluate the performance of the software.

From the mentioned types of software testing, a conclusion can be drawn that implementing tests for most software types is possible but still highly complex. A natural approach to minimizing the risk of producing high-quality software is to ensure that testing is introduced as early as possible in the software development process. This helps keep technical debt at a low level. Unfortunately, the automation of software testing only seemingly reduces the workload for programmers and testers. In the case of a highly developed system undergoing intensive work, changes in the code can trigger a cascade of adjustments needed to align tests with new

realities. Automated software testing requires continuous monitoring and maintenance. This presents a kind of paradox, as automation is intended to reduce manual work. In certain cases, maintaining the automation itself becomes more costly than the initial assumptions. Therefore, a fundamental principle in writing software tests is to ensure their quality and adequacy, so that the number of tests doesn't increase uncontrollably without a corresponding increase in the quality of the developed software.

5. Artificial Intelligence in test automation

Currently, we are witnessing a strong interest in utilizing artificial intelligence (AI) to solve problems that are challenging to address using traditional approaches. In the context of test automation, efforts are also underway to harness artificial intelligence (AI) to develop testing methods that require minimal human involvement in creating and maintaining tests. The progress in utilizing AI in testing has been outlined in the work by Jenny Li and colleagues (Jenny Li, et al., 2020).

In general, AI is most commonly used for test automation in the form of:

- **Self-healing tests**: Traditional test automation tools have specific identifiers to define the components of an application such as locator, usually name, id, Xpath, and type, to run test steps successfully (Shabarish, 2023). When the application is updated or changed in any way, these components can also change. Due to the fixed definitions are given to these elements, the tests functioning fine before the change will now fail and provide a false negative result. Self-healing tests apply artificial intelligence algorithms to automatically identify unexpected errors due to dynamic properties and recommend a better alternative or automatically update the script. This testing stops tests from failing and saves the time a QA might have spent trying to find and fix the issue (Pandey, 2023).
- **Visual Locators**: Usually it is needed to write selectors to target the specific things while interact with during tests. Lots of them. Selectors are critical to test exactly what we are aiming for, but there are challenges. Not only we usually have to write quite a lot of them, but in some cases an obvious selector doesn’t even exist and it is necessary to rig up a creative workaround. It is possible to do it, but that kind of workaround is typically fragile and can easily break as the application develops (Shain, 2021). In AI-based user interface testing, visual locators can now find elements, even when their locators have been altered, on a web application by vision. This eliminates the need for hard coding with Accessibility IDs or other locators. Furthermore, intelligent automation tools can now use OCR and other image recognition techniques to map the application, locate visual regressions, or verify elements (Pandey, 2023).

– **AI Analytics of Test Automation Data**: AI drives automation, performs faster to identify errors and causes, suggests fixes and connect a set of related tests. This not only makes test automation faster but also more precise. AI is capable of automatically accessing data, running tests and identifying errors and other relevant affected tests (Chandrasekharan, 2023). The reason for such a state of affairs is generating by tests copious amounts of data that must be combed to derive meaning. The application of AI to this process dramatically increases its efficiency. More sophisticated applications of AI algorithms can also identify false negatives and true positives in test cases. This can be very helpful and significantly reduce the workload of QAs (Pandey, 2023).

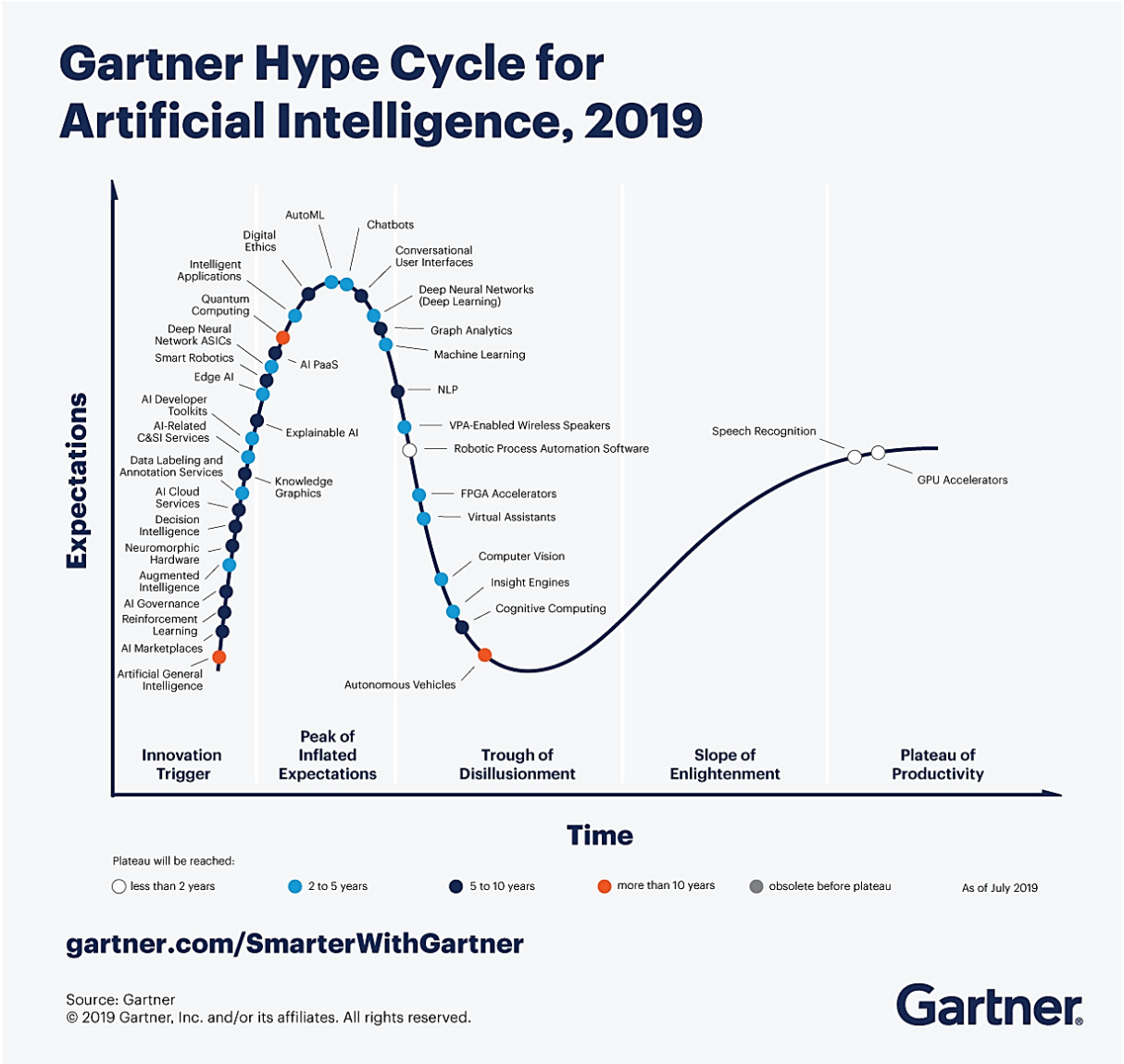

Figure 1. Gartner Hype Cycle for Artificial Intelligence in 2019.

Source: Gartner (2019).

AI-powered test automation is particularly beneficial in complex software projects where manual testing or traditional automation might fall short. However, it's important to note that while AI brings significant advantages, it's not a replacement for traditional testing practices

but rather a tool that enhances and complements them. Careful consideration of the application context, data quality, and ongoing training of AI models are essential for successful implementation.

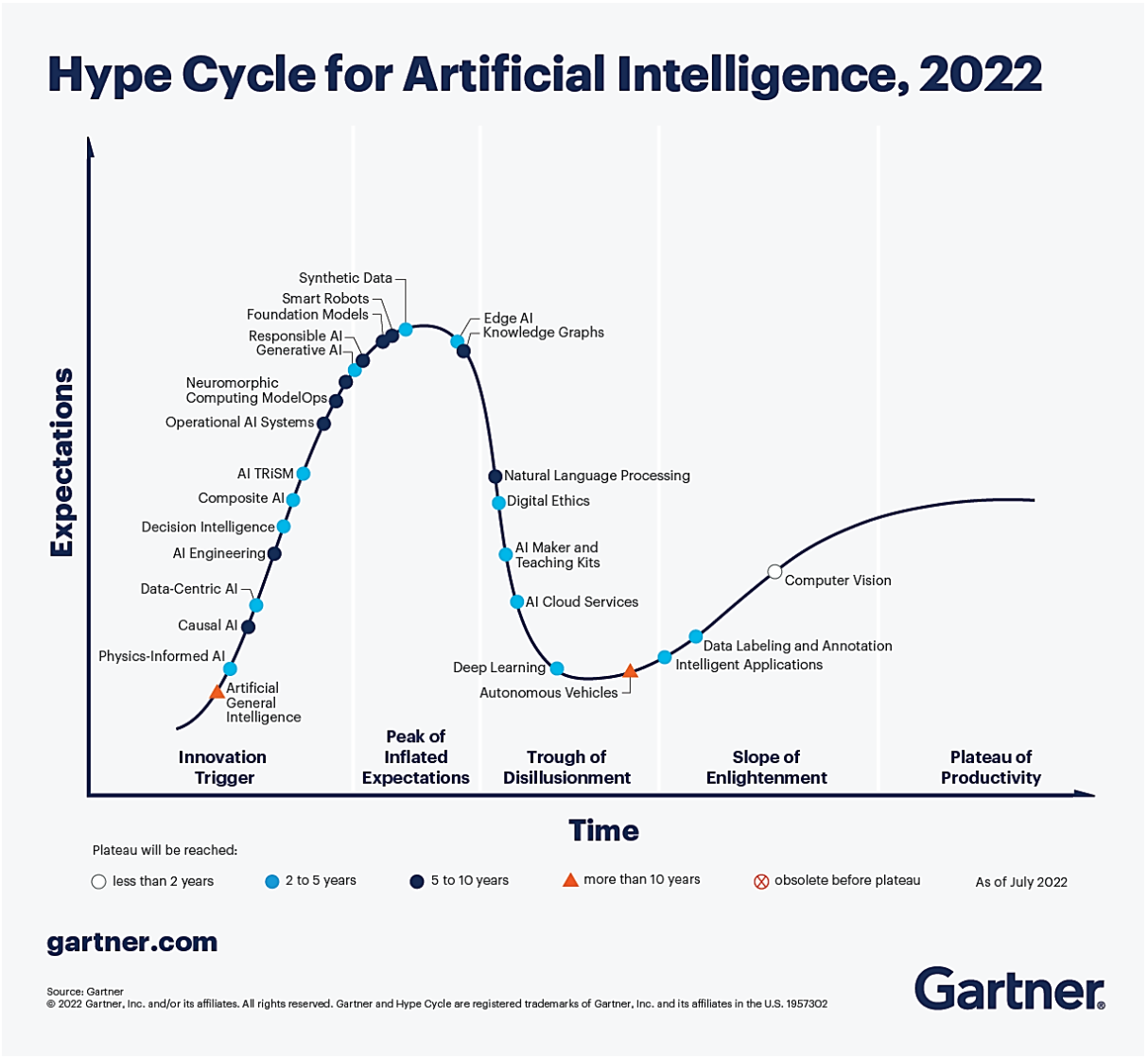

Figure 2. Gartner Hype Cycle for Artificial Intelligence in 2022.

Source: Gartner (2022).

Whether artificial intelligence (AI) will truly be able to assist in the automatic generation and updating of tests is currently difficult to determine, as we are in a peak moment of interest in AI. This is evident from the Gartner's Hype Cycle graphs for year 2019 shown in Figure 1 and in Figure 2 for year 2022. A specific sub-field, deep learning, has caused a lot of this excitement. The graph in Figure 1 indicates that we are in a period of high expectations regarding the potential use of AI. Year 2022 shows similar trends, most AI-related technologies are ahead of peak expectations. However, over time, expectations will likely become more realistic, and the AI technology itself will probably improve the situation related to test automation. It is noteworthy that in the two Gartner diagrams presented, there is no separate category for test automation using AI. The topic is placed in 2019 in the field of AI Developer

Toolkits, while in 2022 it is further generalized to AI Engineering. Both areas are still in the very early stages of development, estimated at five to ten years to mature. However, as always, it won't turn out to be a one-size-fits-all solution for all the challenges associated with it.

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CURRENT INFRASTRUCTURE AS A CODE AUTOMATION TRENDS IN CONTEXT OF CLOUD AGNOSTIC RESOURCE PROVISIONING

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Purpose: The aim of the research is to determine the maturity of the available tools for building Software as a Service (SaaS) services that enable automation of deployment to multiple cloud operators using a single infrastructure definition known as Cloud Agnostic.
Design/methodology/approach: The paper related to the development of areas of software engineering has been the automation of processes for building, testing, integrating, and delivering applications developed by large development teams. It has come to be known as continuous delivery process. We provided an overview of the tools available to automate infrastructure provisioning in Cloud Agnostic manner.
Findings: The research indicated that there are solutions on the market for building automation of cloud infrastructures, however, most of these are not geared towards achieving the Cloud Agnostic definition. One tool called Crossplane was researched, which was designed from the outset to enable Cloud Agnostic definitions for infrastructure provisioning. The research has shown that, as of today, the Kubernetes platform with an extension of Crossplane is the best approach to enable a loose attachment to a single cloud operator.
Originality/value: The proposal to use the Kubernetes platform with additional tools significantly reduces the risk of strong attachment to single operator cloud solutions. The proposed design approach can be helpful for IT system architects in decision making.

Keywords: strategy of infrastructure provisioning, infrastructure automation, software engineering, tool, Cloud Agnostic resource definitions.

Category of the paper: Research paper.

1. Introduction

In recent years, a strongly developing area of software engineering has been the automation of processes for building, testing, integrating, and delivering applications developed by large development teams. Work related to the development of these areas has come to be known as

continuous integration/continuous delivery processes, abbreviated CI/CD. Nowadays, it is no longer sufficient to compile source code into a form suitable only for traditional distribution, e.g. in the form of executable binary files, because the distribution process has changed significantly. In many cases moving towards a *Software as a Service* (SaaS) sales model. The ability to build SaaS applications is closely linked to the ever-increasing popularity of public cloud services provided by major IT players such as Google, Microsoft, Amazon, and Oracle. Many companies tie their commercial success directly to deploying their services on these environments rather than building their own on-premise computing center. This type of approach unlocks significant potential for companies that do not need to have large financial resources at the outset. Cloud services make it possible to spread costs over time and match them closely to current demand, increasing the scalability of investments. The use of public data centers eliminates the need to purchase hardware with a stockpile to ensure uninterrupted continuity of operation with the increasing volume of traffic generated by the customer of a given service.

2. Models of Infrastructure as a Code

The increased interest in cloud computing and the automation of software delivery has forced the cloud market to make available a suitable API and SDK to define hardware resources as code. Tools related to the automation of hardware resource orchestration have been called *Infrastructure as a Code* (IaaC). With usage of many programming languages, IaaC is responsible for provisioning and managing resources in data centers. The main premise of IaaC is to completely eliminate the manual provisioning and configuration of all resources by humans. This is intended to minimize human error and thus minimize the risk of errors in the application environment. Defining infrastructure as a code also ensures that complex enterprise execution environments can be built in a consistent, automated, fast and testable manner. IaaC automation unlocks human resources that can be allocated to other business tasks.

There are two approaches for building IaaC, closely related to the available programming paradigms (ScriptRock, 2015):

- *declarative/functional* approach,
- *imperative/procedural* approach.

The declarative approach involves providing the configuration in the form of a description of *what we want to have*. It is the task of the process performing the automation in question to know how to do it. The opposite approach is the imperative approach, which focuses on describing *how to get to the desired state instruction by instruction* (Loschwitz, 2014). So, in this approach, the programmer uses specific procedures that transform the environment to its final state.

Both approaches for building IaaC have their advantages and disadvantages. The imperative approach offers greater control over the automation process. The imperative language expression provides the necessary programming structures to allow alternative execution of specific procedures. However, in this approach it is very difficult to determine what the target infrastructure configuration should look like. The only way to determine this is by tracing the source code and trying to understand how it works. This problem does not occur with the declarative approach. As the name suggests, this approach inherently defines what we want our environment to look like, without providing instructions on how to get there. This description is completely devoid of instructions defining how to get to that state. The IaaC runtime environment hides the details of the execution of the definition. On the one hand, this is a very tempting assumption that naively relieves us of the compulsion to know how the process works. However, in practice it is often the case that the tool stack in a state where it is unable to transition to a desired new state. In such a situation, the team is relied upon to find a suitable solution to the problem, which many times provides to manually streamlining the process ad-hoc. This is an undesired situation, but unfortunately one that realistically occurs in practice.

Very important issue of IaaC is the problem of defining infrastructure in *Cloud Agnostic* manner. The Cloud Agnostic process has the basic characteristic that one common definition is independent of the specifics of a particular cloud service provider. This is a state that is very difficult to achieve, often due to differences in philosophy and tools provided by individual providers. The primary task of building Cloud Agnostic tools is to prepare IaaC definitions that loosely link us to one provider, allowing us to quickly convert to another provider. In an ideal approach, often not fully achievable, Cloud Agnostic assumes that a single code will work for all platforms (Copado, 2022).

3. Synergy of DevOps teams

The emergence of IaaC processes has also had a significant impact on the organization of the software development and maintenance teams themselves. The work of IT administrator's teams, hitherto understood as imperative, manual control of infrastructure configuration through partial automation in scripts, is slowly being transformed into a nature closer to that of IT developer's teams. This is becoming possible because IaaC and CI/CD, at its foundation, insists on replacing these practices in favor of a full, consistent description in the form of code, which will not be executed directly by humans, but by automations such as, for ex. Jenkins pipelines (Kim, Humble, Debois, Willis, 2016). This has led to the emergence of a new software development methodology called *DevOps* (Azad, Hyrynsalmi, 2023). This methodology recognizes the product as something broader than just software development, also including the processes of software integration, deployment (alternative delivery), maintenance in the

definition of the product. This methodology strongly unifies two teams hitherto seen as separate, creating multidisciplinary teams holistically responsible for the entire process of software development, testing and running in target environments (Kim, Humble, Debois, Willis, 2016).

Automation is a key enabler of business success, according to a study by Dynatrace, published in 2022 by CISO REPORT (Ciso Report, 2023). As many as 90% of the organizations surveyed indicated that the pressure for digital transformation has increased significantly in the last 12 months. At the same time, only 34% of the organizations surveyed have mature DevOps teams, while as many as 55% of organizations face tradeoffs among quality, security, and user experience to meet the need for rapid transformation (Ciso Report, 2023). These studies clearly indicate that the trend of building business success is strongly linked to the introduction of the DevOps model into an enterprise organization.

4. Heterogeneity of Infrastructure as a Code

The emergence of the concept of describing infrastructure in the form of code executed by computers has opened the path of rapid deployment, reducing the time from the publication of new functionality in the code repository to deployment in production to as little as several minutes. Once the changes have been committed to the code repository, the relevant processes, known as pipeline, run automatically testing the quality of the code, provisioning a temporary test infrastructure, and at the end instantly deliver the software to production environment.

The main problem with IaaC is finding the tools to create the required resources, often in heterogeneous environments, which can be a challenge. Typically, meeting a rapid implementation of DevOps methodologies that is cost optimal involves moving the on-premise infrastructure to the cloud. This is not an easy decision, with many factors to be analyzed that affect the ultimate success, from the obvious in the form of cost, to the availability of the necessary resources from a given cloud provider. Also important are legal regulations, forcing, for example, the storage of data in specific regions of the world, and the expectations of end customers, who often only agree to sign a contract if the SaaS hosting infrastructure will be in a specific cloud.

The foundation needed to describe the infrastructure in form of code is for the cloud provider to provide the appropriate tools. In the next chapter, we focus on briefly characterizing the available solutions used in the implementation of IaaC.

5. Cloud native tools for infrastructure automation

Without the right tools provided by the cloud provider, it is impossible to think seriously about infrastructure automation. They act as a fundamental doorway into the cloud, enabling developer interaction with resources. In this paper, we provide a brief overview of these tools available in the three most popular clouds: *Amazon AWS*, *Microsoft Azure* and *Google Cloud*.

5.1. Cloud Command Line Interfaces

The primary tool for interacting with clouds is the *Command Line Interface* (CLI), accessible from the operating system command line. Its most common use is in various shell/bash scripts. From the point of view of infrastructure administrators, it is the most natural choice, as it fits directly into the tools that these teams use on a daily basis. The CLI allows quick interaction from the operating system command line but is also well suited to automating selected processes in, for example, Jenkins pipelines.

Amazon AWS makes the *AWS CLI* (AWS CLI, 2023) available to users in two versions. The newer v2 version is a more extensive offering of its predecessor. The tool is available for all popular operating systems, like *Windows*, *macOS* and *Linux*. It is also available as a *Docker image*, removing the need to install the tool directly on the system. The AWS CLI delivers high functional coverage, allowing configuration and management of almost all offered AWS services. The AWS CLI also allows control over the output format, greatly enhancing the tool's ability to be used in scripts. Both human-readable and software-parsable formats are available: *JSON*, *YAML*, *YAML-stream*, *text*, *table*.

A similar tool is provided by Microsoft Azure, in the form of a CLI called ***az*** (Azure CLI overview, 2023). The tool is available for all leading operating systems like *Windows*, *macOS*, *Linux* and as a *Docker image*. It is also possible to use directly from a web browser in a service called *Cloud Shell*. Coverage of functionality is very high. However, a lot of functionality requires the installation of appropriate extensions called features. This can be inconvenient when writing automation scripts, as you always have to remember to install all the features you will need in the script. Unlike AWS CLI, Azure az has self-upgrade functionality.

The last featured service provider Google Cloud also has a CLI called *gcloud* (Install the glocud CLI, 2023). The tool also has very high functional coverage. It is available like its predecessors for all the platforms mentioned, including as a *Docker image*.

To some extent, each CLI reflects the ethos of their cloud. The AWS CLI is dense, powerful, and occasionally inconsistent. The Azure CLI is rich, easy to get started with, and sometimes more complicated than it should be. And the Google Cloud CLI is clean, integrated, and evolving. However, the differences in these tools and the shell character makes them ultimately a poor fit for mature Infrastructure automation solutions using IaaC. Shell scripts are difficult to analyze and document. Any corrections can be erroneous. Of course, there is no way

to have a Cloud Agnostic solution where one script can execute on all clouds. Wanting to cover multiple clouds we are forced to write multiple versions of scripts.

5.2. Cloud Software Development Kits

While in the case of the CLI, all platforms provide very similar functionalities, the case is more diverse in the case of the SDK. What is an SDK? An SDK is a *Software Development Library* prepared for a specific language or framework. An SDK allows the infrastructure to be defined in the form of imperative code.

Amazon AWS provides SDKs in as many as twelve programming languages, such as (Developer Tools, 2023): *Python*, *JavaScript*, *PHP*, *Java*, *C++*, *NodeJS*, *Go*, *Ruby*, *.Net*, *Kotlin*, *Rust*, *Swift*. However, AWS also provides specific SDKs for *web development*, *mobile development*, or *IoT*.

Microsoft Azure provides SDKs in languages such as Azure-sdk repository (Azure-sdk, 2023): *.Net*, *Go*, *C*, *C++*, *Java*, *JavaScript*, *Python*. Additionally, as with AWS, it provides specific SDKs for *Android* and *iOS*.

Google Cloud, also provides an SDK, but it works a bit differently. What Google calls the Cloud SDK is for using the gcloud CLI tool, and if you want to use a specific language or platform with GCP, then you use one of the hundreds of Google APIs (Google Cloud SDK, 2023). At the same time, Google provides libraries to support interaction with the APIs in languages such as *Java*, *Go*, *Python*, *Ruby*, *PHP*, *C#*, *C++*, *NodeJS*.

Providing SDK libraries to support interaction with cloud computing greatly facilitates the automation of the infrastructure, even allowing the relevant code to be embedded along with the application code. The application itself is given the ability to be aware of where it is installed and the state of the infrastructure. However, all the solutions mentioned above do not allow Clous Agnostic IaaC to be written easily. The differences between the libraries are very large and, in the case of Google cloud, they already differ at the level of operating philosophy. Thus, a solution using the SDK directly forces multiple implementations for each cloud separately. Therefore, achieving Cloud Agnostic IaaC is very expensive.

As with the CLI, answering the question of what the infrastructure contains requires a tedious process of analyzing the source code. This is strongly related to the imperative/procedural nature of programmatic solutions.

5.3. Other cloud specific IaaC tools

The difficulty of analyzing imperative code has forced the development of solutions based on declarative code. Declarative notation is much easier for humans to understand and, above all, much more efficient. The definition is more concise and less error prone. The declarative solution ensures high reproducibility and modularity. The following shows which declarative tools are provided by the three cloud providers.

Amazon AWS provides *CloudFormation* (CF) template functionality in *YAML* or *JSON* format. This is the most supported tool for automating the orchestration of resources by AWS. A CloudFormation template is a declarative record of the list of resources and their configurations to be deployed in the cloud. CF provides an appropriate layer of parameterization and modularity to the templates so that they can be reused. An important advantage of CloudFormation is that it offers the deepest level of integration with the AWS cloud, including features like Designer, which lets you create and modify CloudFormation templates directly on the AWS website. However, there are times when small parts of the infrastructure configuration are not available in the CloudFormation template. An example of this is the inability to create an encrypted version of the SSM Parameter. Although the presented problem with the lack of 100% functionality coverage is found in all described tools. CloudFormation also provides a high level of assurance that your templates will always remain compatible with AWS services, even if Amazon makes changes to its services. An example of a CF template is shown in Table 1. This is an example template that creates a subnet.

Table 1.
Example of AWS and Google templates for subnetwork provisioning

# AWS Cloud Formation template AWSTemplateFormatVersion: "2010-09-09" Metadata: Generator: "notepad" Parameters: SubnetCidr: Type: String Default: "10.0.0.0/24" Resources: mySubnet: Type: AWS::EC2::Subnet Properties: VpcId: Ref: myVPC CidrBlock: !Ref SubnetCidr AvailabilityZone: "us-east-1a" Tags: - Key: stack Value: production	*# Google Cloud template* resources: - name: myNetwork type: compute.v1.network properties: autoCreateSubnetworks: true - name: mySubnet type: compute.v1.subnetwork properties: ipCidrRange: 10.130.0.0/20 network: $(ref.myNetwork.selfLink) region: us-central1

Source: own work.

In Azure, two solutions are available to the user. The first is the *Azure Resource Manager* (ARM) templates, enabling declarative description of infrastructure in *JSON* format. They are an equivalent solution to Amazon CloudFormation, providing similar functionality, including template parameterization. However, Microsoft has gone further and designed a second tool called *Bicep*, which is its own domain-specific language (DSL) solution that provides a declarative description of infrastructure. An important advantage of Bicep is its immediate support for new functionality emerging from Microsoft's cloud. As soon as new resource types and API versions are introduced by the vendor, they can be used in the Bicep file, without having to wait for the tools to be updated before working with the new services.

The language has a simple syntax and compared to a *JSON* template, is more concise and easier to read. An example of a Bicep script is shown in table 2. Presented script creates an example subnetwork. Due to space constraints for the article, an example of the ARM template is not included, as it is based on *JSON*, which by its nature is quite large in a human-readable format.

Table 2.
Example of Azure Bicep template for subnetwork provisioning

```
param location string = resourceGroup().location
resource virtualNetwork 'Microsoft.Network/virtualNetworks@2021-05-01' = {
 name: 'sarahs-network'
 location: location
 tags: {
 Purpose: 'Example subnet'
 }
 properties: {
 addressSpace: {
 addressPrefixes: [ '20.0.0.0/16' ]
 }
 subnets: [
 {
 name: 'mySubnet'
 properties: {
 addressPrefix: [ '20.0.0.0/24' ]
 }
 }
 ]
 }
}
```

Source: own work.

Google Cloud also provides a very similar mechanism to both predecessors in the form of scripts written in *YAML* format. This solution has been given the name *Deployment Manager* (DM) template. Table 1 shows a comparison of the Amazon CloudFormation and Google DM templates. Both scripts create a sample subnet.

The tools shown are very similar in many aspects. However, they are not tools that can be used between clouds, as they are vendor specific. Thus, they have the same problem as already discussed SDK tools. Achieving a cloud agnostic definition requires simultaneous description in all tools.

6. Multicloud IaaC tools

The tools presented in the previous chapter are solutions provided by cloud service developers, thus focusing only on interaction with a specific cloud. They are as sufficient as possible in a situation where an implementation is only planned for one specific cloud. In a situation where there is even a slight assumption that the application under development will be delivered to more than one cloud, or where we are not sure which cloud to choose,

the use of the tools described above will prove to be a significant limitation increasing the cost of the entire project. Today, there are tools that try to solve the above limitation. Tools such as *Ansible*, *Puppet* or *Terraform* have been on the market for many years.

Ansible is widely considered to be simpler. Puppet is model-driven and was built with systems administrators in mind. It follows a client-server (or agent-master) architecture. You install Puppet Server on one or more servers and then install Puppet Agent on all the nodes you want to manage. With both tools user can only provision a subset of available resources on particular cloud. Ansible and Puppet requires the installation of specialized agent software inside the cloud to operate/execute definitions.

Terraform is essentially the first tool to move significantly away from the pure context of administrative work and was designed with the broader DevOps context in mind. Terraform can manage infrastructure on all major cloud platforms. The human-readable *YAML* language helps write infrastructure code quickly. Terraforms state allows you to track resource changes throughout your deployments. For smooth operation, Terraform definitions should be written to the code repository along with the current state. This is related to Terraforms operating model, which saves locally executed operations and compares them with the current state in the infrastructure. If you're using Terraform for a personal project, storing state in a single terraform.tfstate file that lives locally on your computer works just fine. But if you want to use Terraform as a team on a real product, you run into several problems (Brikman, 2016):

- *Shared storage for state files.* To be able to use Terraform to update your infrastructure, each of your team members needs access to the same Terraform state files. That means you need to store those files in a shared location.
- *Locking state files.* As soon as data is shared, you run into a new problem: locking. Without locking, if two team members are running Terraform at the same time, you can run into race conditions as multiple Terraform processes make concurrent updates to the state files, leading to conflicts, data loss, and state file corruption.
- *Isolating state files.* When making changes to your infrastructure, it’s a best practice to isolate different environments. For example, when making a change in a testing or staging environment, you want to be sure that there is no way you can accidentally break production.

The above issues need to be addressed in-house when building the automation of the processes that make up the infrastructure. However, the main drawback of Terraform in the context of Cloud Agnostic automation is that it abstracts definitions in a poor way. In essence, Terraforms definitions are often a one-to-one rewriting of the properties issued by the cloud providers' native APIs. Thus, the only thing we gain relative to the native API is that the multi-cloud definition is given a common form of notation and a central tool responsible for orchestration. Terraform lacks proper abstraction mechanisms to hide implementation details by exposing a simple API.

A separate problem with Terraform is the poor support for deploying applications to a pre-created infrastructure. This is done by injecting initialization scripts onto the virtual machine. The script is usually written as a shell script, leading to a mix of declarative infrastructure definition and imperative initialization scripts.

7. Kubernetes cluster as resource orchestration and execution environment

The decision to choose a cloud provider is a very difficult one. On the one hand, the use of native solutions available from a given provider is very tempting due to the relatively high ease of implementation and the predictability of costs at the time of the decision. On the other hand, a strong attachment to a provider's specific solutions raises concerns about over-dependence, which may result in no easy path out in the future to an environment offering better value for money.

Many companies, for this reason, are opting for a certain compromise to loosen their strong ties to a single cloud, choosing the *Kubernetes* computing cluster environment as their primary runtime tool. The use of Kubernetes as a *Platform as a Service* (PaaS) provides a universal abstraction layer to build independence and loosens many of the strong ties to the native services of a given provider. Each of the major cloud service providers mentioned has Kubernetes cluster as a PaaS offer. In the AWS cloud, this is the *Elastic Kubernetes Service* (EKS), Microsoft provides it in the form of *Azure Kubernetes Service* (AKS) while Google provides it as *Google Kubernetes Service* (GKE).

Kubernetes cluster is a portable, extensible open-source software platform for managing tasks and services running in Docker containers. Most importantly, Kubernetes works with declarative configuration and automation expressed in YAML files called manifests. The state of the environment itself is maintained directly on the cluster itself, thus bypassing many of the problems we encounter when using Terraform. With the requirement to use cloud agnostic definitions, using Kubernetes as an abstraction layer separating us from direct interaction with the cloud is a very welcome solution. On the one hand, our application definitions have one and the same record regardless of the cloud on which the cluster is installed, and on the other hand, it is Kubernetes in the form of the relevant drivers provided by the operator that knows how to scale the demand for virtual machines (VMs) or other specific resources.

However, the problem arises when there is a need to provision resources that Kubernetes itself does not support, e.g. registering a sub domain, running a database, etc. Pure Kubernetes is mainly an execution environment where the orchestration of the necessary resources is severely limited. The following chapter presents a solution to this problem, which extends Kubernetes' capabilities theoretically in an unlimited way.

7.1. Extending Kubernetes functionality with Crossplane

The developers of Kubernetes have predicted the possibility of extending functionality through so-called *Custom Resources* (CR) (Kubernetes, 2023). Custom Resource is an extension to the Kubernetes API that is not necessarily available in the default Kubernetes installation. It represents a customization for a specific Kubernetes installation. However, many core Kubernetes features are now built using custom resources, making Kubernetes more modular (Kubernetes, 2023). CRs can appear and disappear in a running cluster through dynamic registration, and cluster administrators can update CRs independently of the cluster itself. A CR is simply customized structured data. In order to perform additional operations on it, there must be a process to enforce it. This process is the Custom Controller, which performs programmed actions based on the CR. Custom Controller is a specialized Kubernetes Pod, that is observing changes in CRs and respond accordingly to them.

The aforementioned functionality is the basis of the Crossplane tool (Crossplane, 2023). The purpose of Crossplane is to extend the Kubernetes cluster with the ability to provision any resources outside the cluster. This is all done using the same *YAML* manifests when configuring the environment. Crossplane provides extensions to Kubernetes Custom Resources, while also providing the corresponding Custom Controllers responsible for executing these definitions. The advantage of this solution lies in a unified way of deploying the application and instantiating the resources for that application. One common *YAML* manifest format combines both tasks into a single process. Previously described tools unified writing in only one of these areas: deployment or resource orchestration. Kubernetes with Crossplane combines both areas into one consistent mechanism based on *YAML* manifests. Let's take a look at the principles of Crossplane.

Crossplane introduces multiple building blocks that enable you to provision, compose, and consume infrastructure using the Kubernetes API. These individual concepts work together to allow for powerful separation of concern between different personas in an organization, meaning that each member of a team interacts with Crossplane at an appropriate level of abstraction.

The primary concept for extending the Kubernetes API is the *Composite Resource Definition* (XRD) (Crossplane, 2023). The purpose of the XRD is to define the details of the exposed API, which will then be used for resource provisioning. XRD provides the ability to define a cloud agnostic interface that will be translated into appropriate compositions. In order to be able to transform the XRD into specific resources, Crossplane provides the concept of *Composition*. This is an entity whose task is to define particular resource orchestration for given XRD. Composition is executed after the user provides proper *Claim* for particular XRD. Each XRD can have multiple Compositions, where each Composition can be responsible for handling different clouds. A Composition uses the appropriate *Providers* to perform the operation. Providers are implemented by open-source teams as well as by many companies,

including cloud providers. Often, Providers are using internally native APIs, like SDK or CLI prepared by cloud vendor. The task of the Provider is to expose the corresponding API and their execution mechanisms in the form of a Pod running in Kubernetes (Crossplane, 2023).

Let's look at an example in which we will build a Cloud Agnostic API for network provisioning across two clouds: AWS and Azure. Both clouds provide a very similar concept, however the implementation differs between the two. For example, Azure requires a *Resource Group* to be indicated for entities being created which is not the case in AWS. We want to encapsulate these differences in a single consistent definition of XRD. A basic, very simple example is shown in Table 3. The code on the left defines an API scheme for networking. It assumes the existence of three specific properties {region, addressSpace, subnetCidr}. The right-hand side of Table 3 shows an example of the *Claim* that is used to create a network by end user. *Claim* provides information from the user as to what environmental parameters he is interested in. It is an API prepared for the end user. All implementation details are not visible. In the presented example, the user indicates only three available settings.

Table 3.
Example XRD definition of API for subnet provisioning with corresponding Claim for a resource

```
# XRD definition API for networking
apiVersion: apiextensions.crossplane.io/v1
kind: CompositeResourceDefinition
metadata:
 name: xnetworks.example.com
spec:
 group: example.com
 names:
 kind: XNetwork
 plural: xnetworks
 versions:
 - name: v1alpha1
 served: true
 referenceable: true
 schema:
 openAPIV3Schema:
 type: object
 properties:
 spec:
 type: object
 properties:
 region:
 type: string
 addressSpace:
 type: string
 subnetCidr:
 type: string
```

```
# Claim for network
apiVersion: example.com/v1alpha1
kind: XNetwork
metadata:
 name: exampleNet
spec:
 compositionSelector:
 matchLabels:
 cloud: aws
 region: eu-central-1
 addressSpace: 10.40.0.0/16
 subnetCidr: 10.40.32.0/19
```

Source: own work.

The above *Claim*, shown in table 3 is executed by the corresponding *Composition*. Since the example supports two clouds then through the compositionSelector field inside the *Claim* we indicate which composite is to be used to create the resource. The example *Compositions* code is shown in table 4.

Table 4.
Example of two compositions for subnetwork XRD covering AWS and Azure clouds

# XRD definition API for networking apiVersion: apiextensions.crossplane.io/v1 kind: Composition metadata: name: azure.xnetworks.example.com labels: cloud: azure spec: compositeTypeRef: apiVersion: exaple.com/v1alpha1 kind: XNetwork resources: - name: resource-group base: apiVersion: azure.upbound.io/v1beta1 kind: ResourceGroup metadata: name: resource-group patches: - type: FromCompositeFieldPath fromFieldPath: spec.region toFieldPath: spec.forProvider.region - name: vnet base: apiVersion: network.azure.upbound.io/v1beta1 kind: VirtualNetwork spec: forProvider: resourceGroupNameSelector: matchControllerRef: true patches: - type: FromCompositeFieldPath fromFieldPath: spec.region toFieldPath: spec.forProvider.location - type: FromCompositeFieldPath fromFieldPath: spec.addressSpace toFieldPath: spec.forProvider.addressSpace[0] - name: subnet base: apiVersion: network.azure.upbound.io/v1beta1 kind: Subnet spec: forProvider: resourceGroupNameSelector: matchControllerRef: true virtualNetworkNameSelector: matchControllerRef: true patches: - type: FromCompositeFieldPath fromFieldPath: spec.subnetCidr toFieldPath: >- spec.forProvider.addressPrefixes[0]	*# Subnet Composition for Azure* apiVersion: apiextensions.crossplane.io/v1 kind: Composition metadata: name: aws.xnetworks.example.com labels: cloud: aws spec: compositeTypeRef: apiVersion: exaple.com/v1alpha1 kind: XNetwork resources: - name: vpc base: apiVersion: ec2.aws.crossplane.io/v1beta1 kind: VPC patches: - type: FromCompositeFieldPath fromFieldPath: spec.region toFieldPath: spec.forProvider.region - type: FromCompositeFieldPath fromFieldPath: spec.addressSpace toFieldPath: spec.forProvider.cidrBlock - name: subnet base: apiVersion: ec2.aws.crossplane.io/v1beta1 kind: Subnet spec: forProvider: vpcIdSelector: matchControllerRef: true patches: - type: FromCompositeFieldPath fromFieldPath: spec.region toFieldPath: spec.forProvider.region - type: FromCompositeFieldPath fromFieldPath: spec.subnetCidr toFieldPath: spec.forProvider.cidrBlock

Source: own work.

Note that the XRD hide the programming details of how to provision individual resources. The abstract XRD presented for networking is very concise and readable. Its implementation translates differently on different clouds. In the case of AWS, two resources will be created: *Virtual Private Network* (VPC) and *Subnet* inside the VPC. Azure requires three entities to achieve the same functionality. Firstly, we need to create a *Resource Group* (RG), in which we then place a *Virtual Network* (VNet) and one *Subnet*. All resources are listed in the resources section of the *Composition*. Parameter values supplied by the user from Claim are rewritten by the patches sections. The presented patches are a small sample of the possibilities offered by this mechanism.

The *Composite* itself indicates what type it implements in the compositeTypeRef field. Both compositions shown indicate the same XNetwork type. The final indication of which Composition is to be executed by the Crossplane is done by appropriately labelling it in the metadata section.

In figure 1 is presented a conceptual diagram showing the relationship between the Crossplain components. The DevOps team provides an XRD to the Kubernetes cluster describing the APIs available to end users and a set of Compositions that define in detail how the APIs are to be orchestrated. In the diagram from Fig. 1, the DevOps team has provided one XRD and two *Compositions*, using two different *Providers*, Azure and AWS. The respective Azure and AWS Providers were also previously installed on the cluster.

Consumer of a service deploys to Kubernetes *Claim* manifest with specification for requested service. In the example from Fig. 1, the *Claim* points to the AWS environment. Thus, the request will be handled by the respective *Provider*, which, based on the *Claim*, will provision the required resources in the AWS cloud. At the same time, the Composition provides information on which applications are to be installed in the Kubernetes cluster itself.

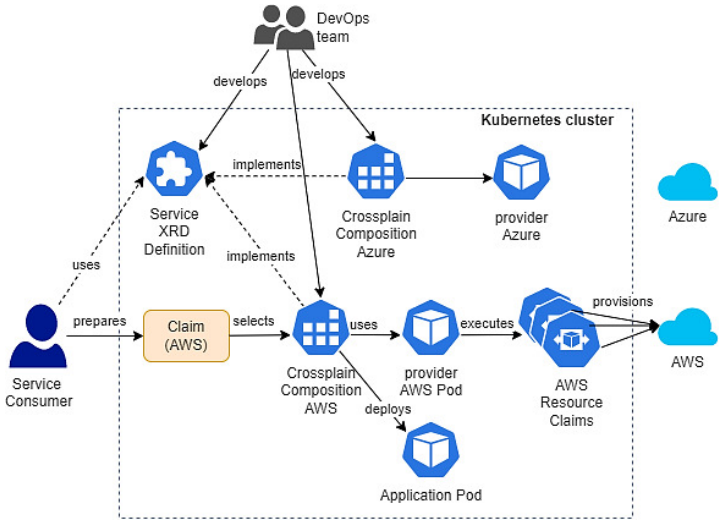

Figure 1. Diagram presenting the conceptual relations between Crossplain components in a Kubernetes cluster

Of course, we are in no way restricted to mixing resources from different clouds in a single *Composition*.

Each resource described in the *Composition* throughout its life cycle has a corresponding record on the Kubernetes cluster. This record stores the required state of the resource. This state is continuously monitored by Crossplane providers and, if differences are detected between the resource and its description in the cluster, the appropriate steps are executed. Through the Kubernetes cluster, Crossplane manages the entire life cycle of resources created in and outside the cluster. Removing *Claim* from the cluster also removes any resources created by it.

The example above illustrates how Crossplane extends Kubernetes functionality to create resources outside the cluster itself. This provides a uniform record of infrastructure definition and application deployment via *YAML* manifests. A state in which an API has been exposed that enables the application to run as a uniform record of the resource list and application deployment, e.g. in the form of a *Helm Chart Release*, is desirable. The orchestration of all elements is overseen by internal mechanisms that manage the lifecycle of Kubernetes objects. Thus, we gain a mechanism to prevent manual changes to the infrastructure, which is one of the requirements for well-designed automation of execution environments.

8. Conclusions

In the article, we provided an overview of the tools available to automate infrastructure. The IaaC problem is not an easy one to solve, particularly if you do not want to be strongly tied to a specific cloud provider. Achieving Cloud Agnostic status is much more difficult than automating within a single provider. In this case, it is not possible to design an effective automation process using the tools that the cloud provider provides. This is because these tools only work within a given provider, so we are forced to duplicate automation by specializing it based on different tools.

Tools that can automate across multiple cloud providers simultaneously may provide a solution to this problem. In particular, Terraform is a good solution. While Terraform provides a common format for declaring resources across multiple clouds simultaneously, it does not provide the ability to hide implementation details. In addition, Terraform was primarily developed for the purpose of automating infrastructure orchestration, and thus provides poor mechanisms for installing applications on the referenced infrastructure.

The most mature solution that meets the requirement for automation in isolation from the specifics of cloud providers' gives Kubernetes in combination with Crossplane. Pure Kubernetes successfully provides mechanisms for automating application deployment. In fact, it was primarily developed for such purposes. The only requirement to run a given application on a Kubernetes cluster is to package the application in an appropriate Docker container. Enriching Kubernetes with Crossplane extends the functionality of the cluster with the possibility of interacting with the external environment. Thus, we get a consistent, central

place where we manage the application as well as the infrastructure in a uniform way. All automation is written in the form of *YAML* manifests. The DevOps team simultaneously works on both infrastructure and deployment declarations, publishing the whole solution as a corresponding package. The definition itself is stored on the Kubernetes cluster providing a unified API. Deployment details are hidden behind the corresponding Compositions, providing the user only with a simplified XRD. At the moment presented solution seems to be most mature design when Cloud Agnosticism is key point on a list of requirements.

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DUAL INGRESS ARCHITECTURE DESIGN PATTERN FOR KUBERNETES APPLICATIONS

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Purpose: The article focuses on the analysis of the mechanism for exposing Services running on a Kubernetes cluster using an Ingress type definition. It discusses the basics of this mechanism, pointing out its fundamental limitation of being able to use only single technology simultaneously in handling traffic to a web application. The paper presents an architectural pattern that enables the simultaneous integration of two Ingress definitions, combining the advantages of both systems used.
Design/methodology/approach: Available solutions for exposing applications served in the Kubernetes cluster were analyzed. As a result of the research, an enhancement was proposed to allow the use of two services simultaneously, providing broader system functionality.
Findings: An approach was proposed to use two Ingress controllers simultaneously in the form of an external cloud service and an internal Nginx service running on a Kubernetes cluster.
Originality/value: A design pattern is presented along with an example implementation of dual Ingress on an AKS cluster **in Azure.**

Keywords: Kubernetes, Ingress, architectural pattern, limitations, Azure, Application Gateway, Nginx.

Category of the paper: Research paper**,** Technical paper.

1. Introduction

The Kubernetes cluster is becoming a mainstream global technology, according to a survey conducted by the *Cloud Native Computing Foundation* (CNCF). As many as 96% of the organizations surveyed indicated that they are using Kubernetes or are in the process of evaluating its capabilities (CNCF Annual survey, 2021). Of these, more than a quarter of respondents indicated that they are using Kubernetes as a cloud service provided by major cloud operators in the global market.

The growing popularity is linked to the provision of solutions that allow for an easily scalable environment compared to applications running on virtual machines. Kubernetes is gaining in proportion to the increasing popularity of application containerization. It keeps code operational and speeds up the delivery process. The Kubernetes API allows automating a lot of resource management and provisioning tasks. According to IBM, the most important factors influencing the choice of Kubernetes are (Top 7 Benefits of Kubernetes, 2022):

- Container orchestration savings,
- Increased DevOps efficiency,
- Deploying workloads in multicloud environments,
- More portability with less chance of vendor lock-in,
- Automation of deployment and scalability,
- App stability and availability in a cloud environment,
- Open-source benefits of Kubernetes.

In this paper, I focus on presenting the problem of making an application running in a Kubernetes cluster accessible to an external environment using the *Ingress* mechanism. Kubernetes *Ingress* is the basic tool that defines access to an application from the outside. Production use of this mechanism requires support in the form of external resources, usually provided by a cloud operator. In this paper, I outline what the basics of *Ingress* are and its limitations. Additionally, I present a way to circumvent the limitation of single *Ingress* per Kubernetes *Service*, allowing two Ingress mechanisms to be used simultaneously for a designated application service running on a cluster.

2. Kubernetes Ingress basics

An *Ingress* is a native Kubernetes object that defines external access to a Service running on a cluster (Burns et al., 2022). The *Service* object itself groups multiple *Pods* under one common type. The task of the *Ingress* manifest is to define a set of rules that govern inbound connection mapping between *Services*. This mechanism consolidates the routing rule to *Services* into a single resource. This routing is based on layer seven of the ISO/OSI model. Without the *Ingress* mechanism, each *Service* to be accessed outside the cluster would require to use separate definitions of e.g. *LoadBalancers* or *NodePorts*. *LoadBalancer* and *NodePort* exposes a service by specifying that value in the service's type. This limitation is particularly challenging for applications designed in microservices architecture. This definition makes it impossible to expose the entire application under one common URL because each new *LoadBalancer* will receive a separate IP address.

Ingress, on the other hand, is a completely independent resource to your *Service*. This makes it decoupled and isolated from the *Services* you want to expose (Burns et al., 2022; Palmer, 2023). An *Ingress* is used when we have multiple *Services* and we want the outbound requests routed to the *Service* based on URL path. Consider an example with two *Services*, *S1* and *S2* in a cluster. Then, for URL myservice.com/s1 we want to route to the *S1 Service* and accordingly for URL myservice.com/s2 we want to expose *Pods* served from *S2 Service*. These routings will be performed by an *Ingress*. Unlike *NodePort* or *LoadBalancer*, *Ingress* is not actually a type of *Service*. Instead, it is an entry point that sits in front of multiple services in the cluster. Figure 1 shows a diagram of how *Ingress* works showing the links between Kubernetes entities. In the example shown, *Service S1* groups two *Pods* of a single *Web1* web application. This way, traffic can be balanced between multiple *Pods*.

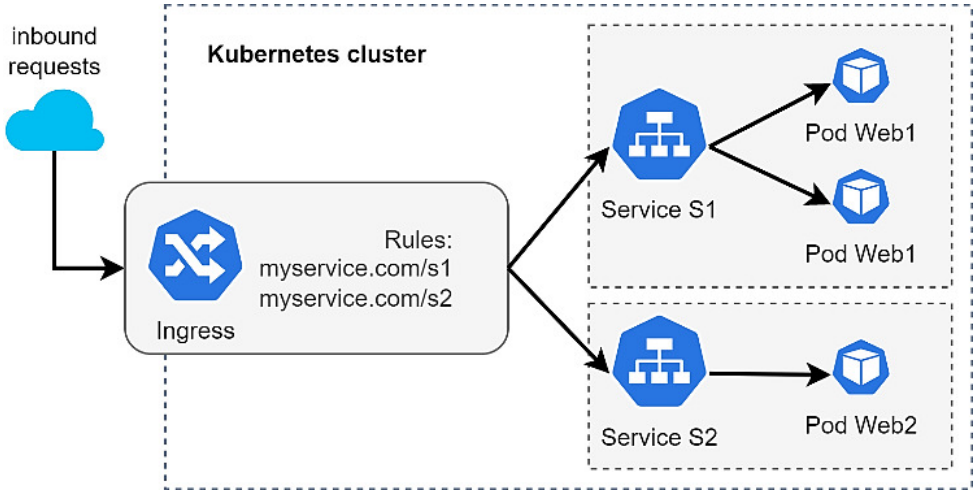

Figure 1. Diagram showing the links between Kubernetes Ingress, Services and Pods.

To use the above mechanism, it must be supported by the environment on which Kubernetes is running. This is because, to function, *Ingress* needs to access the network interface on which external traffic will be handled. By default, the cluster does not have this access, as this is resolved differently in each environment/cloud. Thus, it is the duty of Kubernetes administrators to provide and configure the appropriate mechanism. It is done by installing the appropriate *Ingress Controller*. The most popular *Ingress Controller* is the *Nginx Ingress* (Nginx docs, 2023). This is evident from the direct support by major cloud providers such as AWS, Azure and Google Cloud. The necessary support that cloud operators provide is related to the implementation of specific *Ingress Controllers* that tie the *Nginx* server to external services available in each cloud. In the case of AWS EKS, *Nginx* works alongside the *AWS Load Balancer* (Provide externall access…, 2023). In the case of Microsoft Azure AKS, the native service called *Azure Load Balancer* is used (Microsoft learn: Create an ingress, 2023). Correspondingly, Google Cloud integrates the *Google Cloud L4 Load Balancer* with *Nginx* (Ingress with Nginx, 2023). As can be seen, each of the indicated cloud operators by default uses its own service based on load balancer functionality to integrate with Nginx-based Ingress. This limitation will be further elaborated in the next section.

3. Motivation for research

However, the solution described above has a drawback. When using *Nginx Ingress*, we bind ourselves to a specific physical implementation that the cloud operator uses to integrate with cluster. Typically, it is some kind of a layer four based load balancer. In my example, I will focus on the solution offered by Microsoft Azure. *Load Balancer* provided by Azure is not the only service that can be used here. Other services that Azure offers are *Traffic Manager*, *Front Door* or *Application Gateway*. Each of these services has its own specialized application. The *Load Balancer* itself in Azure operates at layer four of the ISO/OSI model. In Azure, we also find a more tailored service for the requirements of web application/RESTful traffic, which is the *Application Gateway* (AppGw) (Microsoft learn: What is Azure Application Gateway, 2023). *AppGw* has the advantage of working on layer seven of the protocol. However, its advantages do not end there, as *AppGw* in Azure can be extended with a few additional functionalities, such as *Web Application Firewall* (WAF), autoscaling, high availability, URL-based routing, SSL encryption, SSL termination, Cookie-based affinity. With the above in mind, Microsoft Azure provides an *Ingress Controller* for Kubernetes clusters that directly uses *AppGw*. This service is called *AGIC* and is a direct alternative to *Nginx+Load Balancer*. The question here is which solution to use? Officially, you have to decide on one of these services, so when designing the system architecture, the designer has to decide between *Ingress* based on *Nginx+Azure Load Balancer* or *Ingress* based on *Application Gateway*.

Both solutions have many important functionalities. Some of these are available in both solutions. However, some functionalities are only available in one of the solutions exclusively. An example of this is the WAF available in *AGIC*, which is not available in the pure *Nginx Ingress Controller* solution. The WAF functionality is highly desirable for applications with strong IT system security requirements. A web application firewall is highly effective for detecting or preventing web attacks, leveraging the OWASP ModeSecurity Core Rule Set. For example, it can protect web applications from cross-site scripting and SQL injection attacks. On the other hand, *Nginx* provides many functionalities that are not directly available in *AGIC*. Using *Nginx* as an *Ingress Controller* allows you to take advantage of Single Sign-on (SSO) or provides a powerful mechanism for dynamic reconfigurations possible directly from Kubernetes manifests.

With the above in mind, there are situations where the architectural design would indicate the need to use both solutions simultaneously. Such a configuration offers the possibility to implement richer functionality by combining the features of both solutions. However, there is no documented method to achieve this. There is no such *Ingress* manifest definition that could integrate both solutions into a common functionality. In the following section, I present the architecture design pattern with its example implementation that combines both solutions. The key task of the discussed solution is to enable control of the entire system via Kubernetes manifests. Additionally, discussed architecture proposal gains a more elaborate model for the division of responsibilities between the DevOps and Security teams which is discussed in the next chapter.

4. Architecture pattern proposition for Dual Ingress Controller

To address the need to use both *Ingress Controllers* simultaneously, I present a two-tier *Ingress* architecture for a service running on an Azure AKS cluster. The simultaneous use of the *Application Gateway* and the *Nginx Ingress Controller* provides broader functionality and greater flexibility over standard solutions. Figure 2 shows an architectural diagram of the presented system.

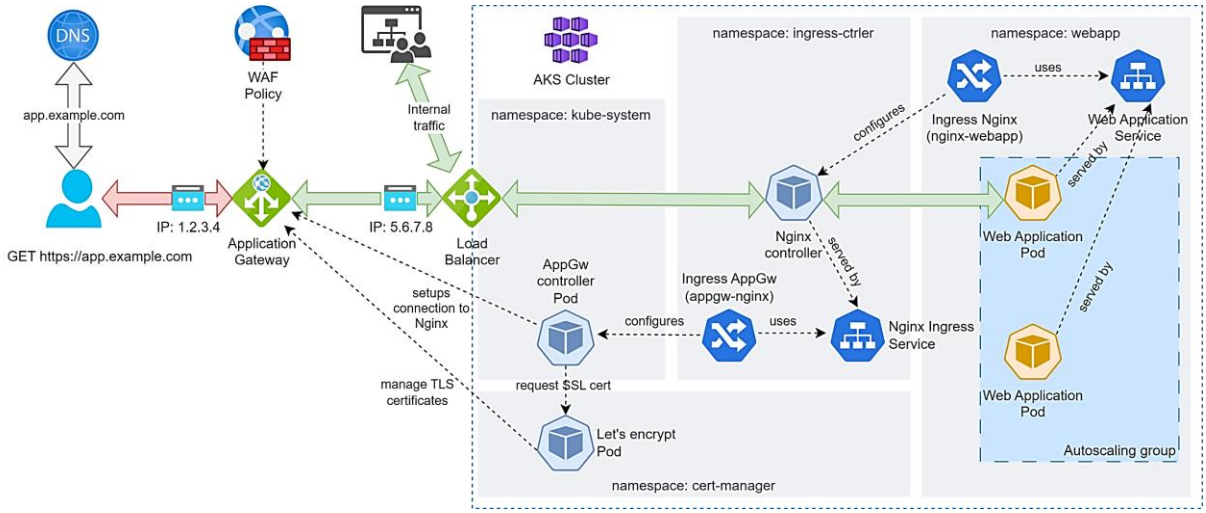

Figure 2. Diagram presenting Dual Ingress architectural pattern. Proposed design uses Application Gateway as an entry point for application and simultaneously Nginx Ingress controller. Diagram describes relations between all entities in presented pattern.

The main functional objective of the system is to run any web or RESTful system on the Kubernetes cluster. In the diagram from figure 2, the target application is installed in the namespace webapp. It consists of two *Pods* and a standard Kubernetes *Service* definition pointing to the application. The described scenario is the standard way how applications are deployed and served from Kubernetes cluster. An example of such a definition is presented in table 1.

The detailed routing to the above application, which will take place on a URL basis, is implemented on the *Nginx Controller*. For this purpose, the controller must be installed on a cluster. In the case of Azure AKS, the controller installation procedure described in (Microsoft learn: Create an ingress controller in AKS, 2023) can be used. In presented example, the Nginx controller is installed in the namespace ingress-ctrler as shown in the diagram in figure 2. The Nginx controller installation consists of a *Pod* on which the Nginx server is running and its own *Service* object. This *Service* directly integrates with the Azure *Load Balancer*. Thus, any network traffic passed to the *Load Balancer* input is effectively passed to the *Pod* with the *Nginx* server configured as reverse proxy. The second very important role of the aforementioned *Pod* is to observe the *Ingress* objects created on the cluster, which specify the ingress class on nginx in the spec.ingressClassName field of the manifest. An example of an *Ingress* definition linking the web application service to the *Nginx* controller is presented in table 2. The purpose of this manifest is to specify the URL path under which the web application is to be accessed externally.

Table 1.
Example Kubernetes manifests for application deployment. On left an deployment for example web application, on right Service definition

```
apiVersion: apps/v1
kind: Deployment
metadata:
 name: webapp-hw
 namespace: webapp
spec:
 replicas: 2
 selector:
 matchLabels:
 app: webapp-hw
 template:
 metadata:
 labels:
 app: webapp-hw
 spec:
 containers:
 - name: webapp-hw
 image: mcr.microsoft.com/azuredocs/aks-helloworld:v1
 ports:
 - containerPort: 80
 env:
 - name: TITLE
 value: "Example WebService"
```

```
apiVersion: v1
kind: Service
metadata:
 name: webapp-hw
 namespace: webapp
spec:
 type: ClusterIP
 ports:
 - port: 80
 selector:
 app: webapp-hw
```

Source: own work.

The next step required to implement the Dual Ingress architecture is installing the *AppGw* controller (AGIC). The *AGIC* controller itself is installed in the Kubernetes cluster as a corresponding AKS extension. It is an internal Azure mechanism that installs according to the instructions available in (Microsoft learn: Creating an ingress controller wit new Application Gateway, 2023), either as an Add-On or a Helm package. The execution of this instruction provides the necessary *AGIC Pod* to the namespace of the kubernetes-system and creates a physical *Application Gateway* in Azure. The installed *AGIC Pod* has a similar role to the *Nginx* controller *Pod*. The task of this *Pod* is to observer the *Ingress* manifests for definitions that indicate the ingress class as azure/application-gateway in the kubernetes.io/ingress.class annotation.

To perform the integration of the two *Ingress* controllers, we need to link the two *Services* to each other in an appropriate manner. Unfortunately, it is not possible to indicate in the *Ingress* definition prepared for the *AGIC* to redirect to another *Ingress*, in our case to the *Nginx Ingress Controller*. The main limitation of *Ingress* definitions is that only objects of type *Service* can be exposed as the target object. This is the primary reason for the lack of solutions that present the possibility of using both mechanisms simultaneously.

Table 2.
Nginx based Ingress manifest exposing Service webapp-hw on URL app.example.com

```
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
 name: nginx-webapp
 namespace: webapp
 annotations:
 nginx.ingress.kubernetes.io/ssl-redirect: "false"
 nginx.ingress.kubernetes.io/use-regex: "true"
 nginx.ingress.kubernetes.io/rewrite-target: /$1
spec:
 ingressClassName: nginx
 rules:
 - host: app.example.com
 http:
 paths:
 - path: /(.*)
 pathType: Prefix
 backend:
 service:
 name: webapp-hw
 port:
 number: 80
```

Source: own work.

Table 3.
Kubernetes Application Gateway based Ingress manifest exposing Nginx controller Service on URL app.example.com. Ingress definition also contains TLS section for encryption and certificate provisioning by Let's Encrypt

```
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
 name: appgw-nginx
 namespace: ingress-ctrler
 annotations:
 kubernetes.io/ingress.class: azure/application-gateway
 cert-manager.io/cluster-issuer: letsencrypt-appgw-http
spec:
 tls:
 - hosts:
 - app.example.com
 secretName: appgw-cert-secrets
 rules:
 - host: app.example.com
 http:
 paths:
 - path: /*
 pathType: Prefix
 backend:
 service:
 name: nginx-ingress-controller-svc
 port:
 number: 80
```

Source: own work.

However, there is a way around this problem and integrate *AGIC* and *Nginx* into a two-tier ingress architecture. To do this, we can take advantage of the fact that the *Nginx Controller* also has its own Kubernetes *Service* object. It is defined in the ingress-ctrler namespace as a mechanism to bind the *Azure Load Balancer* to *Nginix Pod*. In the solution discussed here, I use this definition directly to bind the *AGIC Ingress* to the *Service* of Nginx controller. Such a configuration is shown in the diagram in figure 2. An example implementation of *Ingress* pointing to *Nginx* is shown in table 3. It is important that the *Ingress* definition for the *AGIC* is defined in the ingress-ctrler namespace. This is necessary because the *Ingress* itself can only point to the target *Service* from the same namespace. This does not cause major complications, as *Ingress* controllers are implemented in such a way that they observe the corresponding manifests in any namespace. Using such a solution makes it possible to link the two mechanisms into a chain of two *Ingress Controllers* running one after the other. The *AGIC* acts as a direct external interface where network traffic goes at first to the application. This traffic is then redirected to the internal *Load Balancer* via the *AGIC Ingress*, which points to the *Nginx Controller* as the next step in the network traffic path. The *Nginx* server redirects the traffic in the second step directly to the *Pod* of the target application that handles the user's request. Thus, we have a two-tier architecture for handling network traffic, connecting all the mechanisms available in both *Ingress* controllers.

There are many advantages of this solution, the most important of which I outline below.

4.1. Web Application Firewall as SaaS

The first advantage is the ability to use the *Web Application Firewall* (WAF), which is provided as a SaaS service by Azure. This is a very sophisticated system that enhances the security of a web-based system, with the aim of detecting and responding to anomalies in network traffic. It is important to note that the system administrator does not need to be a high-level expert in this area, as *WAF* uses the OWASP ModeSecurity Core Rule Set providing recommendations available for use. The separation of the *WAF* functionality as a SaaS service available outside the cluster also allows for easier separation of duties for the DevOps and Security teams. The Security team defines the necessary security definitions directly on *AppGw* and *WAF*, without the need to interfere with the Web application itself or the Kubernetes cluster. On the other hand, the DevOps team uses the *Nginx* service to implement the functional rules. In this situation, access to the security rules defined on *AppGw+WAF* may not be available to the DevOps team, as they will deploy their functional rules on Nginx instead. This increases the level of security by narrowing access to defined rules only by Security team.

4.2. SSL offload

Another important asset of the proposed architecture is SSL offloading. SSL offloading is the process of removing the SSL-based encryption from incoming traffic that a web server receives to relieve it from decryption of data. The entire encryption effort has been moved off the cluster to *AppGw*. Network traffic has been secured to the first device, while in many situations internal network connections do not need to be encrypted. This relieves the end devices of additional power requirements, thereby increasing the throughput of the solution and reducing costs.

4.3. Automated TLS certificate renewal

Using HTTPS connection encryption requires obtaining a certificate with which the connection will be encrypted. Since in the solution presented here, all encryption handling has been moved to *AppGw*, we can use the *cert-manager* that works with this service. The *cert-manager* provided by Let's Encrypt can integrate with Azure *AppGw* by installing the corresponding controller on the Kubernetes cluster. For this purpose, the Let's Encrypt *Pod* was installed in the namespace of cert-manager according to the documentation available in (Microsoft learn: Use TLS…, 2023). The *cert-manager* mechanism observes the *Ingress* definitions created for *AppGw* and, when a definition is detected that indicates the need to enable TLS, performs the appropriate steps to automatically acquire a trusted certificate prepared by Let's Encrypt certificate authority. An example of such a link is shown in table 3. The corresponding annotation of cert-manager.io/cluster-issuer and the spec.tls section informs the *cert-manager* mechanism to acquire a certificate and handle encrypted HTTPS traffic. This is done by temporarily manipulating the routing on *AppGw*, exposing temporary URLs

pointing to Let's Encrypt *Pod*. A third-party certification system is then requested in the next step to issue a certificate, and confirmation of domain authority is achieved through a corresponding feedback message provided on the temporary URL. Once the certificate is correctly obtained, this certificate is stored in the *Secret* on Kubernetes cluster and automatically installed on *AppGw* by the *cert-manager*. In addition, Let's Encrypt cert-manager itself takes care of the appropriate rollover of expired certificates automatically.

4.4. Internal entry for maintenance team

Basing communication on two-party access to applications provides the possibility of maintenance operation. If it is necessary to temporarily disable end-user access for administrative work, the easiest way to achieve this is to temporarily redirect traffic on the *AppGw* to the maintenance work page or appropriate HTTP *503 Service Unavailable* response. At the same time, access to the application is still possible from internal corporate traffic directly using the *Load Balancer* interface integrated with the *Nginx Controller*.

4.5. Single Sign-on with Nginx

Nginx proxied applications can use *Single Sign-On* (SSO) to secure access to them. Several solutions providing SSO authorization and authentication can be integrated for this purpose, such as Auth0, Keycloak, OneLogin or Microsoft Active Directory FS. This makes it possible to centralize access handling for individual elements of the overall system.

4.6. Caching, compression, and scaling

Nginx server can also cache and compress a content to increase user experience. If caching is not possible or sufficient to handle the traffic, we can easily scale applications by increasing the number of *Pods* that handle requests. *Nginx* provides a load balancer mechanism to handle scalable network traffic

5. Conclusions

This paper presents an architectural pattern using a Dual Ingress consisting of Azure *Application Gateway* and *Nginx Ingress Controller* as a reverse proxy. The described solution provides several functionalities that combine the capabilities of both mechanisms into a single cohesive system. The use of Kubernetes cluster provides the solution with high scalability alongside with additional SaaS services enhancing the capabilities of the system. The discussed solution has been successfully implemented in a commercial solution providing empirical confirmation of the designed advantages. The dual-tier Ingress system successfully handles variable network traffic using the austoscaler and *Nginx Load Balancer*. The presented

architecture pattern provides a cost-optimized solution, adapting to the requirements of the current network traffic. It allows for flexibility in choosing where to implement certain mechanisms, considering the cost-effectiveness of implementation between *AppGw* and *Nginx*. The entire solution was deployed in the Microsoft Azure cloud, using *Application Gateway Ingress* as the internet facing interface. The presented solution, combined with the tools provided by Crossplane (Crossplane Concepts, 2023), made it possible to achieve full automation of the environment provisioning and application deployment process on Kubernetes cluster. Network traffic is secured by appropriate encryption of connections using automatic acquisition of TLS certificates. At the same time, the presented architecture provides internal access to system components during maintenance windows, which requires temporary disconnection of services from public access.

It is worth mentioning that the proposed architectural pattern of the Dual Ingress on Kubernetes cluster is not limited to the Azure cloud only. The presented example was discussed in the context of cloud from Microsoft, however, the general concept is also feasible to implement in other Kubernetes service providers, like AWS or Google. The required changes will only relate to the practical application, which requires the installation of corresponding controllers available from the respective service provider.

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THE PROACTIVE PERSONALITY OF YOUNG WORKERS – WHAT ARE THE CHALLENGES FOR EMPLOYERS?

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Purpose: The main purpose of the study was to examine the proactive personality of young workers in Poland.
Design/methodology/approach: Data were collected from young workers using an e-questionnaire. The study followed the approach developed by Bateman and Crant. The U Mann-Whitney test was used in the data analysis. The study focused on identifying specific proactive behaviors of young workers.
Findings: Young employees with certain professional experience are characterized by highly proactive personality. The male employees showed higher overall levels of proactiveness than their female counterparts. In turn, the particular age of the young employees was not observed to affect their proactive attitudes. Gender-dependent statistical differences were observed in terms of some proactive behavior, which facilitated the formulation of specific recommendations for employers.
Research limitations/implications: The study was carried out only in Poland. In the future, the author plans to expand the scope of the study to include countries of varying cultural characteristics and allow international comparisons.
Practical implications: Employers are recommended to implement targeted efforts aimed at enhancing proactive employee behavior, particularly among female staff members. These should include the establishment of a proactive work environment and implementation of suitable HRM practices, e.g. in terms of proactiveness-focused career path planning and targeted employee development (individual and team coaching, mentoring, design thinking).
Originality/value: The study identifies the proactive personality of young employees and uses the obtained results to formulate recommendations for employers in terms of HRM management that duly accounts for the procreative personality of employees.

Keywords: proactive personality, young employees, HRM practices, employer.

Category of the paper: Research paper.

1. Introduction

To effectively function in a turbulent environment, an organization needs to continuously adapt to the evolving conditions and take advantage of opportunities as soon as they present themselves. To do so, however, it needs to recruit employees capable of coping with such challenges. Moreover, given the prognosed labor shortages and highly varied levels of respective employees' engagement, it is important that the organization holds on to staff members best suited to perform the tasks with which they are assigned. Ultimately, the organization's ability to face challenges will always depend on its employees' capacity to effectively make responsible decisions, which is why employees with proactive personality can be a valuable asset. Proactive personality, as a personal initiative construct, enriches the growing body of literature in the field of business, management, and psychology(Din et al., 2023).

A proactive personality is understood as an active approach to changes in one's environment (Krupski, 2007). Moreover, proactive individuals are able to adapt their work environment to their specific needs and abilities (Bateman et al., 1993). This is particularly important in the context of the current changes that necessitate constant adaptation of methods, tools, and performance approaches. However, leaders may regard employees' proactivity as a threat to their own work status (Sun et al., 2023). Hence, it is important to properly shape employee management practices in an organization with the above in mind. In turn, identification of the proactive personality in employees will facilitate better assignment of specific tasks and more effective planning of activities. This is really crucial because sustainable businesses go beyond mere regulatory compliance by proactively identifying and addressing sustainability challenges (Wolniak, Grebski, 2023a).

Even though there have been numerous publications on the characteristics of employees active in the job market, few have been focused specifically on the young workers currently entering the same, and none have considered the particular aspect of young workers' proactive personality. Given the above, we conducted the following literature review and empirical study exploring this particular area.

The main goal of the paper was to examine young Polish workers in terms of the proactive quality of their personality using the 17-item scale developed by Bateman and Crant (Bateman et al., 1993). With a view to achieving the above, the following research questions were considered:

RQ1: What is the level of proactivity personality in young workers?

RQ2: Are there any significant gender-related differences in terms of proactive behaviors of young workers?

Hypothesis 2.1. Proactive personality in young workers is significantly different for gender groups.

RQ3: Are there any significant age-related differences in terms of proactive behaviors of young workers?

Hypothesis 3.1. Proactive personality in young workers is significantly different for age groups.

The paper consists of 4 parts including introduction, literature review, methods, results, and summary and discussion.

2. Literature review

In a rapidly developing economy, knowledge can quickly become obsolete, and it is necessary to constantly be on the lookout for potentially more beneficial or efficient solutions. In this context, employees, and especially their "proactive personalities," play an increasingly significant role. Said proactiveness is a determinant of proactive behavior displayed in a variety of areas. T.S. Bateman and J.M. Crant defined a proactive person as someone with a "relatively stable behavioral tendency" to initiate change in the environment (Bateman, Crant, 1993). Interest in this personality-based approach remains strong due to the fact that proactive individuals exhibit their proactiveness across multiple contexts and over time, regardless of the contingencies of a situation at work or in one's career (Parker, 2016).

The literature review indicated two primary approaches to proactiveness. Some researchers define it as proactive personality (Bateman, Crant, 1993), i.e. the character of an individual who is relatively unconstrained by situational forces and able to scan for opportunities, show initiative, take action, and persevere until they achieve closure by bringing about change. In the alternative approach, it is defined as personal initiative, i.e., behavior independently engaged of one's own volition (self-starting), proactive and lasting (Fay, Frese, 2001). However, as stressed by A. Bańka, the difference between a proactive personality and personal initiative is rather subtle, and both approaches agree on the key point that proactiveness is a certain predisposition dependent on personality-related factors (Bańka, 2015).

In literature, the concept of proactiveness has been analyzed from the individual, team, and organizational perspectives (Parker et al., 2006). By considering individual proactiveness, it is possible to identify proactive predispositions and behaviors in various areas of human activity. T. Bateman and J.M. Crant observed that proactive individuals tend to display seven interrelated traits, which prompted them to develop the Proactivity Personality Scale – PPS under this theoretical construct (Bateman, Crant, 1993). It is a unidimensional scale that allows researchers to measure the effects of proactiveness.

There are many benefits that hiring of proactive individuals can yield for organizations. The outcomes that are most frequently studied in terms of proactive personality can be grouped into three categories: employee attitudes, job behaviors/performance, and career-related

outcomes (Parker, 2016). A growing empirical literature demonstrates that proactive behaviors can increase well-being (Zambianchi, Ricci Bitti, 2014). Empirical studies also show that managerial personality traits that particularly facilitate building positive interpersonal relationships include a conciliatory disposition and a proactive personality (Gurszyńska, Katarzyna, 2013). Moreover, research demonstrates that change recipients can venture outside the limits of passivity to positively and proactively react to changes initiated by others (Bayiz Ahmad et al., 2020). In turn, non-proactive employees show little initiative, rely on others to be forces for change, and passively adapt to, or simply endure, their circumstances (Bateman, Crant, 1993). As such, they pose a considerable challenge for employers and necessitate the implementation of adequate organizational policies.

Proactive activity is further directed toward change and positive impact on both the overall situation and the individual undertaking action (Parker et al., 2006). This includes the concept of proactive communication (Curcuruto et al., 2020). During the COVID-19 pandemic, under circumstances marked by considerable uncertainty, proactive coping was associated with less COVID-19 stress for older adults relative to younger adults, as seen in the cross-over interaction (Pearman et al., 2021). When considering the benefits of proactiveness, one should also point out that individuals who expressed more proactive mindsets reported more expansive views on roles as fulfilling fundamental motives of agency and communality (Benson-Greenwald, Diekman, 2022).

As such, it is necessary to shape employee management practices in organizations so as to fully utilize the potential of the employees themselves and promote an environment conducive to employee proactiveness. Organizations desiring proactive employee behavior would be well advised to take one of three courses of action:

- select employees with proactive personality who will generally behave proactively regardless of the situation,
- develop transformational leaders who will motivate, inspire, and support proactive employee behavior,
- or cultivate a climate of innovation and flexibility, which will create a strong situation that fosters proactivity regardless of employee individual differences (McCormick et al., 2019).

Proactiveness is particularly important for young employees at the onset of their professional development as it is bound to impact their future careers (Forrier, 2023). Known factors influencing student proactiveness in professional contexts include, e.g., the type of their place of residence as well as the professional experience and education of the mother (Krause, 2012). Moreover, studies point to a strong relationship between a proactive personality and personal initiative/personality (Tornau, Frese, 2013). Conclusions reached in other studies suggest that the more proactive a person is, the more likely they are to declare the desire to start their own business in the future (Okręglicka, 2018).

However, as the natural proactiveness of individual employees is bound to vary, it is important to undertake targeted action at the organizational level. In the case of low-proactiveness employees and early-career employees, the development of specific career competencies is recommended (AlKhemeiri et al., 2021). They could help in showing current trends in the job market and required competencies. Nowadays, predictive analytics plays a crucial role in Industry 4.0 (Wolniak, Grebski, 2023b). The research of literature shows the need to expand the area of research in the field of proactive personality (Jiang et al., 2023; Sun et al., 2023).

3. Methods

The study was conducted using the statistical opinion poll method. The technique employed was a survey with the corresponding questionnaire used as the research tool. The study aiming to measure the proactive personality of young workers was conducted in Poland in 2022 and supplemented in 2023. The research questionnaire consisted of 17 questions and respondent metrics. The questions were adopted from the Proactivity Personality Scale – PPS (Bateman, Crant, 1993). Responses given to the questions were measured using the 7-point Likert scale ranging from "1 = strongly disagree" to "7 = strongly agree", with the respondents choosing one of seven response variants, arranged symmetrically. The survey questions were accompanied by a record specifying respondent gender, age, and education.

The collected data were analyzed statistically using classical and positional descriptive analysis. Moreover, the significance of respective differences between the obtained mean values for individual gender and age groups was also considered. The Mann–Whitney U test was used to compare two groups with a non-normal distribution. All statistical tests were performed for the significance threshold of $\alpha = 0.05$. The variables constituted average values of responses regarding proactive behaviors were combined together, and an indicator- Proactive personality was built. The Cronbach's alpha for this indicator of proactive personality was calculated (0,908). A premise was made that the reliability index ought to amount to at least 0.65 (Bourque, Clark, 1999).

The respondent selection was targeted. The aim of the study was to survey young employees with some professional experience. After the initial selection of questionnaires, 334 respondents were qualified for further analysis. Table 1 contains detailed information on the respondents participating in the survey.

Table 1.
Structure of respondents

Gender of the respondents [%]	
Female	**Male**
73,95%	26,05%
Age of the respondents [%]	
Less than 20 years - 8,1%	20-25 years - 91,9%
Level of education [%]	
Postgraduate	0,3 %
Higher II	2,4 %
Higher I	41,7 %
Secondary	53,9 %
Basic/Junior high	1,7 %

Source: Based on own study.

4. Results

Answering the first research question, RQ1, the above-mentioned average declarations of respondents were analysed. The results are presented in Table 2.

Table 2.
Descriptive statistics on proactive behaviors and proactivity personality in young workers

Items	**Total average**	**Total median**	**Woman average**	**Men average**
1. I am constantly on the lookout for new ways to improve my life	5,63	5,76	5,64	5,64
2. I feel driven to make a difference in my community, and maybe the world	5,43	5,60	5,43	5,43
3. I tend to let others take the initiative to start new projects*	4,84	5,07	4,77	5,03
4. Wherever I have been, I have been a powerful force for constructive change	4,51	4,58	4,39	4,84
5. I enjoy facing and overcoming obstacles to my ideas	5,36	5,49	5,27	5,62
6. Nothing is more exciting than seeing my ideas turn into reality	6,02	6,28	6,00	6,08
7. If I see something I don't like, I fix it	5,82	5,96	5,83	5,79
8. No matter what the odds, if I believe in something I will make it happen	5,29	5,47	5,27	5,33
9. I love being a champion for my ideas, even against others' opposition	5,01	5,20	4,96	5,17
10. I excel at identifying opportunities	5,01	5,11	4,88	5,36
11. I am always looking for better ways to do things	5,88	6,08	5,78	6,15
12. If I believe an idea, no obstacle will prevent me from making it happen	5,14	5,29	5,08	5,33
13. I love to challenge the status quo	4,59	4,60	4,47	4,92
14. When I have a problem, I tackle it head-on	5,47	5,60	5,42	5,63
15. I am great at turning problems into opportunities	4,81	4,90	4,72	5,01
16. I can spot a good opportunity long before others can	4,87	4,96	4,77	5,15
17. If I see someone in trouble, I help out in any way I can	5,93	6,09	5,92	5,94
Proactive personality	**5,40**	**5,44**	**5,33**	**5,59**

Note. Scale: "7" means "I completely agree" and "1" means "I completely disagree.

Source: Based on own study.

As follows from Table 2, the respondents declared the most often that they are excited seeing their ideas are turn into reality. However, the lowest acceptance score was recorded for having a powerful force for constructive change. The average of proactive personality manifested by young employees with certain professional experience is 5,4.

Answering the second and third research questions, RQ2 and RQ3, the presence of statistically significant differences was assessed using the non-parametric U Mann-Whitney test (Table 3). In a further step of the analysis of the results, it was demonstrated that between 17 proactive behaviors and proactivity personality in young workers and, gender, and age.

Table 3.
U Mann- Whitney result test for proactive behaviors and proactivity personality in young workers

	Gender		**Age**	
Items	**Test M-W: Z**	**p**	**Test M-W: Z**	**p**
1. I am constantly on the lookout for new ways to improve my life	0,457	0,647	1,094	0,274
2. I feel driven to make a difference in my community, and maybe the world	0,12	0,990	1,874	0,061
3. I tend to let others take the initiative to start new projects*	1,355	0,175	-0,188	0,851
4. Wherever I have been, I have been a powerful force for constructive change	2,700	**0,007**	0,630	0,528
5. I enjoy facing and overcoming obstacles to my ideas	2,076	**0,038**	-0,497	0,619
6. Nothing is more exciting than seeing my ideas turn into reality	0,805	0,421	-0,191	0,848
7. If I see something I don't like, I fix it	-1,002	0,316	0,174	0,862
8. No matter what the odds, if I believe in something I will make it happen	0,688	0,492	1,442	0,149
9. I love being a champion for my ideas, even against others' opposition	1,119	0,263	2,182	**0,029**
10. I excel at identifying opportunities	2,804	**0,005**	0,013	0,99
11. I am always looking for better ways to do things	2,188	**0,029**	1,756	0,079
12. If I believe an idea, no obstacle will prevent me from making it happen	1,601	0,109	0,036	0,971
13. I love to challenge the status quo	2,429	**0,015**	1,469	0,142
14. When I have a problem, I tackle it head-on	1,259	0,208	-0,234	0,815
15. I am great at turning problems into opportunities	1,671	0,095	0,314	0,754
16. I can spot a good opportunity long before others can	1,940	0,052	0,860	0,39
17. If I see someone in trouble, I help out in any way I can	0,041	0,967	-0,140	0,889
Proactive personality	2,054	**0,04**	1,009	0,313

Source: Based on own study.

The following proactive behaviors examined differed according to gender (Table 3):

- Wherever I have been, I have been a powerful force for constructive change.
- I enjoy facing and overcoming obstacles to my ideas.
- I excel at identifying opportunities.
- I am always looking for better ways to do things.
- I love to challenge the status quo.

However, only one proactive behavior – "I love being a champion for my ideas, even against others' opposition" examined differed according to age (Table 3).

In the case of the statement that proactive personality in young workers is significantly different for gender groups, the male employees showed higher overall levels of proactiveness (5,59) than their female counterparts (5,33). The gender analysis showed significant differences between the opinions of women and men ($p = 0.04$). In this way, the Hypothesis 2.1 was confirmed.

Moreover, the statement that proactive personality in young workers is significantly different for age groups was examined. The age analysis showed no significant differences between the opinions of respondents under 20 years and respondents in 20-25 age ($p = 0.313$). Thus, the Hypothesis 2.1 were rejected.

5. Summary and discussion

Many contemporary professions require a conscious effort to constantly search for new opportunities in the environment, gain new knowledge and experience, and demonstrate individual workplace initiative. A proactive personality of an employee goes a long way to facilitating such abilities. It is essential to analyze the personality traits of young employees as it will largely determine their long-term professional engagement and potential. As follows from the conducted study, the early-career employees surveyed showed a high overall proactive personality, although the average results were lower in the case of female respondents. Given the above, organizations are recommended to take steps towards enhancing proactive attitudes in employees, particularly women.

The study allowed us to identify challenges faced by employers and formulate specific recommendations in terms of HR management, with due consideration for the procreative personality of employees. Current challenges for entrepreneurs include taking into account proactive personality in HRM practices, in particular when selecting and hiring employees. Moreover, the challenge is to support superiors in the development and creation of opportunities to use employees' proactiveness, as well as to create a proactive organizational culture. Specifically, the following managerial implications were identified.

1. Design HRM policies that will facilitate a goal-oriented employee focus.
2. Make efforts to ensure more seamless onboarding of female employees at the beginning of their professional careers. To this end, targeted HRM practices aimed at supporting women and enhancing their individual potential should be implemented. Institutions such as e.g. career offices already during university studies, NGOs, business organizations, and entrepreneur associations can all contribute to such efforts.

3. Plan the career paths of young employees taking their proactive personality into account. This will be helpful both in terms of more effective task assignment and proactiveness support.
4. Create conditions conducive to the development and utilization of employee proactiveness, which may help to limit employee turnover.
5. Create a proactive work environment with proactive communication practices that aim to emphasize opportunities rather than problems.
6. Employ HRM practices in the area of employee development to encourage and support desirable changes in employee behavior. Implementing teamwork methods rooted in creative problem solving, including design thinking, may help staff members to question the status quo. In turn, training programs, as well as individual and team coaching, can all contribute to improving employee abilities in terms of change management and constructive implementation. In this context, individual mentoring can be particularly recommendable in raising the employees' self-esteem and belief in their own abilities.

Proactiveness refers to a specific, desirable type of employee behavior, which is why, although it can pose a challenge for employers, it is worth enhancing and supporting through various targeted efforts.

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TOWARDS A SMART CITY: MODELLING A BIKE-SHARING STATION VIA A QUEUEING LOSS SYSTEM

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Purpose: The article aims to build a mathematical model of a bike-sharing station based on an appropriate queueing system and show the model's usefulness in practice.
Design/methodology/approach: In designing the model, constructing a queueing system described by exponential distributions with a finite accumulating buffer was used. The existence of the steady state of the system and the global balance principle were used to obtain analytical results.
Findings: The most important analytical results are the stationary probability distribution of the number of rented bikes, the so-called loss probability (the probability that the customer has to resign from sharing due to the lack of bikes), as well as the average (mean) values of the number of rented bikes.
Originality/value: The paper fits into the broadly understood trend of research related to the smart city concept. The proposed model may be beneficial in practice when designing specific solutions related to the development of bicycle rental stations.

Keywords: Bike-sharing station, customer loss, queueing system, smart city, stationary state.

Category of the paper: Research paper.

1. Introduction

The concept of smart cities requires an in-depth analysis of the market and consumer needs. This, of course, involves proposing appropriate communication solutions, including bicycle rental stations. Analytical models in this area can, therefore be actively used in practice. The use of queueing models in practical modeling is common today and is constantly gaining in importance (see, e.g., Bose, 2002; Ng, Soong, 2008; Chan, 2014; Shortle et al., 2018 and Lakatos et al., 2019). Queueing systems are used to design network protocols and solve logistics and transport issues (including communication nodes and traffic control systems).

An overview of the results regarding the modeling of bicycle rental stations can be found in (Fishman, 2016). In (Ashqar et al., 2017; Yang et al., 2018), artificial intelligence algorithms, particularly deep machine learning, were used to analyze the functioning of bicycle rental stations. The article (Wang et al., 2015) considered the influence of the location of a bicycle rental station on its operational characteristics. An optimization approach to this issue was proposed in (Qian et al., 2022).

The paper proposes a queueing model describing renting and returning bicycles from a bike-sharing station. This model is based on exponential distributions describing the process of incoming customers (who want to rent a bike) and servicing them (understood here as the time of using the rented bike). The maximum system size corresponds to the number of service stations in an appropriately chosen queueing model. Indeed, by a single service station, we can mean a single bicycle in use. Occupying all service stations, therefore means renting all available bicycles. This number is equal to the maximum number of customers in the system (in the model, we assume that when the bike-sharing station is empty, the potential customer does not wait for a bike but resigns from the station's services).

For the stationary state of the system, after its stabilization, analytical results are presented for the distribution of the number of customers, understood here as the number of rented bicycles. In particular, a representation for the so-called loss probability, i.e., the probability that all bicycles are rented, is given, as well as the formula for the average (mean) value of the number of rented bicycles.

2. Model description

In the article, we analyze a mathematical model of a single bike-sharing station described by means of a finite-capacity queueing system with Poisson arrivals of customers with a given rate a. The Poisson arrival stream describes potential customers of the station who would like to rent a bike. In practice, the arrival rate changes in time: its values can differ in different periods. A typical engineering approach in such a situation is to divide the observation period into a finite number of subperiods in which the intensity of arrivals can be accepted to be constant. The service process reflects the process of using the rented bike: we assume that successive processing times are independent and identically distributed random variables with the mean b^{-1}. The station "capacity" equals $m \geq 1$, i.e., we have m bikes that can be rented. If a customer occurs when there are no bikes available for rent, he leaves the station without service (in the "language" of queueing theory, we say that such a customer is "lost"). Thus, using the classical Kendall notation, the considered queueing model can be classified as the *M/M/m/m*-type system (a kind of system with customer losses without a waiting room).

Critical from the point of view of ensuring the appropriate quality of customer service (QoS) is constant monitoring of the number of bicycles available for rent. Thanks to this, it is possible to optimally use the station - avoiding a situation in which no bikes are available for rent for a long time during the day, or a small number of them is rented compared to the total number of bikes offered. When describing the model probabilistically using an appropriate queueing system, we are interested in the probability distribution of the number of bicycles available at the station, and the probability that an arriving customer will find the station empty (no bicycles to rent) will be significant for us. We will consider the model in the steady state, i.e. at $t \to \infty$. Of course, because the system contains a finite buffer, regardless of the intensity of customer input and the speed of their service, the steady state exists (see e.g. Adan, Resing, 2015; Tijms, 2003; Heyman, Sobel, 1982 for basics of stochastic modeling in this area).

3. Analytical results

Let us introduce the following notation:

$$q_n \stackrel{\text{def}}{=} P\{X = n\}, \tag{1}$$

where X stands for the number of rented bikes, $n \in \{0, 1, \dots, m\}$. Obviously, the following normalization condition is satisfied:

$$\sum_{n=0}^{m} q_n = 1. \tag{2}$$

The global balance principle (see e.g., Adan, Resing, 2015), which can be applied to any steady-state queueing model, states that the output flow of customers from a given state is equal to the input flow to the state. Note that the output stream of customers to state 0 (0 bikes rented, all bikes available) is equal to the product of the intensity of customers coming to the service station and the probability q_0 that the system is in state 0. In other words, the fraction aq_0 of the input stream corresponds to the transition from state 0 to state 1. Similarly, the input stream to state 0 "comes" from state 1 and amounts to bq_1, where b is the intensity of customer service (in our bike-sharing station model, it corresponds to the intensity of returning rented bicycles). Similarly, the fraction bq_1 of the total stream describing the intensity of customer service per time unit corresponds to the transition from state 0 to state 1. Comparing both streams to each other, we obtain the equation

$$aq_0 = bq_1. \tag{3}$$

Now consider state 1. The customer output stream from this corresponds to a transition from state 1 to state 2 (customer influence), but also to a transition from state 1 to state 0 (customer service). Therefore it is equal to $aq_1 + bq_1 = (a + b)q_1$. In turn, the input stream to state 1 is related to the arrival of the customer to the "empty" system (aq_0) or with the end of customer service in a system that was in state 2 ($2bq_2$), it is then equal to $aq_1 + 2bq_2$. The quantity $2b$ is related to the fact that in the considered queueing model "being" in state 2, the intensity of

"customer service" is $2b$ – each customer who rented a bike returns it with intensity b (merging property of Poisson process describing the service in the considered model). Equating both streams to each other, we obtain the equation

$$(a+b)q_1 = aq_0 + 2bq_2. \tag{4}$$

For state 2, in consequence, we obtain an analogous equation, applying the global balance principle

$$(a+b)q_2 = aq_1 + 3bq_3. \tag{5}$$

In general, for state n, where $n \in \{1, \dots, m-1\}$, we have the following equation:

$$(a+b)q_n = aq_{n-1} + nbq_n. \tag{6}$$

A specific situation occurs for state m, corresponding to the situation in which all available bicycles have been rented. It is no longer possible to move from this state to a higher state so that the appropriate equilibrium equation will be

$$aq_{m-1} = mbq_m. \tag{7}$$

Let us observe that the consequence of the previous equations is the following recursive formula:

$$aq_{n-1} = nbq_n, \tag{8}$$

where $n \in \{1, \dots, m-1\}$.

The above recurrence can be solved explicitly. The solution, so the representation for the stationary number of rented bikes in the station containing strictly m bikes, has the following form (see also e.g. Adan, Resing, 2015):

$$q_n = \left[\frac{(a/b)^n}{n!}\right] : \left[\sum_{i=0}^{m} \frac{(a/b)^i}{i!}\right] = \frac{\rho^n/n!}{\sum_{i=0}^{m}\rho^i/i!}, \tag{9}$$

where $n \in \{0, 1, \dots, m\}$ and $\rho = \frac{a}{b}$ denote the so-called offered load (traffic load) in the considered queueing model and defines the proportion between the arrival rate and service speed.

The so-called blocking probability is of particular importance for assessing the system is functioning, i.e., the probability that all available bikes will be rented and, consequently, the upcoming customer will be lost. This probability is equal to q_m, and hence

$$q_{block} = \frac{\rho^m/m!}{\sum_{i=0}^{m}\rho^i/i!}. \tag{10}$$

It is possible to use blocking probability to represent the average (mean) number of rented bicycles without calculating the sum of the appropriate numerical series. We have (see e.g. Adan, Resing, 2015)

$$E(X) = \rho(1 - q_{block}). \tag{11}$$

4. Numerical examples

The numerical results were obtained by a Python program using a math library, which code is presented in figure 1 below.

```python
import math

def calculate_probabilities(a, b, m):
    ρ = a / b
    denominator_sum = sum([(ρ ** i) / math.factorial(i) for i in range(m + 1)])
    probabilities = [(ρ ** n) / (math.factorial(n) * denominator_sum) for n in range(m + 1)]
    return probabilities

def calculate_blocking_probability(ρ, m):
    return (ρ ** m) / math.factorial(m)

def calculate_mean_number_of_bikes(ρ, blocking_probability):
    return ρ * (1 - blocking_probability)

if __name__ == "__main__":
    a = 1.5  # Arrival rate
    b = 1.0  # Service rate (return rate)
    m = 5    # Number of available bikes

    ρ = a / b

    probabilities = calculate_probabilities(a, b, m)
    blocking_probability = calculate_blocking_probability(ρ, m)
    mean_bikes = calculate_mean_number_of_bikes(ρ, blocking_probability)

    print("Probabilities q_n:")
    for n, prob in enumerate(probabilities):
        print(f"q_{n}: {prob:.5f}")

    print("\nBlocking Probability (q_block):")
    print(f"q_block: {blocking_probability:.5f}")

    print("\nMean Number of Rented Bicycles (E(X)):")
    print(f"E(X): {mean_bikes:.5f}")
```

Figure 1. Program code.

Source: Authors' own.

The results differ depending on the input parameters (a, b, and m). The numerical results are presented in Table 1.

Table 1.
Numerical results

Input parameters: a = 1.5, b = 1.0, m = 5	Input parameters: a = 2, b = 1.0, m = 5	Input parameters: a = 1.5, b = 1.5, m = 5	Input parameters: a = 1.5, b = 2.0, m = 5
Probabilities q_n: q_0: 0.22413 q_1: 0.33619 q_2: 0.25214 q_3: 0.12607 q_4: 0.04728 q_5: 0.01418	Probabilities q_n: q_0: 0.13761 q_1: 0.27523 q_2: 0.27523 q_3: 0.18349 q_4: 0.09174 q_5: 0.03670	Probabilities q_n: q_0: 0.36810 q_1: 0.36810 q_2: 0.18405 q_3: 0.06135 q_4: 0.01534 q_5: 0.00307	Probabilities q_n: q_0: 0.47243 q_1: 0.35432 q_2: 0.13287 q_3: 0.03322 q_4: 0.00623 q_5: 0.00093
Blocking probability (q_block): q_block: 0.06328	Blocking probability (q_block): q_block: 0.26667	Blocking probability (q_block): q_block: 0.00833	Blocking probability (q_block): q_block: 0.00198
Mean Number of Rente d Bicycles (E(X)): E(X): 1.40508	Mean Number of Rented Bicycles (E(X)): E(X): 1.46667	Mean Number of Rented Bicycles (E(X)): E(X): 0.99167	Mean Number of Rented Bicycles (E(X)): E(X): 0.74852

5. Source: Authors' own

The results show that if the arrival rate increases, the mean of rented bicycles also increases. In case the service rate increases, the mean of rented bicycles decreases. The numerical examples show that the model works properly and can be easily described from a 'human's point of view'.

6. Conclusions

To declare the city as smart, it is necessary to provide different services for the inhabitants. One of the most popular services is a bike-sharing station. As we assume, the number of users, the number of bikes, and many more parameters should be considered as crucial to the proper service of inhabitants. The presented paper shows that the queuing model can provide the proper satisfaction level based on real data for a chosen city. The satisfaction of citizens is one of the requested values for a smart city.

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A NEW APPROACH TO PREPROCESSING OF EMG SIGNAL TO ASSESS THE CORRECTNESS OF MUSCLE CONDITION

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Purpose: Electromyography (EMG) is a technique dealing with the recording and analysis of myoelectric signals formed by physiological variations in the muscle fiber membrane. The voltage potential of surface myoelectrical signals (sEMG) varies over time and depends on the characteristics of the individual subject. One of the main drawbacks of sEMG analysis is that the given acquisition conditions strongly determine the amplitude of the signal. The analysis of sEMG requires appropriate preprocessing, including proper filtering and artifact removal. Moreover, the sEMG data must be converted to a scale standardized for all measurements. This research aimed both to propose a method of sEMG processing to eliminate the occurring disturbances, in particular impulsive artifacts, and to determine the level of muscle excitation based on normalized sEMG. The analysis of muscle excitation level can be applied to assess muscle activity during physical activity.
Design/methodology/approach: The proposed algorithm uses set of digital filters, probabilistic distribution and the decomposition of the sEMG signal to attenuate artifacts. Variance analysis of the sEMG derivative is used to determine muscle excitation. The sEMG signals were acquired with the VICON system with the sampling frequency set at 1000 Hz, and processed in MATLAB. During sEMG recordings, standard silver/silver chloride (Ag/AgCl) surface electrodes were used.
Findings: The suggested technique was validated using sEMG recorded for eight persons during deep squat. Normalized excitation was determined for the left and right muscles, the rectus femoris, the vastus medialis, and the biceps femoris. Obtained outcomes indicate a possibility to assess the correctness of muscles condition.
Originality/value: The combination of the proposed filter and the analysis variance-based thresholding method can effectively eliminate impulse artifacts within the surface myoelectrical signals.

Keywords: Spikes disturbance, EMG, Muscle excitation, Filtering, Kurtosis.

Category of the paper: Research paper.

1. Introduction

Electromyography (EMG) is a technique that deals with, records, and analyzes myoelectrical signals formed by physiological variations in the state of sarcolemma – the muscle fiber membrane. The EMG signal is based upon action potentials that occur in the muscle fiber membrane as a consequence of depolarization and repolarization processes (De Luca, 1979). These rapid sequences of voltage changes in the sarcolemma induce the resulting excitation (electromechanical coupling) and finally cause a shortening of the contractile elements of the muscle cell manifested by muscle contraction (Konrad, 2005). Although excitation and contraction present a highly correlated relationship, it is known that weak excitation does not have to result in contractions (Konrad, 2005). The cell body, dendrites, and the motor neuron axon that innervates the bunch of muscle fibers is the smallest functional unit, so-called motor unit (motor neuron plus muscle fibers), of neural control of the muscular contraction process (Moritani et al., 2004; Staudenmann et al., 2010). The term unit is used because all muscle fibers within motor units behave and act as one in the innervation process. Methods used to measure these signals include surface EMG (sEMG), where electrodes are placed on the skin over the measured muscle, or intramuscular EMG (iEMG), where the electrodes are inserted through the skin into muscle tissue (Farina et al., 2016; Trontelj et al., 2004). The sEMG signal is a superposition of individual motor unit action potentials (MUAPs) within the pick-up range of the surface electrodes (Rodríguez-Carreño et al., 2012). Recruitment of MUAPs and their firing frequency could be pointed out as the major control action to adjust contraction and modulate the force output of the involved muscle (Konrad, 2005; Michell, 2013). Surface EMG is very attractive for researchers from various disciplines, such as medicine (Zwarts et al., 2004; Sadikoglu et al., 2017; Chmielewska et al., 2019; Jórasz et al., 2023; Wang et al., 2010; Martín et al., 2012; Merletti, Parker, 2004; Zieliński et al., 2022a, 2022b; Yin et al., 2020; Xu et al., 2022; Pilkar et al., 2020), sport or rehabilitation (Merletti, Parker, 2004; Yin et al., 2020; Xu et al., 2022; Pilkar et al., 2020) mainly since its significant constituents, motor unit recruitment, and rate coding, are also the precursors of active force generation (Staudenmann et al., 2010; Farina et al., 2002, 2016; Vigotsky et al., 2018). Muscle force production is preceded by excitation input from the central nervous system into the muscle. This signal triggers the excitation-contraction coupling, which leads to muscle activation (Dulhunty, 2006). Finally, muscle force is produced after cross-bridges are formed, and it is transmitted through the muscle (Zajac, 1989). With appropriate processing, sEMG can provide information on the timing and degree of muscle excitation and could be useful for providing insight into how the neuromuscular system behaves.

Muscles are the motors or brakes of locomotion, but they act reflexively, guided by the commands of the central nervous system (CNS) (Konrad, 2005). Muscle activation expresses an active contribution to muscle force and does not take into account passive components.

Furthermore, activation versus force production is not affected by fiber length and velocity. Activation reflects the number of fibers that are active, not the force-generating capacity of those fibers (Vigotsky et al., 2018). Because sEMG measures changes in the polarity of muscle fiber sarcolemma resulting from neural excitation, it could be accepted that sEMG is a measure of muscle excitation but not a direct measure of activation. Excitation precedes muscle activation (Zajac, 1989), so the existing relationship is reflected in sEMG. An unfiltered and unprocessed signal detecting the superposed MUAPs is called a raw sEMG. Raw sEMG is mostly affected by motor unit recruitment and rate coding. The envelope of this signal may be regarded as the sum of MUAPs of the sarcolemma of the area of muscle over which the electrode is located. Since raw sEMG is a complex signal, its processing, for example filtering, could provide data that are referred to muscle excitation (Vigotsky et al., 2018) and can be used to detect muscle fatigue (Sarillee et al., 2014; Calderón et al., 2014; Sun et al., 2022).

The aim of this paper is to propose a new approach to sEMG signal processing in order to eliminate the disturbances occurring in the surface electromyography signals (Chowdhury et al., 2013; de Luca et al., 2010), in particular, impulse artifacts and to determine the level of muscle excitation. The suggested method could enable an assessment of the muscle condition. The proposed approach focuses on determining the level of muscle activation in such a way as to eliminate the basic disadvantage of the standard method, in which the determined maximum excitation is usually based on the maximum or average value (Konrad, 2005) and can take into account the appearing impulse disturbances.

The paper is organized as follows. In the section Materials and Methods the detailed description of algorithm for preprocessing sEMG signal, in particular attenuation of impulse artifacts, and method of determining muscle excitation are provided. In the section Results, based on real sEMG signals recorded for eight athletes during deep squat, the proposed methods are used to determine the excitation of the rectus femoris, vastus medialis, and biceps femoris. Next, the results obtained are compared to the results provided by the chosen classical method and simple statistical analysis is performed for both sets of results. Finally, the outcomes are discussed in section Discussion.

2. Materials and Methods

This section introduces the method of preprocessing the sEMG signal, finding the signal envelope and threshold value connected to the muscle excitation. The calculated threshold corresponds to the maximum excitation value of the muscle. The paper presents the operation of the proposed method and an example of the results of research carried out on eight athletes during deep squat activity. The average age of surveyed athletes was 25.86 years (range: 23-29), and the average body max index (BMI) was 24.56 kg/m^2 (range: 22.7-26.3).

Each athlete gave their written consent to participate in the study. The sEMG signals were acquired with the VICON system with the sampling frequency set at 1000 Hz, and processed in MATLAB (R2021a). During sEMG recordings, standard silver/silver chloride (Ag/AgCl) surface electrodes were used. The electrodes had a Ag/AgCl disk with a diameter of about 7 mm. Therefore, the conductive surface was about 38 mm^2. The skin was rubbed with a mild abrasive to improve electrode-skin contact. The electrodes were placed according to SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) recommendations (Stegeman, Hermens, 2007). The SENIAM project is a European concerted action in the Biomedical Health and Research Program (BIOMED II) of the European Union. The SENIAM project developed important guidelines for EMG measurements that include, in particular, information on the characteristic and position of the electrodes (Hermens et al., 1999; Freriks, Hermens, 1999). All sessions with the recording of the sEMG signal took place in the first half of the day.

In our tests, participants (athletes) were asked to generate a maximum voluntary contraction for about 5 seconds, and this activity was repeated two times. The other exercises (deep squats) studied in this work were repeated twice in each trial. A kurtosis value calculated in the moving window was used to represent the quality of muscle excitation. For further analysis, the intervals of sEMG with kurtosis closer to 3 were taken to estimate MVC activity level (determined for selected muscle). The MVC-related activity was used for the normalization process performed for the sEMG signals recorded during deep squat exercises. Normalization was performed by dividing determined muscle excitation by the MVC value.

2.1. Surface EMG processing pipeline

The proposed method of sEMG processing consists of two main steps, that is, filtering and envelope calculation with threshold process. The sEMG processing pipeline is shown in Figure 1.

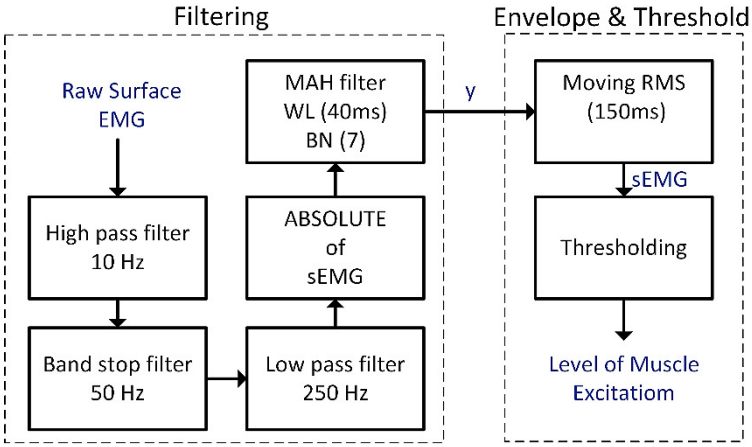

Figure 1. The block diagram with two main steps of the proposed sEMG processing method. The first: filtering with a set of dedicated digital filters, and the second: envelope calculation and threshold process.

This is due to the fact that the sEMG signal is weak and can present a lot of artifacts (Konrad, 2005; Reaz et al., 2006), the analysis of sEMG requires appropriate preprocessing, which includes proper filtering and artifact removal methods (Qiu et al., 2015; Yeon, Herr, 2021; Boyer et al., 2023). The sEMG signal is usually smoothed by a method based on the root mean square (RMS) calculation (Burden et al., 2014; Arabadzhiev et al., 2010; Gupta et al., 2017; Rose, 2014; Karabulut et al., 2017; Arozi et al., 2020; Josephson, Knight, 2019). RMS reflects the mean power of the signal (Luca, 1997). During the preprocessing stage, the EMG signal was filtering by three types of digital finite impulse response filters (FIR): the high pass filter (HPF) with a cutoff frequency set to 10 Hz (Stegeman, Hermens, 2007), the low pass filter (LPF) with a cutoff frequency set to 250 Hz, and the band stop filter (BSF) to suppress the mains interference (50 Hz). A moving average (Smith, 1997-1998; Kabe, Sako, 2020) hole filter (MAHF) slid a window of 2WL length (WL = 40 ms) along the sEMG data. The seven-bin histogram of the sEMG data contained in the window: X = {x[n], x[n − 1], ... x[n − (2WL − 1)]} was calculated. Then the vector D of the sEMG samples d[i], for i ∈ {k, k − 1..., (K − 1)}, where K < 2WL, belonging to the three most numerous bins, was created. The mean value of D is the output of the filter. The principle of the operation of MAHF is presented in Figure 2.

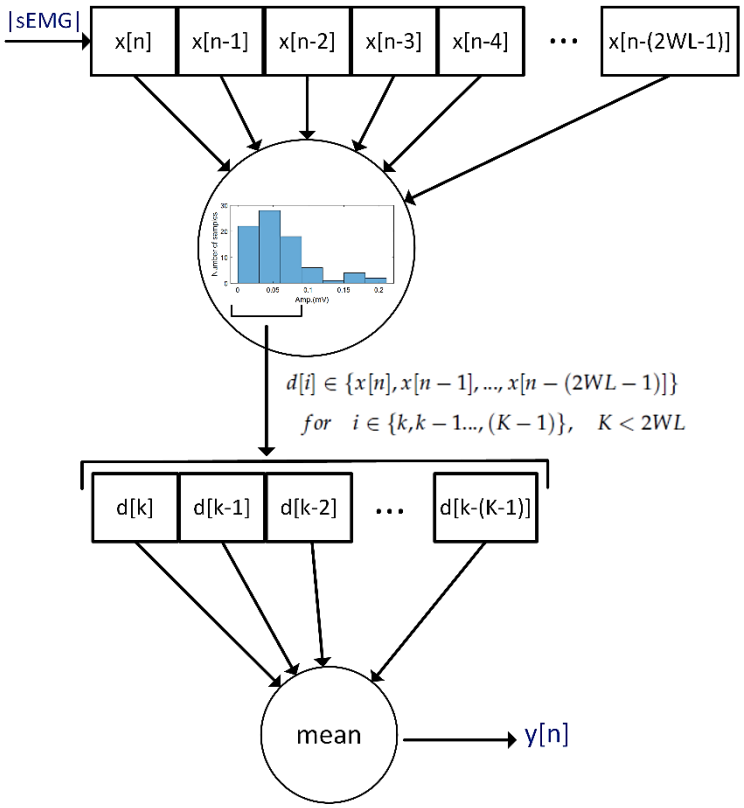

Figure 2. The principle of the operation of MAHF. The seven-bin histogram of the sEMG data contained in the window (X = {x[n], x[n − 1], ... x[n − (2WL − 1)]}) of 2WL length is calculated. Next, the vector D of sEMG samples d[i], for i ∈ {k, k – 1 ..., (K − 1)}, where K < 2WL, belonging to the three most numerous bins, is created. The mean value of D is the output of the filter.

Next, the signals were processed using an RMS window length of 150 ms (Burden et al., 2014). The kurtosis parameter was used to assess the influence of the proposed filtering method on sEMG signal. Next, by determining the threshold value of the sEMG signal, the level of muscle excitation was determined.

2.2. Kurtosis

According to the literature (Michell, 2013), more motor unit action potentials are fired with increasing the force level during contraction. Because the sEMG signal is the superposition of these potentials, it tends to be a Gaussian process at high force levels (Nazarpour et al., 2005, 2013). In this research, kurtosis was used to evaluate the Gaussianity of sEMG signals. Kurtosis (1) is a classic method of measuring non-Gaussianity (Hyvärinen, Oja, 2000). It is a measure of the sensitivity of the distribution to outliers. In classic terms, kurtosis is expressed by (1) (Hyvärinen and Oja, 2000):

$$kurt(s) = E\{s^4\} - 3(E\{s^2\})^2, \tag{1}$$

where s is a signal and E{s} is expected value of the signal s. In our study to calculate the kurtosis of a discrete sEMG signal, the following formula (2) is used:

$$kurt(s) = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^4}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^2\right)^2}, \tag{2}$$

where μ is the mean of the discrete signal s = [x_1, x_2, ..., x_N] and N is the number of signal samples. Kurtosis for the Gaussian random variable (s) calculated according to the formula (2) is equal to 3.

2.3. Thresholding

Threshold calculation is performed on sEMG intervals presenting muscle excitation split into 100 ms segments. In the first step, the level of artifacts is found. To gain insight into the rate of amplitude changes, for each segment, the first derivative is calculated, and the variance of the derivative is determined (variance is the measure of dispersion). Then, the mean (MD) and standard deviation values (STDD) of variance from the segments of derivatives are calculated by (3) and (4), respectively.

$$MD = \frac{1}{N}\sum_{i=1}^{N} v_i, \tag{3}$$

$$STDD = \sqrt{\sum_{i=1}^{N}\frac{(v_i-MD)^2}{N}}, \tag{4}$$

where v_i denotes the variance of derivatives of i-th segments of sEMG signal for all (N) sEMG segments under consideration. The threshold level for detecting artifacts (TAL) is determined using the following formula:

$$TAL = MD + sl \cdot STDD, \tag{5}$$

where MD (3) and STDD (4) are the mean and standard deviation (Kabe and Sako, 2020) of variance from the segments of derivatives, respectively, and sl is a constant that determines the

sensitivity of artifacts detection. In our case, it was set to 0.95. In the second step, the variance value of each segment is compared with TAL. If the variance of the first derivative of a given segment exceeds the TAL value, the analyzed segment of the sEMG signal is marked as noisy. Next, the maximum amplitude of the sEMG signal is determined (MA) according to:

$$A\big(x(n)\big) = \max_{i\in\{1,2,\ldots K\}} x(i), \tag{6}$$

where x(n) is discrete sEMG signal and K denotes the length of analyzed sEMG (not noisy marked).

Segments marked as noisy are omitted when determining the maximum amplitude. Then, samples of the sEMG signal exceeding the maximum are dropped. The maximum value and time location are searched in the sEMG signal prepared in this way. In the last step, a 2D (D = 50 ms) length window was created relative to the determined position. The threshold value was defined as the mean of the sEMG signal in the assumed window and refers to the level of muscle excitation. The illustration of the threshold operation is shown in Figure 3.

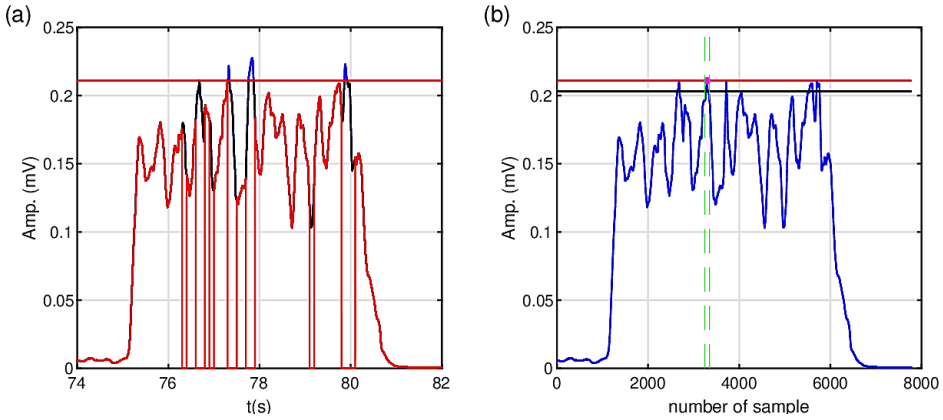

Figure 3. Illustration of the threshold operation; analyzed fragment of sMEG (red), noised segment (black), MA (horizontal red dashed line), spikes excluded from threshold analysis (blue) (a); sEMG after removing spikes (blue), MA (horizontal red line), level of muscle excitation determined (horizontal black line), 2D (100 ms) length window (vertical green dashed lines) for determining level of muscle excitation (b).

3. Results

The operation of the proposed method is illustrated in Figures 4-7. An example of a raw sEMG signal recorded for the normalization process (MVC estimation) of the left rectus femoris muscle during two repetitions is depicted in Figure 4.

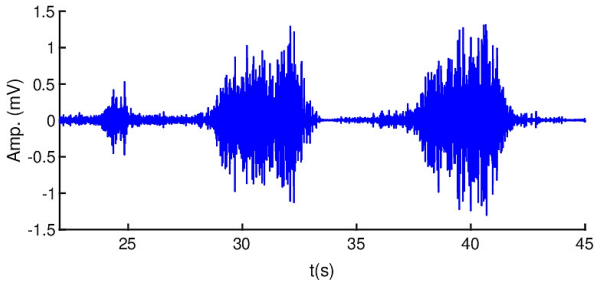

Figure 4. An example of raw sEMG signal recorded for normalization process from left rectus femoris muscle during two repetitions.

Figure 5 shows the filtered (by HPF, LPF and BSF), rectified samples of raw sEMG versus the sEMG signal processed by the proposed method.

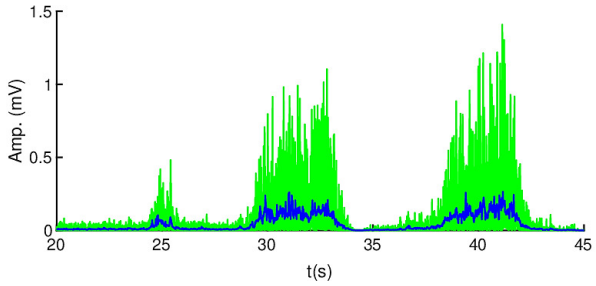

Figure 5. An example of the absolute value of filtered (by HPF, LPF and BSF) rectified sEMG signal (green) and sEMG after filtering by MAH filter (blue).

Figure 6 shows the comparison of the RMS values of the sEMG signal obtained by the standard and proposed method.

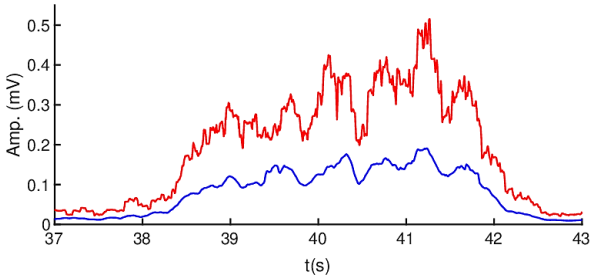

Figure 6. Comparison of RMS values of sEMG obtained by classic (red line) and proposed method (blue line).

Figure 7 presents both the calculated MVC level by the proposed method and the maximum value of the sEMG amplitude. Figure 8 shows the RMS values of the sEMG signal for normalization and the calculated MVC levels obtained by the classic and proposed method in the second repetition, while Figure 9 shows the RMS values of sEMG signal and the determined level of vastus medialis excitation in the deep squat calculated by the classic and proposed method.

Kurtosis of the sEMG fragment was estimated for each repetition before and after preprocessing to determine the MVC level. For the first repetition of the normalization exercise, kurtosis was equal to 4.16 and 3.30, before and after preprocessing, respectively, and 5.59 and 2.92 for the second repetition. As the sEMG signal distribution for the MVC estimation should tend to a normal distribution, the second repetition after preprocessing with kurtosis equal to 2.92 was taken into further analysis.

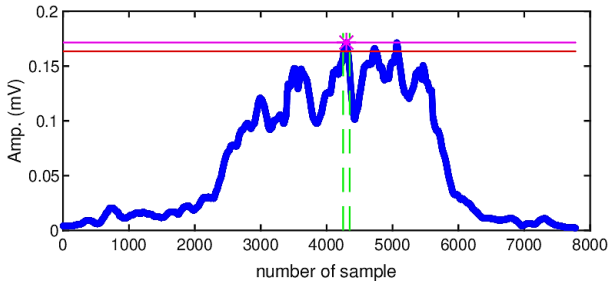

Figure 7. Determination of MVC level. The maximum amplitude of the sEMG signal is marked by a *sign and a line in magenta color, and a red line marks the MVC level determined by the proposed method. The sampling frequency is equal to 1000 Hz.

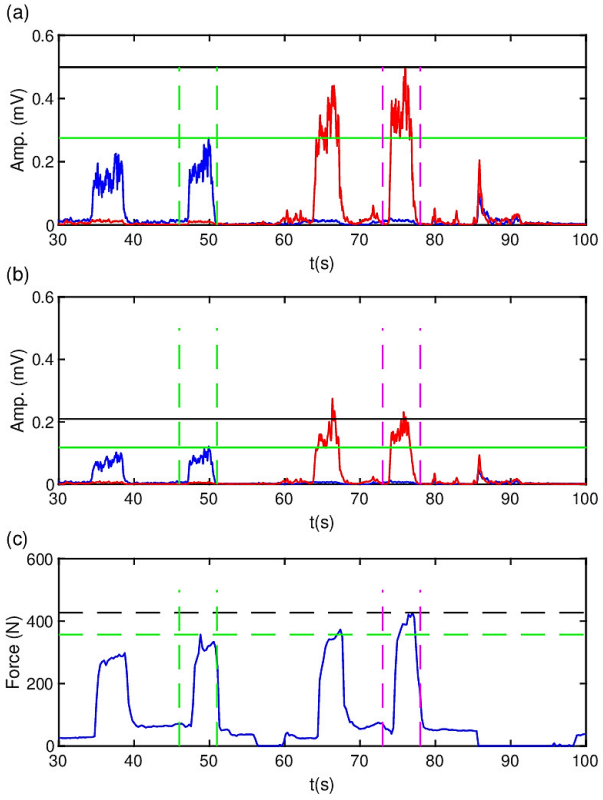

Figure 8. Example of MVC determination levels for RMS obtained by the classic (a) and proposed method (b) for left (blue line) and right (red line) vastus medialis. A horizontal line marks the MVC for the second repetition in green for the left muscle and black for the right muscle. Additionally, the corresponding values of measured force are presented (c).

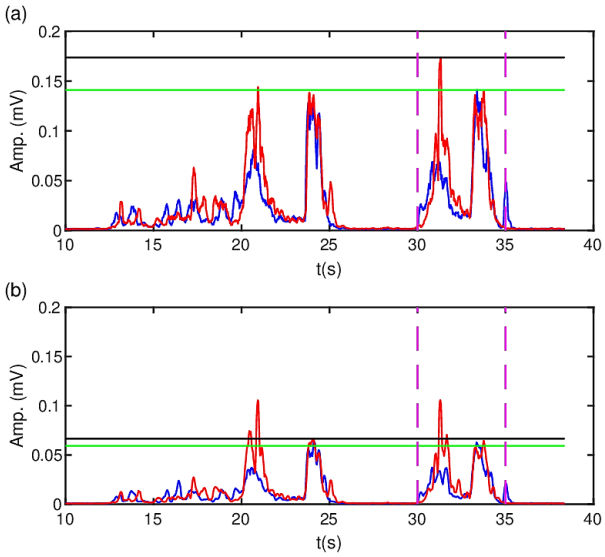

Figure 9. Example of determined levels of vastus medialis excitation in deep squat calculated for RMS obtained by classic (a) and the proposed method (b) for left (blue line) and right (red line) vastus medialis. A horizontal line marks the MVC for the second repetition in green for the left muscle and in black for the right muscle.

The results of maximum excitation expressed in %MVC for the left and right rectus femoris, vastus medialis, and biceps femoris muscles for the classic and proposed method during deep squat activity are summarized in tables 1-2 and 3-4, respectively. Based on analyzed sEMG signals and level of muscle excitation, the outcomes obtained were divided into two groups. The main factor that suggested the division into groups was the difference in the level of excitation in the biceps femoris. Tables 1, 3 and 2, 4 show the results for groups 1 and 2 for both the classic and proposed methods.

In addition, the excitation levels of the rectus femoris, vastus medialis, and biceps femoris for each group and each person (for the left and right muscle separately) are illustrated in Figures 10-11 (classic method) and 12-13 (proposed method).

Table 1.
The results (classic method) of maximum excitation in %MVC for left and right rectus femoris, vastus medialis and biceps femoris muscle during deep squat activity for group 1

Person	Muscle	Rectus Femoris %MVC	Vastus Medialis %MVC	Biceps Femoris %MVC
1	Left	62	58	10
	Right	79	65	5
2	Left	68	29	3
	Right	49	30	3
3	Left	85	76	16
	Right	124	42	11
4	Left	21	49	11
	Right	34	59	12

Table 2.
The results (classic method) of maximum excitation in %MVC for left and right rectus femoris, vastus medialis and biceps femoris muscle during deep squat activity for group 2

Person	Muscle	Rectus Femoris %MVC	Vastus Medialis %MVC	Biceps Femoris %MVC
5	Left	15	66	31
	Right	31	50	8
6	Left	54	68	3
	Right	63	109	25
7	Left	63	45	62
	Right	51	85	12
8	Left	12	38	75
	Right	59	37	24

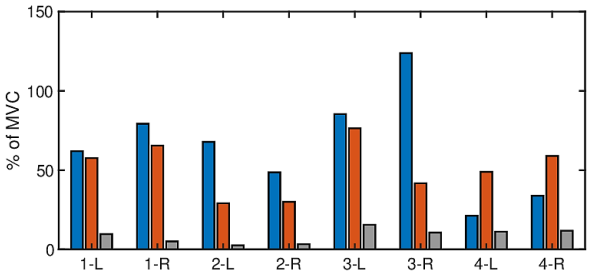

Figure 10. The results (classic method) of maximum excitation expressed in %MVC for left and right rectus femoris (blue bar), vastus medialis (red bar) and biceps femoris (gray bar) muscle during deep squat activity for group 1.

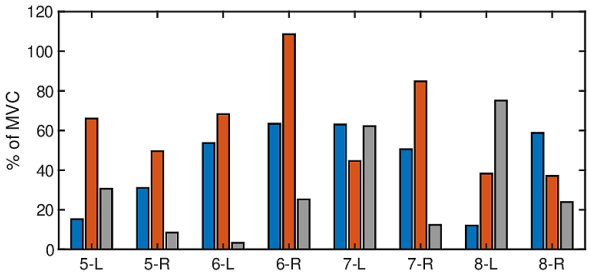

Figure 11 The results (classic method) of maximum excitation expressed in %MVC for left and right rectus femoris (blue bar), vastus medialis (red bar) and biceps femoris (gray bar) muscle during deep squat activity for group 2.

Table 3.
The results (proposed method) of maximum excitation in %MVC for left and right rectus femoris, vastus medialis and biceps femoris muscle during deep squat activity for group 1

Person	Muscle	Rectus Femoris %MVC	Vastus Medialis %MVC	Biceps Femoris %MVC
1	Left	48	51	7
	Right	37	51	5
2	Left	77	34	2
	Right	38	40	3
3	Left	92	93	12
	Right	126	45	14
4	Left	23	47	13
	Right	29	58	9

Table 4.
The results (proposed method) of maximum excitation in %MVC for left and right rectus femoris, vastus medialis and biceps femoris muscle during deep squat activity for group 2

Person	Muscle	Rectus Femoris %MVC	Vastus Medialis %MVC	Biceps Femoris %MVC
5	Left	13	67	15
	Right	26	32	4
6	Left	69	58	3
	Right	57	86	21
7	Left	60	55	66
	Right	32	64	11
8	Left	14	69	77
	Right	30	41	17

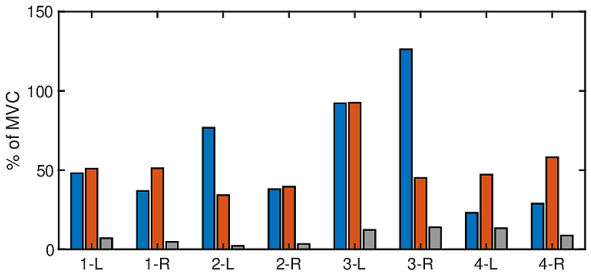

Figure 12. The results (proposed method) of maximum excitation expressed in %MVC for left and right rectus femoris (blue bar), vastus medialis (red bar) and biceps femoris (gray bar) muscle during deep squat activity for group 1.

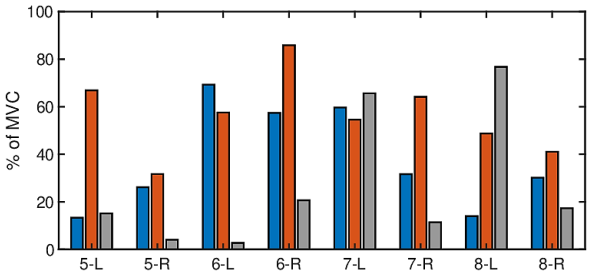

Figure 13. The results (proposed method) of maximum excitation expressed in %MVC for left and right rectus femoris (blue bar), vastus medialis (red bar) and biceps femoris (gray bar) muscle during deep squat activity for group 2.

3.1. Statistical Analysis

In the first step of the statistical analysis, the consistency of the results obtained by the methods considered: classic and proposed was validated. The normal distribution of data (for whole data and separately for data obtained with the classic and proposed method) were tested by the Lilliefors-Corrected Kolmogorov-Smirnov test because of the not known expected value and variance for the whole population. In general, the data examined were not normal distributed (for the rectus femoris, vastus medialis $p > 0.2$ and biceps femoris $p < 0.05$), therefore the nonparametric (independent of the distribution of random variable) Mann-Whitney U test was performed. Based on the non-parametric Mann-Whitney U test, it was shown that the null hypothesis that randomly selected samples came from populations

with equal medians could not be rejected (p =0.44 for rectus femoris, p = 0.87 for vastus medialis, and p = 0.79 for biceps femoris), which would indicate the consistency of the results obtained for individual methods. Analyzing the box plots (Figure 14) of muscles excitation during deep squat for the classic and the proposed method, it could be noticed a decrease in the dispersion of excitation values for vastus medialis in the case of the proposed method.

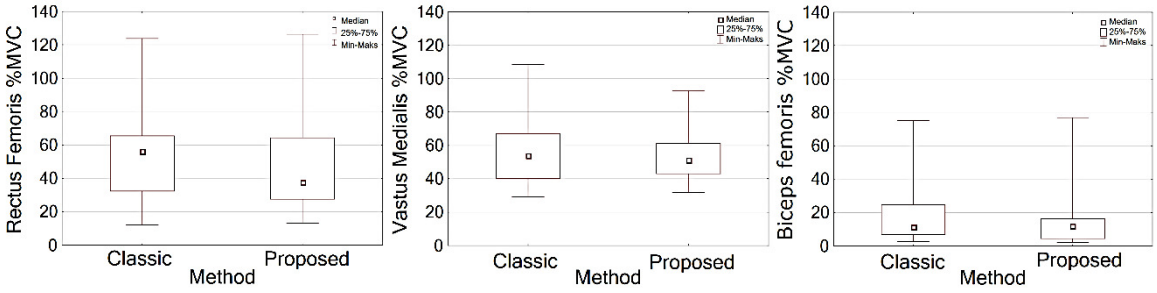

Figure 14. Box plots of rectus femoris, vastus medialis and biceps femoris muscles excitation levels for classic and proposed methods.

Box plots in Figure 15 show the relationship between the excitation of individual muscles in groups 1 and 2, depending on the method used.

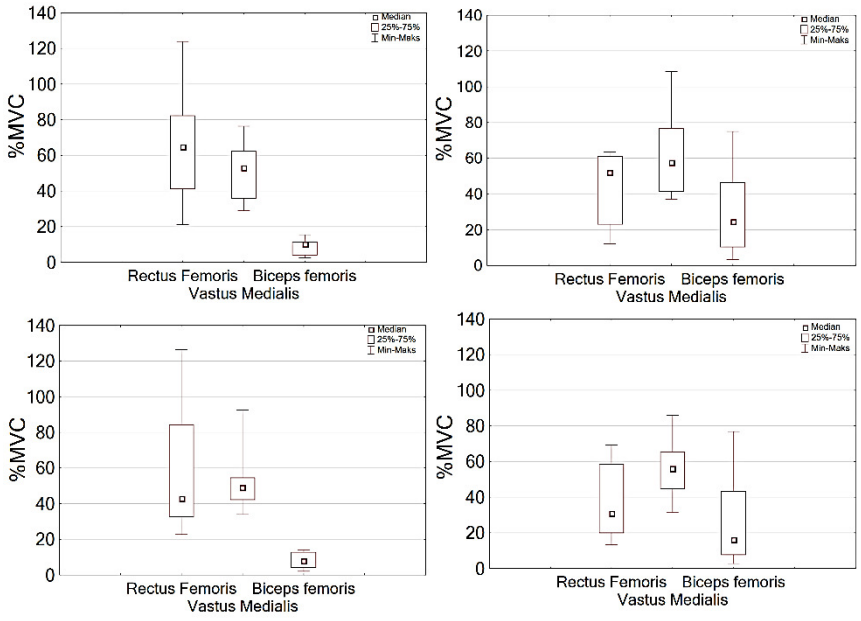

Figure 15. Box plots of rectus femoris, vastus medialis, and biceps femoris muscles excitation levels obtained for the classic (in the top) and the proposed (in the bottom) methods. Results for groups 1 and 2 are presented on the left and right columns, respectively.

4. Discussion

The presented work proposes an sEMG signal processing method to determine the value of muscle excitation, which relates to muscle contraction. The described method can be used to assess motor control strategy, that is, muscles contribution to particular physical activity. The main motivation for proposing this method of sEMG signal processing was the need to eliminate impulse interference (narrow spikes) from the sEMG signal. The common cause of these artifacts is both the EMG signal's nature and its recording technique (e.g., use of surface electrodes, recording during movements) (Qiu et al., 2015; Boyer et al., 2023). Narrow spikes appearing in the sEMG signal might significantly influence the correctness of the classic method of estimating muscle excitation, mainly because these disturbances are often of great amplitude and interfere with the maximum value of amplitude taken into account in the classic method (Konrad, 2005; Josephson, Knight, 2019).

The healthy relaxed muscle produces no significant excitation due to the lack of depolarization and repolarization of the sarcolemma of muscle fiber, that is, the lack of action potentials. Appearing action potentials recorded in a raw sEMG are randomly shaped spikes because the actual set of recruited motor units is constantly changing (Cavalcanti Garcia, Vieira, 2011), so they also change their diameters and distances from the electrodes. Suppose some motor units in the close neighborhood are recruited at the same time. In that case, the generated action potentials superimpose, and if the motor units are additionally located near the electrode, a significant spike may be observed in the raw sEMG (Roeleveld et al., 2003).

The reason is that the sEMG signal is usually recorded during physical activity, which results, for example, in the problem of ensuring proper electrode-skin contact (Yeon, Herr, 2021). Temporary loss of electrode contact may also cause disturbances (Olmo, Domingo, 2020), which, if not eliminated, may significantly affect the determination of some parameters of the sEMG signal (e.g., the value of maximum excitation, which reflects maximum muscle contraction). The proposed algorithm attenuates disturbances both at the stage of sEMG signal preprocessing and at the stage of determining the maximum value of muscle excitation (thresholding). The exemplary outcomes of the proposed sEMG signal processing method, presented in the results section, show the effectiveness of eliminating impulse interference at the filtering stage and during determining the level of muscle excitation.

It can be noticed that the presented method affects the amplitude of the processed sEMG signal compared to the classic method. However, it does not affect the calculated normalized muscle excitation level as long as the normalization process (Chalard et al., 2020; Halaki, Ginn, 2012) is correct and the normalized and normalizing signals are processed using the same (proposed) method. The comparison of kurtosis for raw signals and signals processed with the proposed method shows that the method minimizes too aggressive filtering of the sEMG signal. In the case of the analyzed fragments of sEMG signals in the interval where MVC was

determined, the post-filtering signal distribution was close to normal, with kurtosis of about three.

Performed statistical analysis did not point out the significant differences between the outcomes obtained by the classic and proposed method in terms of maximal excitation of the rectus femoris, vastus medialis, and biceps femoris muscles in the deep squat. Both methods give consistent results, especially for good-quality sEMG signals. The problem arises when the impulse interference appears in the sEMG recording and has not been eliminated by the RMS method, which can be observed in Figure 8, in such cases, the proposed method gives better results (Figure 14 (for vastus medialis)), and the estimated maximum excitation seems to be closer to that of physiological origin.

According to the assessment of physiotherapists, the main active muscles in the deep squat are the rectus femoris and the vastus medialis, while the biceps femoris was rated as weakly active or even inactive in this exercise. Analysis of the muscle excitation values for the deep squat using both the classic and proposed methods allowed to distinguish two groups of athletes depending on the excitation of the biceps femoris muscle.

For group 1 the excitation of the biceps femoris does not exceed 16%MVC (mean = 8.70, std = 4.58, stderror = 1.62) in the classic method and 14%MVC (mean = 8.20, std = 4.61, stderror = 1.63) in the proposed method, therefore, the excitation of the biceps femoris is low enough to confirm the suggestion of the physiotherapists that in the deep squat the excitation of the biceps femoris is at a low level with the dominant excitation of the vastus medialis and rectus femoris. The results obtained (Figures 10, 12) show that this tendency is maintained for both the left and right muscles.

In the case of group 2, both methods indicate a decrease in the rectus femoris excitation by an average of approximately 21%MVC compared to group 1, while increasing biceps femoris excitation by more than 21.46%MVC (compared to group 1) in the classic method and 18.51%MVC in the proposed method. For the vastus medialis, the classic method showed a decrease in excitation of about 11.14%MVC in relation to group 1, while the proposed method showed an increase in excitation of about 14.56%MVC. The observed effect of activation of the biceps femoris muscle may result from a limited range of motion in the ankle joint or too little flexibility of the posterior muscle band. Activation of the antagonist's muscle may indicate that the person performing the exercise was trying to compensate, for example, for the tendency to valgus the knee resulting from the above limitations. Differences in the assessment of the excitation of the vastus medialis muscle using the classic method and the proposed method probably result from artifacts disturbing the maximum value of the amplitude in the sEMG signals (Figures 9, 14 (for the vastus medialis)).

Correctly evaluating individual muscle excitation for a given exercise can provide a deeper insight into how the muscles work during this exercise and can also be used to assess progress during training or rehabilitation. The emerging disproportion in muscle excitation can be both a remnant of a past injury and a harbinger of an injury in the future. In the future, enlarging

group 1 with a larger number of athletes, for whom the muscles excitation (active muscles: rectus femoris and vastus medialis) would be assessed by both the classic and proposed method, could allow for definite the ranges of excitation for considered muscles in the case of a properly performed exercise. The excitation ranges obtained could be the reference values for assessing any athlete's muscle condition in the deep squat. The limitation and disadvantage of the proposed method may be that in some cases, due to the nature of the sEMG or EMG signal, which is random and non-stationary, part of the signal may be treated as an impulse disturbance. Therefore, the proposed method should not be used during studies concerned with the analysis of single muscle fiber excitation, which may be in the form of short pulses of high amplitude, is important. Also, depending on the sEMG signal recording parameters, for example, the value of sampling frequency, some parameters of the proposed method, such as the number of histogram bins used in the proposed FMAH filter, may need to be changed.

5. Conclusions

The determination of proper muscle excitation requires preprocessing and normalization of the sEMG signal. The selection of the normalizing exercise, as well as the careful execution of this exercise, are of great importance for the normalization process and muscle excitation estimation. The proposed approach for sEMG analysis provides an effective method for assessing muscle excitation during sports activity. The combination of the MAHF filter and the analysis variance-based thresholding method can effectively eliminate impulse artifacts (pulse with high amplitude, e.g., caused by electrode contact variation) within the sEMG signals, which makes the determined level of muscle excitation more reliable. The results of preliminary studies are promising because they seem to be closer to that of physiological origin and consistent with the suggestions of physiotherapists. The proposed method was also developed to reduce computational complexity and to be easily applied to online sEMG analysis.

Contributions

The authors participated in all activities that contributed to the writing of this article. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Conflicts of Interest

The authors declare that they have no competing interests. Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body Mass Index
BN	Number of Bins
BSF	Band Stop Filter
CMS	Central Nervous System
CP	Cut-off Point
EMG	Electromyographical signal
FIR	Finite Impulse Response Filter
HPF	High Pass Filter
iEMG	Intra-Muscular Electromyographical Signal
LPF	Low Pass Filter
MA	Maximum Amplitude of the sEMG Signal
MAHF	Moving Average Hole Filter
MD	Mean of Variance from the Segments of Derivatives
MVC	Maximum Voluntary Contraction
MUAPs	Motor Unit Action Potentials
RMS	Root Mean Square
SENIAM	Surface Electromyography for the Non-Invasive Assessment of Muscles
sEMG	Surface Electromyographical Signal
STDD	Standard Deviation of Variance from the Segments of Derivatives
WL	Window Length

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THE APPLICATION OF EYE TRACKING AND ARTIFICIAL INTELLIGENCE IN CONTEMPORARY MARKETING COMMUNICATION MANAGEMENT

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Purpose: Paper aims to fill the cognitive gap regarding the role, importance and potential of integrating eye tracking research and artificial intelligence. The main goal of the work was to design a proposal for the synergistic use of eye tracking and artificial intelligence for marketing communication management.
Design/methodology/approach: To achieve the planned goal and answer the research questions, methods of systematic literature review, online content analysis, expert interviews and pilot eye tracking studies using the Gazepoint GP3 device and Gazepoint Analysis V6.9.0 software were used. The considerations are conducted in the field of behavioral economics.
Findings: During the discussion and analysis of various aspects related to the use of eye tracking, artificial intelligence and neuro research in the context of marketing communication management, the following was established: the importance, applications and synergy of eye tracking and AI in marketing communication; the future of new technologies in marketing; key benefits, challenges and potential of the tools discussed, with particular emphasis on the need for their responsible use along with continuous development in this field.
Research limitations/implications: Suggestions for future research on the issues discussed include: ethics and privacy; technological limitations; future dynamics changes. Suggestions for future research include broader analysis of user experience, integration of methods with other technologies, longitudinal research on the impact of AI-generated content personalization, measurement of consumers' emotional engagement. The indicated research areas may contribute to better use of technology in marketing and expand knowledge about non-declarative consumer behavior.
Originality/value: The value of the article lies in providing conclusions and practical recommendations as well as identifying areas for further research, which may contribute to a better understanding and use of eye tracking, AI and neuro research in the field of marketing. The entire research project allowed for the design of a proposal for the synergistic use of eye tracking and artificial intelligence for marketing communication management. The article may be valuable for marketing specialists, researchers, students and people interested in the use of modern technologies in marketing. Thanks to its comprehensive perspective, it can be a guide for people interested in introducing these technologies into marketing practice.

Keywords: neuromarketing, eye tracking, artificial intelligence, marketing communication.

Category of the paper: Research paper.

1. Introduction

Modern marketing is dynamically evolving, responding to changing consumer behavior and expectations. In this context, tools such as eye tracking research and artificial intelligence provide invaluable support for amateurs and professionals dealing with marketing communication management. Eye tracking, which allows for tracking eye movements and analyzing visual attention, and artificial intelligence, which uses algorithms to analyze large data sets, are revolutionizing the way marketers understand and respond to the needs of their audiences.

The enormous amount of information generated by consumers when interacting with marketing content opens the door to new opportunities. Eye tracking allows you to precisely monitor what recipients focus on, which allows you to better understand consumer preferences, reactions and behaviors. In turn, artificial intelligence, thanks to the ability to analyze and interpret data on a scale impossible to achieve manually by humans, enables the personalization of content, forecasting trends and optimization of marketing campaigns in a way that seemed unrealistic until recently.

This article aims to explore the topic of the role, importance and potential of integrating eye tracking and artificial intelligence in the area of marketing communication management. By analyzing their applications, synergies and prospects, the article provides a look at an innovative approach to effectively reaching audiences, creating content and making strategic marketing decisions. Understanding and using these tools not only ensures competitiveness in the market but also opens the door to new forms of interaction with consumers, adapting to the changing trends and expectations of the modern market.

2. Basic concepts and an overview of marketing practices

In forming the background for further considerations, it is necessary to define the basic concepts used in the topic discussed.

Neuro research is a field of science that studies the structure, function, development and disorders of the nervous system. It uses research methods and techniques from neuroscience, psychology, neuroscience, and other scientific fields to understand brain functions and mental processes (Bear et al., 2016; Purves et al., 2018).

Neuromarketing is an interdisciplinary field that combines neuro research with marketing to understand how the human brain responds to marketing stimuli and what the biological basis of consumer behavior is. It uses neurobiological and psychological techniques to analyze the

brain's response to advertisements, products or other marketing elements (Lee, Chamberlain, 2007; Plassmann et al., 2012).

Eye tracking is an analysis method that records and monitors eye movements to understand what people pay attention to when interacting with various static or dynamic materials (Holmqvist et al., 2011; Duchowski, 2017).

Artificial Intelligence (abbreviated as AI) is a field of computer science that involves the development of computer systems capable of performing tasks that typically require human intelligence. It includes machine learning, natural language processing, pattern recognition, and decision-making (Lee, Park, 2018; Russell, Norvig, 2021).

2.1. Eye tracking in marketing communication management

Eye tracking is a research method that involves tracking eye movements to analyze respondents' perceptions of moving and stationary research objects. Eye movements are monitored using a video recorder placed on the respondent's head (mobile eye tracking) or mounted under the monitor screen (stationary eye tracking). This method can be used using various devices, from advanced laboratory equipment to portable devices that enable data collection in natural conditions. The main measures used in eye tracking research are fixations and saccades. Eye tracking enables qualitative analysis of research results, including the development of visualizations (presenting the distribution of attention directed at a given element in the form of heat maps and inverted heat maps, eye scanning paths in the form of fixation maps and bee swarms, as well as moving graphics and AOI areas for which of in turn, quantitative analysis is also possible). Importantly, the results obtained are based on the level of respondents' behavior, not just declarations. This data collection method allows you to track gaze sequences and time spent on specific areas of content, which provides valuable information about how audiences perceive marketing messages.

Eye movement technology allows you to determine what elements users pay attention to and which areas or elements are of no interest to them at all. Eye tracking is used, among others, to examine websites, advertisements, product packaging, and store shelves. As part of marketing communication management, the results of eye tracking research may prove particularly useful in the following activities:

- Consumer attention analysis – allows you to understand what the consumer focuses on when interacting with marketing materials, such as websites, video ads, or graphics. This tool allows you to identify key attention areas, which allows you to better adapt your messages to the expectations and needs of your audience.
- Layout and design optimization – eye tracking data is used to improve the layout of the website, advertising graphics or product packaging. Analyzing how people view these materials helps designers optimize visual elements and create more engaging and intuitive designs.

- Testing the effectiveness of campaigns - eye tracking allows you to assess the effectiveness of advertising campaigns by tracking non-declarative reactions of recipients. By analyzing visual attention and behavior, you can assess which elements of the campaign attract attention and which may require improvement.

The use of eye tracking in marketing enables a more precise and effective approach to creating campaigns by better understanding what attracts consumers' attention and what elements may be decisive in making purchasing decisions. This tool becomes irreplaceable in the process of improving marketing communication, enabling better adjustment of messages to the expectations and preferences of the target audience.

2.2. Artificial intelligence in marketing communication management

Artificial intelligence is used in many areas, including marketing. Based mainly on Reinforcement Learning methods (RL), they are the foundation not only of Industry 4.0 but also of modern financial markets and internet marketing. AI creates new possibilities in optimizing processes, making decisions and increasing efficiency

In internet marketing, machine learning and artificial intelligence use search engines, websites, websites, marketing tools, web developers, conversion optimization specialists, internet marketing specialists in optimizing Google advertising campaigns, e-commerce, content creation, strategy development SEO, email marketing, and social media marketing. Examples of AI applications in marketing include, among others, automation of marketing processes, data analysis and creation of advertising content. AI can also help companies determine the best marketing channels and optimize their advertising budget.

Artificial intelligence plays a key role in today's marketing, offering a range of tools and opportunities that are changing the way marketers communicate with customers. Selected methods include:

- Data analysis and predictive analysis – AI enables the analysis of large data sets, which allows you to identify trends, preferences and consumer behavior and predict future market behavior. AI enables the automation of many processes, which translates into saving time and resources. Thanks to machine learning and natural language processing algorithms, AI can analyze large amounts of data in ways that are impossible for humans to achieve. AI in decision-making can analyze data and provide information in real-time, which helps in making more optimal decisions. AI systems can identify trends, forecast results, and support decisions in more complex issues, such as investment portfolio optimization or risk management.
- Audience segmentation – using machine learning algorithms, AI helps to more precisely define target groups and better understand their needs, which allows for more effective adaptation of messages.

- Personalization of offers and recommendations – artificial intelligence is key in creating and delivering personalized offers. Customer service personalization is the use of AI to tailor customer experiences by analyzing behaviors and preferences. This allows organizations to provide personalized recommendations and solutions, which increases customer loyalty and improves satisfaction. By analyzing consumer data such as purchase histories, preferences and online behavior, it can help:
  - Creating personalized offers – based on data analysis, SI can propose products or services tailored to the individual needs of customers.
  - Recommendations and recommendation systems – using recommendation algorithms, AI suggests products to customers based on their current preferences, which increases the likelihood of making a purchase.
- Automation of marketing processes. AI is revolutionizing marketing processes by automating various activities, which brings many benefits:
  - Automation of advertising campaigns – thanks to AI, it is possible to personalize and optimize advertising campaigns, which allows for more precise reaching of recipients and better use of the advertising budget.
  - Automation of decision-making processes – which is particularly useful in situations where there are many variables to take into account. An example is the use of chatbots in the customer service area, where AI can solve simple problems and transfer more complex cases to employees.
  - Data analysis – AI can automatically analyze huge amounts of data, drawing important conclusions and trends from them, which accelerates marketing decisions. Data management and predictive analytics AI in data analytics enables the identification of patterns and relationships that would be difficult to detect using traditional methods. This allows for a better understanding of the market, customers and competition, which is crucial for effective management of the organization.
  - Content management – automatic AI systems are used to manage content on websites, social media or e-mail marketing, providing personalized and sometimes interactive content for users.

Artificial intelligence is revolutionizing the way marketers analyze data, personalize communications and automate processes, which translates into more effective and efficient marketing strategies tailored to individual customer needs.

3. Systematic review of literature and research

To clarify the research gap in the area of implemented projects on the topic of modern technologies, a deductive approach was used, based on a systematic analysis of the literature on the subject. During the research process, a system of stages was used according to the recommendations of Czakon (2011). The analysis included scientific works in the Scopus and Web of Science Core Collections databases. When building the basic database, three keywords were used in the search: "eye tracking", "artificial intelligence" and "marketing", in the research period 2013-2023.

2,962 publications from various fields were found in the entire Scopus database, and 19 in the Web of Science Core Collections.

Analysis of the number of publications (see Figure 1) indicates a further phase of development in the life cycle of the discussed issues and allows us to notice high research activity.

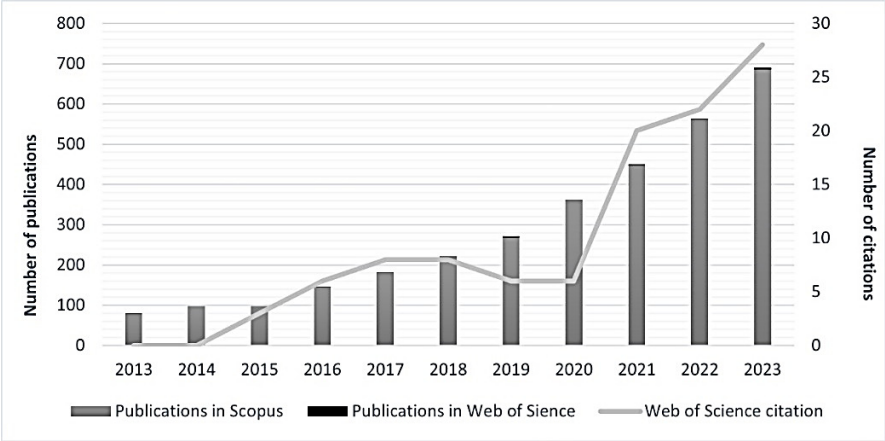

Figure 1. Number of publications and citations in the selected research area.

Source: preparation of results based on searching the Scopus and Web of Science databases; performed: December 2023.

A review of available information sources made it possible to obtain research reports covering scientific projects carried out in various thematic areas. In a further step, the author also decided to get acquainted with the results of commercial work by conducting an online analysis of the content posted on the websites of marketing agencies and research agencies dealing with market and public opinion research.

The results of the systematic literature review indicate the importance of the discussed issues in management practice and allow us to conclude that this topic is still a current and important research area.

A critical review of available reports by various scientists also became a direct contribution to clarifying the research gap in the field of research on the possibilities of using eye tracking and artificial intelligence in the process of marketing communication management to optimize the activities of marketers in the current market conditions

4. Research methodology

As a result of a review of the literature on the subject, it can be concluded that eye tracking and artificial intelligence are important and current issues. However, there is a paucity of comprehensive scientific studies treating these areas synergistically, more broadly and from different perspectives. Marketing strategies using methodically selected eye tracking methods, tools and procedures in connection with data generated by artificial intelligence have not been identified.

This research paper therefore aims to fill the cognitive gap regarding the possibilities of using eye tracking and artificial intelligence in contemporary marketing communication management.

The literature review prepared by the author, the analysis of available projects on the discussed topic and the exploratory research conducted became the basis for the preparation and implementation of empirical research. The adopted basic research problem included learning how, in current market conditions, a marketer can and should use eye tracking research and artificial intelligence in the marketing communication process.

The main goal of the work was to design a proposal for the synergistic use of eye tracking and artificial intelligence for marketing communication management.

The following research questions were identified:

P1. How and to what extent do marketing entities and agencies use modern technologies to optimize marketing activities?

P2. How do entrepreneurs/marketers use artificial intelligence to create marketing value for offered products and influence buyer behavior?

P3. What impact does eyetracking research have on the value of various promotional materials in the marketing communication process as perceived by customers?

To achieve the planned goal and answer the research questions, the following research methods and measurement tools were used:

- analysis of online content of marketing agencies' websites, including information on the tools and services in the field of eye tracking research they use in practice;
- semi-structured expert interviews with 9 marketers working in marketing agencies. Cooperation with people professionally dealing with the discussed issues was considered particularly important in the context of developing and verifying the author's proposal for the synergistic use of eye tracking and artificial intelligence to market communication management;

- exploratory eye-tracking research of promotional materials generated using Microsoft Bing AI artificial intelligence. The selected research method involved tracking eye movements and analyzing respondents' perception of stationary research objects presented to them on the screen - stimuli in the form of samples, which were elements of the brand's visual identification, the product and promotional materials in the form of posters and leaflets. As a result of the research, information was obtained about the areas and elements noticed by the respondents first, those that focused attention for the longest time, and those that were partially or completely omitted. A particularly important addition in the context of this work is the fact that the results are based on the level of behavior and actions, and not on the respondents' declarations, so they are objective. The research tool used was a stationary Eyetracker Gazepoint GP3 device and Gazepoint Analysis V6.9.0 software.

5. Results of empirical research

By triangulation of research methods, the considerations included identifying opportunities among experts, verifying the use of identified activities and good practices among marketers, and ending with the analysis of the perception of recipients of the activities, including their behavioral reactions. This part of the work will present the most important results of the obtained empirical research.

Firstly, it was established that modern marketing communication management requires the use of various tools, including eye tracking and artificial intelligence. Thanks to them, you can learn about customer preferences, understand their behavior and adapt the offer personalized to their needs.

The synergistic use of technologies such as artificial intelligence, eye tracking or neuro research in general in marketing brings many benefits but also carries certain limitations and challenges.

The benefits include mainly:

- A better understanding of consumer behavior. Eye tracking allows you to track what the consumer pays attention to, which helps to better tailor the content to their needs. AI analyzes this data in the context of preferences, which allows personalization and delivery of more relevant offers. Eye tracking provides information about what consumers pay attention to, while AI can analyze this data in the context of preferences and purchase history, providing more insightful and comprehensive data about customer behavior.

- Personalization and better targeting. The use of AI enables the personalization of marketing content and offers, which increases the effectiveness of communication with customers by providing more relevant messages. Combining data from eye tracking and AI allows for more precise personalization of marketing communications. It is possible to provide content that not only meets consumers' preferences but is also constructed in such a way as to attract their attention based on the analysis of visual clusters.
- More effective advertising campaigns. Eye tracking and AI can support the creation and optimization of advertising campaigns, enabling better use of advertising budgets and increasing campaign effectiveness.
- Optimizing user experience. Integration of eye tracking with AI enables a dynamic response to user behavior. By analyzing visual clusters, you can instantly adjust content and interfaces in real-time to ensure optimal experiences.

About the limitations, the key aspects turned out to be:

- Privacy issues. The use of technologies such as eye tracking and AI collection of consumer data may raise privacy and ethical concerns, which may be limiting for some consumers.
- Costs and availability. Implementing advanced technologies can be expensive, which may be a barrier for smaller companies. Moreover, they are not always easily accessible to all industries or markets.
- Adapting to change. Rapid technological development means the need to constantly adapt to new tools and methods, which can be a challenge for marketers.

Barriers and challenges were also identified, focusing primarily on:

- Data interpretation and analysis. Large amounts of data generated by eye tracking and AI require advanced analysis and interpretation, which can be difficult and time-consuming.
- Education and skills. Implementing these technologies requires appropriate knowledge and skills. The challenge may be providing adequate training for employees to use these technologies effectively.
- Maintaining a balance between innovation and ethics. The introduction of advanced technologies in marketing requires attention to ethics and responsible use of data, which is extremely important to maintain consumer trust.

5.1. An integrated approach of eye tracking and AI in marketing communication management

The combination of eye tracking and artificial intelligence opens new horizons in analyzing consumer behavior and improving marketing strategies. Integrating these technologies brings many benefits. The development of both technologies indicates even more advanced possibilities in marketing communication management. The future of eye tracking and AI in marketing indicated by experts in interviews includes:

- The evolution of visual analysis accuracy. Eye tracking may become even more precise and more accessible across devices, enabling more accurate monitoring of user responses in different conditions and contexts.
- Development of AI algorithms. Artificial intelligence is becoming more and more sophisticated. Machine learning algorithms and data analytics are expected to become more advanced, enabling an even better understanding of consumer behavior and more effective personalization of communications.
- Integration of other technologies. There is a trend of integrating eye tracking and AI with other technologies, such as augmented reality (AR) or virtual reality (VR), which may create completely new opportunities for customer interaction and personalization of experiences.

The integrated use of eye tracking and artificial intelligence is the key to improving marketing strategies, allowing for more precise understanding and better interaction with audiences. The future of these technologies in the area of marketing is directed towards even more advanced methods of data analysis, which will allow companies to better adapt to the changing needs and expectations of customers. The interlocutors emphasized that the aspect of creating multisensory experiences, focusing on experience design, with the comprehensive involvement of all possible human senses, is extremely important. Five respondents mentioned, including one (Respondent Number 3 - abbreviation R3) strongly emphasized the need to create unique and original experiences, not only "positive" ones, which the recipients have already encountered many times and to which they are accustomed. One of the interlocutors called such a process "developing the concept of sensory experiences" (R5) as if it were a more complex idea resulting from previously adopted assumptions and a plan. Not an ordinary idea, but an "unforgettable experience" (R1), and also an "emotional and engaging event" (R4) and, in other words, "immersive" (R6). One of the respondents even mentioned "creating multisensory and virtual concepts" (R9), and another indicated a recommendation resulting from his own experience: "We use various available tools and installations, such as the appropriate selection of scents, special sounds, tastings, visual and interactive shows or innovative technologies to provide a full sensory experience related to the brand and product. Artificial intelligence helps to properly personalize the content created" (R2) when creating unique consumer experiences. Opinions overwhelmingly prevailed that there is a great need to

use innovative technologies and tools that are effective from the recipient's point of view in marketing strategies. Marketers paid attention to modern solutions and interactive technologies, such as touch screens, interactive presentations, virtual reality, and augmented reality. Artificial intelligence was presented as an opportunity to create the most intense sensory engagement possible for recipients and provide them with unique experiences on many levels. One of the respondents (R3) cited an example of a solution using Digital Signage technology, which is additionally connected to active digital systems and with appropriately synchronized devices that release, among others, scent notes specially selected by the AI algorithm, attracting attention and having an appropriate impact on passers-by in a public place. The interlocutors also emphasized the possibilities and resulting opportunities of implementing innovative solutions when shopping online, by creating appropriate incentives and stimulants. The respondents' statements mainly presented examples and good practices in the space of remote shopping, including shopping via mobile applications. The need for: visual attractiveness of websites and applications was repeatedly emphasized; satisfying and precise materials presenting a given product: accurate and detailed photos and/or recordings, the ability to zoom in on graphics, product presentation in 3D and details visible in various forms. An example of the exemplary practice was the opportunity to virtually try out a particular cosmetic product directly on the face in real-time, using the customer's camera and AI technology, for example on a mobile phone or laptop (R9). The next practice concerned an intelligent system that allows, after creating an example fashion composition on one's figure, to directly publish photos on social networking sites through automatic AI functions available in the application (R8).

In summary, the recommendations obtained during the interviews and data from the analysis of online content of marketing agencies' websites allowed us to generate sample promotional materials for the brand, in the form of proposals for a new visual identification, a new product and proposals for three ready-made variants of promotional posters and leaflets. The graphics generated by Microsoft Bing AI were subjected to eye-tracking tests in a sample of 10 respondents. The obtained results indicated that the respondents focused their attention the longest on the poster that contained a clear and distinct advertising slogan, as well as on the product that was placed in the central part of the poster. In turn, a leaflet that contained a lot of text and few graphics was the least effective in attracting the respondents' attention. In the design of product packaging and promotional materials, the presence and location of sensory stimuli (such as intense colour, fruit, face/skin, hair, product - packaging) that attract the greatest attention of respondents (due to the longest average exploration time and relatively short average time to reach the elements). Respondents were interested in the presented materials, and in a later interview, they assessed them as visually attractive. No one expressed any doubts or comments that the visualizations were created not by humans, but by artificial intelligence.

The entire research project allowed for the design of a proposal for the synergistic use of eye tracking and artificial intelligence for the needs of real-time marketing communication management, as illustrated in Figure 2.

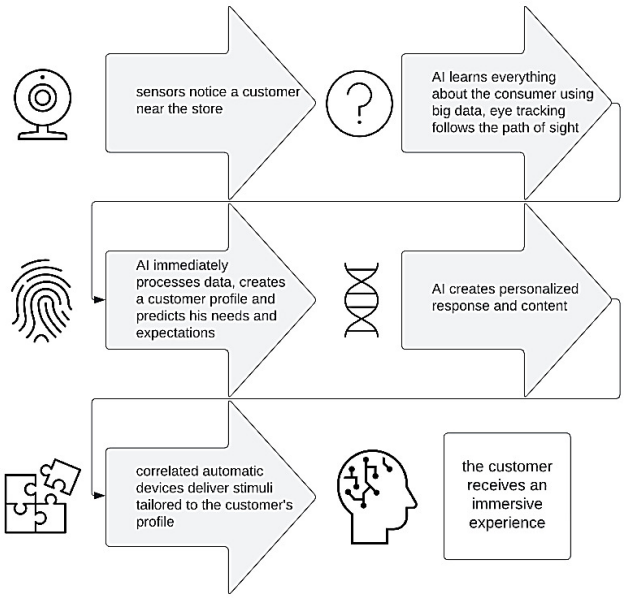

Figure 2. Mechanism of synergistic use of modern technologies to implement marketing activities. Source: own study based on research.

Good practices in planning the form of marketing communication influencing the generation of the value of the market offer are also summarized:

- communicating directly (verbally) the unique values of products,
- communicating the values expected by the client at a subliminal level,
- synesthetic information and communication,
- sensory and immersive experiences,
- personalization of created content and selected tools for transmitting it,
- adjusting the content and offer in response to the observed customer reactions to the stimuli used,
- creating a feeling of inaccessibility, including time and quantity limitations,
- emphasizing the uniqueness of the offer,
- adapting the form and structure of promotional tools to high standards and expectations,
- proper product display according to merchandising principles,
- storytelling with a coherent and interesting structure.

Signalling the actions and their effects also motivated attention to the need to use big data technology (Wieczorkowski, Pawełoszek, Chomiak-Orsa, 2022), artificial intelligence and other solutions to optimize stimuli for generating an appropriate set of product values for the customer. Contemporary conditions are heading towards blurring the boundary between the online and offline worlds, where digital technologies are an essential element of everyday life, and the digital world is perceived as a natural extension of the physical world. New generation

technologies, such as artificial intelligence, voice control or robotization, create the opportunity to match the planned stimuli to the created customer profiles as precisely as possible based on collected data sets. Modern society is characterized by inclusiveness and pro-social activities, and the expectation of interactive consumer experiences at every point of contact with the brand is a universally expected value. The obtained results motivated to propose a graphical summary of sensory stimuli selected and designed using artificial intelligence, which creates appropriately personalized marketing activities, based on the created consumer profile (see Figure 3). These values may subsequently influence the customer's reactions and behaviors precisely defined and expected by the marketer.

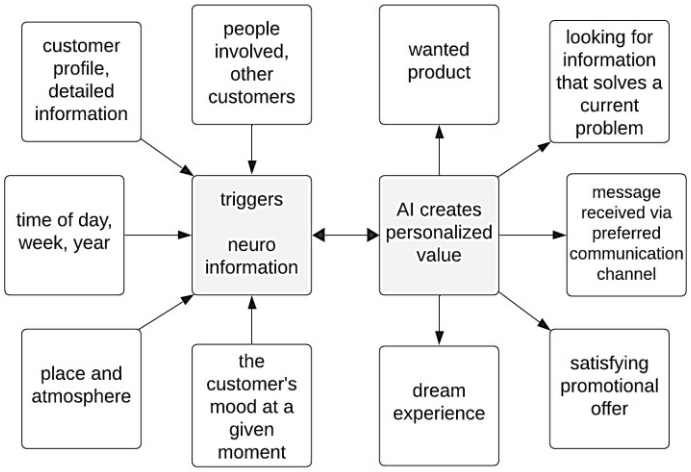

Figure 3. Sensory stimuli that create personalized value for the customer.
Source: own study based on research.

6. Summary and Conclusions

In recent years, a revolution has been observed in the approach to data analysis in the area of marketing. Traditional methods of collecting information and assessing the effectiveness of marketing campaigns have begun to give way to modern technologies that enable a more precise understanding of consumer behavior. Eye tracking and artificial intelligence have emerged as key tools that not only provide information about customer preferences and reactions but also enable dynamic adaptation of marketing strategies.

Eye tracking, initially used in research on visual perception, quickly found application in marketing. Thanks to advanced eye tracking technologies, it allows you to record, analyze and interpret what consumers pay attention to when interacting with marketing content. This tool not only reveals which elements of the campaign are more attractive or attention-grabbing but also helps understand what emotions they evoke and how they influence purchasing decisions.

In turn, artificial intelligence, based on machine learning algorithms and data analysis, enables a deeper understanding of consumer preferences and behavior. AI allows you to personalize your shopping experience by providing personalized offers and recommendations that are more effective and precisely tailored to the individual needs of customers, but also to the situation and mood in which the recipient is at a given moment.

The increasing importance of these tools also results from the increasing amount of data generated by consumers in the digital world. Analyzing this data using traditional methods becomes impossible due to its huge amount and complexity. Eye tracking and AI address this challenge by offering the ability to process and interpret large data sets in real-time, enabling faster responses to changing consumer preferences and behavior.

Therefore, eye tracking and artificial intelligence are not only changing the way data is analyzed but also revolutionizing the approach to marketing communications management. Their growing importance is an undeniable indicator of the future direction of marketing strategies, enabling marketers to better understand their audiences and reach them with the right messages more effectively. Eye tracking and artificial intelligence (AI) are currently key tools in the field of marketing communication management, allowing you to create and optimize marketing strategies more and more effectively.

However, it should be noted that the use of modern technologies in marketing communication management is not without challenges. This requires appropriate infrastructure adaptation, understanding of technology and employee training. Additionally, there are also concerns about data privacy and ethics surrounding automation and machine learning. Nevertheless, the benefits of using eye tracking and AI in organizational management are very motivating. This gives organizations a competitive advantage, allows for more efficient use of resources, reduction of costs, and improvement of the quality of services. As AI technology develops, its role in marketing can be expected to increase. Eye tracking research and the use of artificial intelligence in marketing communication management open up new opportunities for understanding consumer behavior and improving marketing strategies.

To sum up, the synergy between eye tracking and artificial intelligence is an extremely promising direction in the field of marketing communication management. Implementing these technologies will allow companies to better understand customers, reach them more effectively with appropriate automatically generated messages (without human intervention), and dynamically adapt marketing strategies to changing market expectations.

Prospects for further research in this field include the pursuit of even greater precision of visual analysis in eye tracking, the development of more advanced AI algorithms and the integration of these technologies with others, such as AR and VR. This research will focus on an even better understanding of consumer behavior and creating more effective and personalized experiences for customers.

In the face of these challenges, marketers must improve their analytical skills, ensure data protection and at the same time use these technologies responsibly to reap the full benefits of their use in marketing.

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TRANSACTIONS WITH RELATED ENTITIES IN THE LIGHT OF TAX SOLUTIONS AND CSR GOALS

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Purpose: The aim of the article is to analyze the impact of transactions with related entities on the company's financial results and the implementation of sustainable development goals. The lack of the tax dimension of corporate social responsibility in the literature encourages research in this area.
Design/methodology/approach: Based on the study of literature and legal regulations, reference was made to the transfer pricing policy as the main instrument of tax optimization in the light of CSR solutions. It also conducted its own survey research to learn more about the relationship between the use of corporate social responsibility in a company's strategy and its approach to taxation.
Findings: The article shows that the proposed changes in the publication of financial statements and non-financial reporting, together with the transfer pricing policy, constitute a new face of tax optimization in the context of corporate social responsibility. Based on the study, it can be concluded that CSR should be extended to include tax issues in the field of transactions with related entities.
Originality/value: Little is known in the literature about tax issues in CSR, although solutions are increasingly being introduced to encourage companies to behave socially responsibly. Recommendations for solutions in the field of disclosing information about transactions with related entities involving CSR in the context of tax avoidance constitute the originality of the article.

Keywords: corporate social responsibility, corporate taxation, tax avoidance, transfer pricing, capital groups.

Category of the paper: Research paper.

1. Introduction

Corporate social responsibility (CSR) is an interdisciplinary issue that is broadly understood and focuses not only on increasing the value of the company, but also on the natural environment, ethical business conduct and openness to the needs of the broadly understood environment. Tax solutions are increasingly being introduced in individual countries to encourage companies to behave socially responsibly. However, in the literature on CSR, little is known about the importance of taxes in this area, especially regarding transactions with related entities.

Transfer prices, i.e. prices established between related entities, are an important element of accounting and business management. In recent years, non-financial reporting, including sustainability (ESG) reporting, has become increasingly important. In this context, transfer pricing can play an important role in providing information on the environmental, social and governance impact of a company's activities.

The aim of the article is to examine the relationship between the use of corporate social responsibility in the financial relations of a capital group and its approach to taxation in the area of transfer pricing. Attention was drawn to the challenges facing non-financial reporting in the field of sustainable development goals.

2. Domestic and international related entities

The organizational structures of capital groups, mainly multinational corporations, are complicated and it is difficult to determine the relationships between individual entities and who may influence their activities. The provisions of tax law relating to prices in controlled transactions and the sanctions contained therein may be applied when it is proven that these prices have been manipulated only between entities that can be called related entities under the law, as specified in the introduction to the OECD Guidelines on transfer valuation in controlled transactions (OECD, 2010). Defining related entities is therefore a very important issue for determining the area of application of the mentioned regulations, as well as the established sanctions. Therefore, tax regulations in most countries strictly define under what circumstances entities can be considered related. Definitions of related entities were also formulated by the OECD and International Accounting Standards (Sojak, Baćkowski, 2003, pp. 29-30).

The international definition of the concept of related entities formulated by the OECD is included in Art. 9 section 1 (a) and (b) of the Model Tax Convention on Income and Capital, hereinafter referred to as the OECD KM (OECD, 1992), as well as in the above-mentioned OECD Guidelines. Two enterprises are linked when one of them participates directly or

indirectly in the management, control or capital of the other or the same person participates directly or indirectly in the management, control or capital of both enterprises. In individual OECD countries, related entities may be defined differently, which may result in double taxation in practice. Most of them also differ from the OECD definition contained in Art. 9 OECD KM. In addition, they may be defined differently for different purposes, e.g. accounting, taxation, etc. All definitions contained in national transfer pricing regulations particularly address the issue of control exercised by one entity over the activities of another.

Poland became a member of the Organization for Economic Co-operation and Development in 1996. One of the requirements for joining this organization was the introduction of transfer pricing regulations in line with OECD guidelines (Sojak, Baćkowski, 2003).

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Relationships between entities according to Polish tax regulations may occur in the following cases:

- a domestic entity participates directly or indirectly in the management or control of a foreign enterprise or has a share in the capital of this enterprise;
- a foreign entity participates directly or indirectly in the management or control of a domestic entity or holds a share in the capital of this entity;
- the same person (natural or legal) or an organizational unit without legal personality directly or indirectly participates in the management or control of a domestic entity and a foreign entity or holds a share in the capital of these enterprises;
- a domestic entity participates directly or indirectly in the management or control of another domestic entity or holds a share in the capital of that entity;
- the same person (natural or legal) or an entity without legal personality directly or indirectly participates in the management or control of domestic entities or holds a share in the capital of these entities (Ustawa…, 1992; Ustawa…, 1991).

The definition of related entities has a significant impact on the scope of application of regulations in connection with the application of transfer pricing, as it lists the entities to which these regulations apply. The concept of control is extremely important, as it is the most important factor determining the effectiveness of all regulations regarding related entities (Krzewski, Michalak, 2000).

3. Taxation of enterprises and CSR goals

Corporate social responsibility is a concept that has no universal and universally accepted definition. For this reason, determining its scope is not an easy task. Due to the lack of unambiguous standards, it is difficult to precisely determine which behaviors of enterprises are a manifestation of social responsibility (Kozłowska-Makóś, 2020).

In accordance with ISO 26000, CSR is an organization's responsibility for the impact of its decisions and activities on society and the environment, which is ensured through transparent and ethical conduct that:

- contributes to sustainable development, including social well-being and health,
- takes into account the expectations of stakeholders,
- is in accordance with applicable law and consistent with international standards of conduct,
- is integrated with the organization's activities and practiced in its relations (ISO 26000, 2010).

Therefore, the concept of corporate social responsibility should be understood as a concept thanks to which companies at the stage of building a strategy voluntarily take into account social, local, environmental protection as well as relations with various groups of stakeholders. Corporate social responsibility means not only meeting all formal and legal requirements as part of business operations, but also increased investment in human resources, environmental protection and relations with the company's environment, i.e. additional voluntary commitment. Therefore, CSR is a process in which enterprises manage their relationships with various stakeholders who can have a real impact on the success of their business.

Pro-social activities are costly and not every company would voluntarily bear this type of burden. Therefore, at least some of the activities, including paying taxes, must be obligatory, i.e. regulated by the state by relevant legal provisions, to ensure a proportionate distribution of these burdens to all enterprises, thus maintaining comparable operating conditions (Brigham, Houston, 2005).

The development of capital groups, as well as their financial results, do not depend only on the efficiency of management, but also on how much of the added value generated is discharged in the form of taxes and para-taxes. Taxes are a source of financing public and social goods, which are also used by business entities.

Corporate income tax plays a special role here, as it is mainly the larger enterprises that demonstrate in their business strategies that they implement socially responsible activities.

However, related entities are reluctant to pay taxes, which results in unethical or even aggressive tax planning. This is related to the phenomenon of tax avoidance, which occurs in varying degrees and in different forms of individual countries. Escaping from taxes can be understood and implemented in various ways. In the context of the problem under consideration, the most important thing is to distinguish these activities according to the legal criterion, i.e. without or in breach of law.

The first of these, known as tax avoidance, is a taxpayer's action that meets all of the following conditions:

- is in line with the letter but is contrary to the spirit of tax law (ratio legis),
- leads to the taxpayer obtaining a tax advantage, in particular reducing or liquidating tax obligations,
- the tax advantage is an important motive for the taxpayer to take the action under consideration.

It is believed that the tax avoidance thus defined leads to total or partial non-payment of tax in the jurisdiction in which the enterprise derives economic benefits (i.e. the place of the source). Unlike avoidance, tax evasion is an illegal phenomenon involving the concealment or misrepresentation of the nature of a transaction (Kozłowska-Makóś, Kluzek, 2018).

4. Taxation avoidance in the related parties

International capital groups are the effect of running economic activities of varied scope in different countries. Regardless of whether the group of related entities was established for business or financial reasons, one of the consequences of its operation is the taxation of direct income from activities in various tax jurisdictions. In this context, income tax becomes one of the risk factors for the operations of an international capital group.

Taxation of international capital groups is associated with such phenomena as: tax optimization or international tax avoidance. These phenomena occur in varying intensity and in different forms in particular countries. All activities of business entities aimed at minimizing tax burdens within the limits of applicable law are referred to as tax optimization (tax planning). Capital groups striving to minimize the tax burden have two options to choose from: tax savings and tax avoidance.

Tax savings involve the use of tax benefits, tax rebates and exemptions offered by the legislator, as well as the selection of the most favorable form of taxation.

Tax avoidance is based on the taxpayer's operation in a legal way, using the legal forms allowed. He will be looking for the most favorable way to minimize tax burdens by using gaps in the law. It is important to distinguish between avoiding taxation from tax evasion. Tax avasion means that the taxpayer violates applicable law. This is punishable.

Noteworthy is the concept of "international tax avoidance" defined as ethical tax planning, which uses legal methods to avoid excessive taxation. Typically, as part of tax optimization in the international market, capital flows through countries offering tax privileges). The activities of international capital groups are based on at least several tax laws of individual countries, EU tax law, as well as international tax law. This diversity and multitude of regulations allow related entities to create such a strategy that will use various instruments to optimize, and thus to avoid taxation. In addition, in their tax strategies, capital groups use a number of financial instruments, which often complicate the real verification of transparency and credibility by the tax administrations of individual Member States.

It is worth noting that in today's era complex capital structures use highly advanced tax technologies, which are mainly based on multi-pass hybrid solutions using complex derivative instruments. The multiplicity and complexity of instruments, which at the same time are subject to dynamic "mutation", contributes to ineffective and helpless tax control in individual countries. Another important element of the lack of effectiveness in the fight against international tax avoidance is the lack of a modern holding tax law. The idea of a modern holding tax law should be based on tax constructions satisfying not only international groups guided by honest intentions, but also protecting the state budget interest. The lack of the concept of a modern holding tax law is one of the key reasons for the ineffective state struggle against international tax avoidance.

Undoubtedly, the situation is also complicated by the phenomenon of international harmful tax competition between countries. In intra-EU relations, tax competition should be considered a phenomenon involving the use of various taxation techniques to develop the national economy and prosperity by increasing the competitiveness of domestic economic activity or attracting foreign investments. Tax competition is a natural consequence of globalization processes, because in the world of growing economic interdependencies taxation has an increasing impact on investment decisions of capital groups. It is an expression of a discrepancy between the interests of a single country (a member state of the European Union) and the interest of all countries (the European Union). More and more often the boundary between harmful and favorable tax competition is difficult to determine. This is particularly noticeable when the Member States (most often neighboring) form their tax policy, basing it on constructions that directly or indirectly influence the decisions of international capital groups regarding the change of their tax residence (Kozłowska-Makóś, 2022a). Bearing in mind the above tendencies, it is worth looking at the instruments used to avoid taxation by international capital groups.

5. Corporate social responsibility and transfer pricing policy

In the valuation of transfers between related entities there is still one very important aspect, namely a differentiated tax system in the countries in which the various responsibility centers of a capital group are located.

Complex capital structures take appropriate policy of price transfer, depending on whether they are an international group, which has subordinate companies located in countries with different tax rates. Tax effect in this case of differentiated prices in the international groups is best demonstrated by the same transfer using so-called high and low transfer price. In the country of the company-supplier, where is a higher rate of income tax it pays to fix the transfer price at a lower level. Lower transfer price means that we pay less corporate income tax. We obtain the lower profit after taxation. However, in the country of the company-recipient, where is a lower tax rate, the low transfer price means that we pay more income tax. In the end we get a higher taxable income (Figure 1).

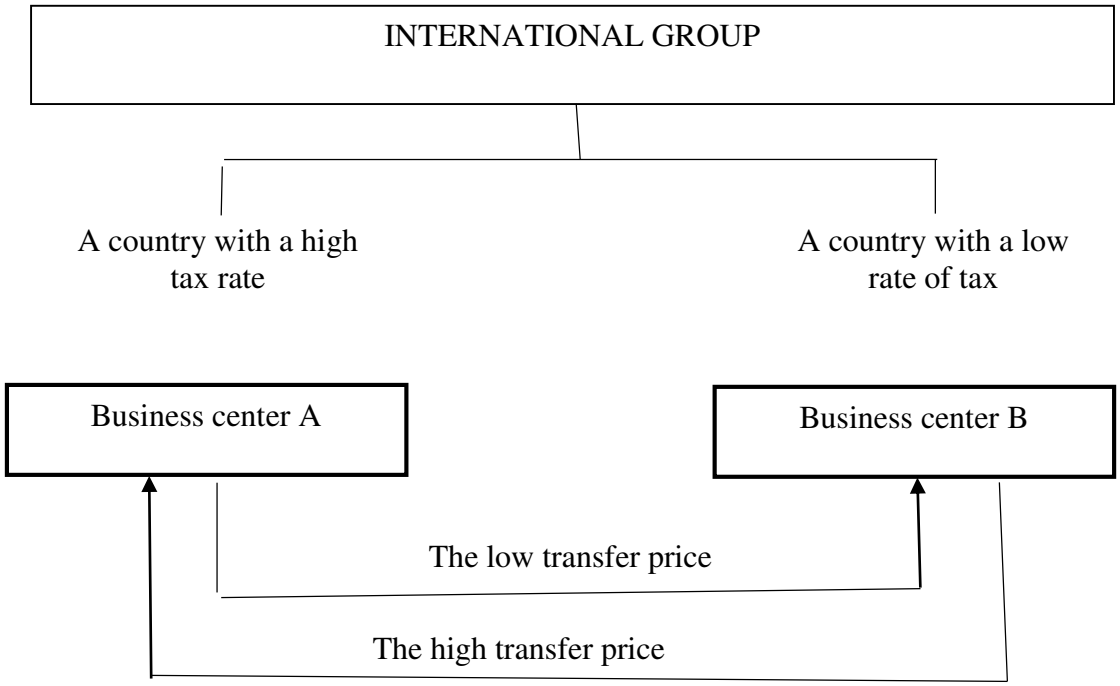

Figure 1. Preferences of transfer.

Source: Kozłowska-Makóś, 2022b.

It can be argued that the phenomena involving the income shifting between companies lying in the different countries of the same capital group to reduce tax liabilities will remain a problem on a global scale. Due to the fact that the unification of tax rates around the world is impossible, in order to minimize this phenomenon, international consensus on tax law concerning related entities is required, which at present is imperfect and raises important issues between the taxpayer and tax administration.

Although the issue of taxation as one of the key elements of CSR is not widely accepted, research in this field is already under way in the world. Our own survey was conducted in order to learn more about the relationship between the use of corporate social responsibility in the strategy of a company and their approach to taxation. The survey covered 300 respondents who were senior and middle managers, as well as owners (Figure 2).

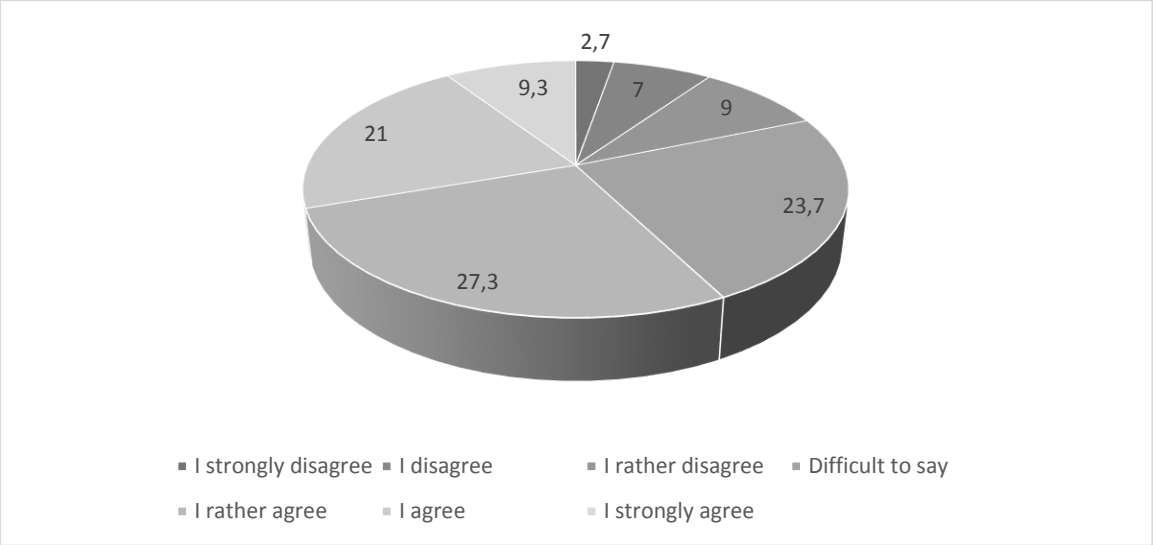

Figure 2. Impact of the CSR concept on corporate taxation.
Source: Own research.

The survey results indicate that tax issues are rather part of the Polish CSR program. The relationship between CSR and tax liabilities was identified in more than half of the surveyed enterprises. Almost a quarter of respondents had no opinion, and for a fifth of respondents the concept of CSR in taxation definitely does not matter.

From a utilitarian perspective, you can conduct a cost-benefit analysis to assess whether specific actions result in maximum well-being for most people. Avoiding taxation in one jurisdiction may result in investment and improvement of conditions in another country, but ethical relativism can be problematic. Ethics is a reflection of local social morality, so there are differences, especially between developed and underdeveloped countries.

6. Challenges in the use of transfer pricing in financial, non-financial and ESG

Accounting and tax compliance has been the subject of a vast amount of research. However, tax compliance is relatively rarely the subject of research in terms of its inclusion in business processes and treatment in a systemic perspective.

The multitude of tax and balance sheet law regulations imposes on enterprises a number of supervisory and reporting obligations. For example, according to Polish accounting regulations, the management board of a commercial law company is responsible for, mong others, the internal control necessary for the correct preparation of financial statements, including the correctness of tax settlements, and the supervisory board is responsible for supervising the financial reporting process. In addition, companies listed on the Warsaw Stock Exchange should annually submit a statement on the company's compliance with the corporate governance principles contained in Best Practice for GPW listed companies. The regulations do not contain guidelines as to how the internal control system in the field of accounting, financial reporting, and taxes, is to be constructed in practice (Sulik-Górecka, 2022).

In recent years, non-financial reporting, including sustainable development (ESG) reporting, has become increasingly important (Emerling et al., 2022). In this context, transfer pricing can play an important role in providing information about the impact of a company's activities on the environment, society and governance. Transfer pricing can have a significant impact on information disclosed in non-financial reporting. For example, high transfer prices set for transactions involving greenhouse gas emissions may indicate that the company is not sufficiently active in environmental protection. In turn, low transfer prices set for salary-related transactions may suggest that the company does not provide employees with appropriate working conditions.

In the following years, the scope of disclosure of non-financial information, including that in terms of sustainability and corporate social responsibility, will evolve and expand. As of 1 January 2021, taxpayers in Poland whose revenue value in the tax year exceeded the equivalent of EUR 50 million (according to the average NBP exchange rate, announced on the last business day of the calendar year preceding the reporting year) and tax capital groups regardless of the amount of revenues achieved are required to publish information on the executed tax strategy on their website or the website of a related entity (Ustawa…, 1992).

Pursuant to the regulations, the minimum scope of information on the implemented tax strategy includes among others:

- information on transactions with related entities, the value of which exceeds 5% of the balance sheet total of assets,
- information on the processes and procedures for managing the performance of obligations under tax law and ensuring their proper performance,
- information on the settlements in countries applying harmful tax competition (transactions with entities based in tax havens).

The variety of reporting obligations in Poland results from the wide scope of various types of taxes functioning in the Polish tax system. It is obvious that the tax authorities are concerned with the greatest possible tax revenues, hence instruments are implemented to capture any irregularities (Sulik-Górecka, 2022). In order to counteract the phenomenon of tax avoidance, also anti-abuse clauses are used, including, in particular, the General Anti-Avoidance Rules

(GAAR). Another exemplary instrument to prevent tax avoidance is the need to report information on tax schemes Mandatory Disclosure Rules (MDR) in a situation where the taxpayer has applied some arrangement, the main purpose of which is to achieve a tax benefit (Ustawa…, 1997). Regulations regarding transfer pricing issues are also included in the OECD Model Convention. Its content includes the basic principle relating to transfer prices, i.e. the arm's length principle, the essence of which consists in recommending the valuation of transfer between related entities, taking into account commercial and financial conditions in force on the free market. A less popular instrument for the prevention of tax avoidance is the provisions relating to the controlled foreign corporation. Their essence consists in adding to the income of a shareholder in the country of his tax residence the income of a subsidiary located in another country and the taxation of the sum of this income in the first country. This taxation also takes place when the income has not been paid in the form of a dividend. Their task is to counteract the phenomenon of income retention in tax havens. Many countries have developed lists of countries that use harmful tax competition and taxed the income of controlled foreign companies when these companies are located in the jurisdictions listed in the list (locational approach).

A novelty in Polish regulations are the provisions of the Tax Ordinance, section IIB, entitled "Cooperation", introduced by the Act on resolving disputes related to double taxation and concluding advance pricing agreements (Ustawa…, 2019, Ustawa…, 1997), enabling the conclusion of the so-called "cooperation agreements" in the field of taxes. Such a civil law contract will allow for obtaining a number of special privileges, mainly in the form of no tax inspections, no obligations in relation to the so-called "national schemes", or (under certain conditions) limiting certain sanctions, e.g. in VAT.

The risks associated with failure to pay adequate attention to tax compliance include not only tax risks manifested in the necessity to pay taxes with interest, but also the imposition of penalties or sanctions or consequences provided for in the Fiscal Penal Code. The consequence of violating tax compliance can be the loss of a company's credibility and reputation, as well as a number of negative consequences for managers who will be held responsible in this regard (Sulik-Gorecka, 2022). Current applicable laws and regulations will not resolve all tax avoidance problems. However, the increasing social pressure and public interest caused that some international enterprises began to perceive the discharge of taxes to the budget as part of the policy related to sustainable development and corporate social responsibility (Wasilewski, Bischoff, 2017).

7. Summary

Currently, many enterprises, especially larger and prosperous ones, indicate that corporate social responsibility is an indispensable element of their business strategy. Corporate social responsibility is relatively rarely associated with transactions between related entities forming a capital group.

Imprecise regulations, lack of case law on complex transfer pricing issues, and limited experience of tax authorities in examining and assessing transactions concluded in capital groups increase the transfer pricing risk for taxpayers. Corporate social responsibility (CSR) is a response to the challenges posed by the concept of sustainable development.

Related entities face challenges in concluding internal transactions, especially in the area of non-financial reporting. ESG reporting is becoming more and more popular among enterprises. This is due to the growing expectations of stakeholders, such as investors, customers and employees, regarding responsible business conduct. Transfer pricing can be used to improve the quality of ESG reporting. For example, companies can use transfer pricing methods that take into account ESG factors such as environmental impact or employee rights. Thanks to this, the information disclosed as part of ESG reporting will be more reliable and transparent.

It therefore follows that the use of transfer pricing in non-financial and ESG reporting poses certain challenges. One of them is the lack of uniform standards for ESG reporting. As a result, companies may use different disclosure methods, which may make comparisons difficult. Another challenge is the lack of access to transfer pricing data. This data is often confidential and not publicly available. As a result, companies may have difficulty estimating the impact of transfer pricing on their financial and ESG performance.

To increase the importance of transfer pricing in non-financial and ESG reporting, it is necessary:

- development of uniform ESG reporting standards that would take into account transfer pricing factors,
- ensuring access to transfer pricing data, including publicly available data,
- development of transfer pricing methods that would take into account ESG factors.

Implementation of these recommendations would improve the quality of ESG reporting and increase its credibility.

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THE EFFECTIVENESS OF ALTERNATIVE INVESTMENTS IN THE ERA OF GEOPOLITICAL CHANGES

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Purpose: The purpose of the article is to identify the volatility of the rates of return, as well as the profitability of investments in precious metals in relation to traditional investments during the unstable epidemic and geopolitical situation, including the identification of the impact of the method of calculating the simple rate of return on investment decisions.
Design/methodology/approach: The article uses literature analysis and a statistical research method as research methods. A review of the world literature on the changes taking place on investment markets in the context of the COVID-19 pandemic and the war in Ukraine was carried out. The empirical part of the article presents the results of the analysis of the level of return on metals, compared to traditional investments, in the period 20.03.2018-21.03.2023.
Findings: The level of annual rates of return differed from the level of average annual rates of return. Therefore, the conclusions about the profitability of individual investments depend on the chosen method of calculating simple rates of return.
Research limitations/implications: This article does not exhaust the examined issue. In subsequent studies, it is worth reviewing the literature not only of the most recent publications, but also of older ones. It is also worth analyzing other types of alternative investments. In future analyses, it is also worth considering the use of statistical tests.
Practical implications: Identifying changes in ores markets compared to traditional investment markets and indicating the impact of the simple rate of return calculation method on its value may be useful in making and evaluating investment decisions, as well as in better understanding of the changes taking place in these markets.
Originality/value: The paper compares two methods of calculating the rate of return during an uncertain economic situation. The choice of the method of calculating the rate of return affects the results obtained, which translates into investment recommendations.

Keywords: rate of return, alternative investments, precious metals, COVID-19 pandemic, war in Ukraine.

Category of the paper: Research paper.

1. Introduction

In the times of risk and uncertainty, investors change their behavior. In such periods, risk aversion increases among investors, while expectations regarding the amount of return on investment decrease. Investors take actions to reduce the risk of their portfolio (Juras, 2021). The uncertainty caused by the COVID-19 pandemic, followed by the war situation beyond Poland's eastern border, prompted some entities to change the way they save and invest. Investing capital in precious metals has been seen for centuries as a way to invest, but also to secure savings (Lejman-Gąska, 2021). Although investments in ores are popular regardless of the economic situation, they are more in demand in the times of uncertainty. During these periods, investors pay more attention to their investments aimed at securing their savings. They can invest capital through traditional investments, which include equity instruments, such as shares and debt instruments – bonds. They can also choose alternative investments, in other words, investments that are alternative to traditional ones. The most common are hedge funds, private equity investments, real estate and commodities, including metals (Tomaszewski, 2013). In the times of uncertainty, the portfolio is diversified with alternative investments because their rates of return are negatively correlated with the rate of return on traditional investments (Juras, 2021).

Due to the greater uncertainty caused by the epidemic and geopolitical situation, some investors are leaning towards investments considered safer than investments in company shares. At such times, they may consider both other traditional investments and alternative investments – including investments in precious metals such as gold, silver, platinum or palladium. In Poland, investments in ores are still often chosen form of investment, primarily in gold or silver, but also in other precious metals (Lejman-Gąska, 2021).

The years 2020-2023 can be considered a time that was characterized by greater uncertainty. In 2020-2022, the COVID-19 pandemic contributed to this, while in 2022-2023 – the ongoing war in Ukraine. This may be particularly important in emerging markets, as COVID-19 has had the greatest negative impact on these markets (Harjoto et al., 2021). These events may have changed the way people save and invest, as well as encourage investors to make investments considered safer.

The aim of the article is to identify the volatility of the level of rate of returns, as well as the profitability of investments in ores in relation to traditional investments during the unstable epidemic and geopolitical situation, including the identification of the impact of the method of calculating the simple rate of return on investment decisions. Identifying changes in ores markets compared to traditional investment markets and indicating the impact of the simple rate of return calculation method on its value may be useful in making and evaluating investment decisions, as well as in better understanding of the changes taking place in these markets.

The structure of the article was subordinated to the implementation of the above aim. The first part of the article reviews the world literature on the changes taking place on investment markets in the context of the COVID-19 pandemic and the war in Ukraine. Next, the applied statistical research method and issues related to the calculation of a simple rate of return are described. In the next part of the article, the results of the empirical analysis of the level of return on metals and traditional investments in the period between 20.03.2018 and 21.03.2023 are presented.

2. Literature review

Both the COVID-19 pandemic and the war in Ukraine have caused sharp changes in stock and commodity prices, exchange rates and an increase in inflation. These events have a significant impact on, among others, stock, gold and oil prices (Shaik et al., 2023).

The first of these events, that is the COVID-19 pandemic, had a negative impact on the economy, by increasing difficulties in the transport of goods, or negatively affecting stock and indices prices on the stock exchange (Harjoto et al., 2021). The pandemic has caused negative shocks on stock markets around the world (Harjoto, Rossi, Paglia, 2021). It also had a negative impact on the five main European equity markets surveyed: French, German, Italian, English and Spanish (Espinosa-Méndez, Arias, 2021). The relationship between the COVID-19 pandemic and stock returns was greater the worse the epidemic situation was (Harjoto et al., 2021). The COVID-19 pandemic has also affected the situation on commodity markets, which include bullion markets. As an example of such a market, Harjoto, Rossi, Lee and Sergi (2021) cite the oil market, which was affected by information on the number of deaths from COVID-19.

The pandemic has had a negative impact on the economies of both developed and emerging countries. The problem is therefore global, but it has hit the economies of emerging countries harder. This may be due to the fact that emerging economies have less developed payment system infrastructure and lower liquidity, as well as greater information asymmetry (Harjoto, Rossi, Paglia, 2021). As such, the tightening of pandemic restrictions has had a negative impact on emerging markets in particular (Harjoto et al., 2021). Due to the lack of a single, consistent definition of emerging markets, there are various classifications of markets belonging to this group (Rubaj, 2020). For this reason, there is also no consensus on the qualification of Poland to this group of markets. Białkowski and Sławik (2021) point out that Poland belonged to emerging markets until September 2018. Also according to the FTSE Global Equity Index (FTSE Classification of Equity Markets, 2023) of March 2023, Poland is classified as a developed market. However, according to the Standard Poor's index (S&P Dow Jones Indices' 2022 Country Classification, 2022) from June 2022, Poland is classified as an emerging market.

Due to the lack of a clear assignment, the COVID-19 pandemic could also have had a greater impact on the Polish market. Information on the number of COVID-19 cases and deaths affected the rates of return of instruments listed on stock exchanges in developing countries. However, they did not have a significant impact in developed markets, despite the fact that in developed markets the worsening epidemic situation also caused uncertainty among investors (Harjoto et al., 2021).

Moreover, the response to new COVID-19 cases also depended on the stage of the pandemic. Reactions to new cases and deaths at the stage of pandemic development were different than at the stage of its stabilization or decline (Harjoto et al., 2021). Ashraf (2020) points out, however, that the reactions on the stock exchanges were primarily related to the increase in the number of confirmed cases of COVID-19, and not to the number of deaths due to COVID-19. The author explains this by the fact that experienced investors pay more attention to early signals – which may be the number of COVID-19 cases – rather than to late signals – such as the number of deaths that result from the disease.

The situation on the markets was also affected by the war in Ukraine. This event increased the uncertainty that was already present due to the COVID-19 pandemic. The war also had a negative impact on the economy, through the interruption of some supply chains or problems with transport. This situation has also affected the global economy due to the fact that Russia is one of the largest crude oil producers, as well as an important exporter of gas and metals. As a result, prices on stock and commodity exchanges increased (Shaik et al., 2023). Shaik (2023) points out that historically, stock, gold and oil prices have reacted strongly to geopolitical changes in the world, including during the COVID-19 pandemic.

Precious metals are seen as an appropriate hedge, especially in conditions of uncertainty, in a period when inflation rises and the local currency depreciates (Lejman-Gąska, 2021). Tran and Nquyen (2022) point out that in Europe, stock market prices, gold prices and exchange rates are interrelated, so a change in one market causes changes in the others. Therefore, when stock prices fall, investors should withdraw their capital from the stock market and reinvest it in gold and cash, with a particular focus on US dollars, due to the lower risk associated with these investments. When the situation is more stable and investors are more willing to risk, they should reduce their investments in gold and currencies and increase their investments in equities. During the pandemic, investors were therefore more cautious when choosing the investment market.

During the pandemic, the situation on the gold market looked different than on the stock market. When stock indices fell, gold appreciated. The COVID-19 pandemic has therefore had a positive impact on gold price volatility. Gold prices have typically risen as COVID-19 cases and deaths have increased. This was the result of the search for safer investments during the fear of the consequences of the pandemic, which caused investors to withdraw their funds from exchanges and invest in safer investments, including gold (Tran, Nguyen, 2022), which is

widely considered to be the safest mean of investing capital (Przyłuska-Schmitt, Jegorow, Bučková, 2022).

During the COVID-19 pandemic and the war in Ukraine, gold remained a safe way to invest and diversify the investment portfolio (Shaik et al., 2023). This is confirmed by Juras (2021), noting that in the years 2000-2019 there was no Pearson linear correlation between the value of the WIG20 index and the value of gold (r = 0.24), while in 2020 a negative linear correlation between these prices was recorded (r = -0.52), so an increase in the value of WIG20 is accompanied by a decrease in the average value of gold. Gold was therefore perceived as a safe component of long-term investments, which effectively diversifies and reduces the risk of the investment portfolio. It was used as an alternative investment because it was perceived as risk-free and not subject to inflationary pressures (Tran, Nguyen, 2022).

For this reason, during the pandemic, investments in gold began to be considered more often as a form of safe capital investment. Investors, reducing the share of riskier investments in the portfolio and increasing the share of investments with a lower level of risk, were more likely to choose investments in gold and US treasury bonds (Bentes et al., 2022). Siemaszkiewicz (2023) mentions that gold can be used as a universal, safe investment. On the other hand, ores such as silver, palladium or platinum can be seen as safe investments only in the short term. She also points out that gold and silver during the COVID-19 pandemic could have been successfully used for diversification purposes (Siemaszkiewicz, 2023). Lejman-Gąska (2021) notes that during the pandemic, interest in investments in ores, primarily gold, silver, platinum and palladium, grew on the Polish market.

3. Research methods

In order to identify the profitability of investments in ores, their rates of return were checked and compared with other possibilities of investing capital. For this purpose, data were analyzed on:

- alternative investments – in gold, silver, platinum and palladium,
- traditional investments:
  - in shares – on the example of the WIG20 index,
  - in bonds – on the example of Polish 10-year bonds sold on the secondary market,
  - deposits – based on the average interest rate on deposits lasting from 6 months to 1 year.

The profitability of these investments in three periods was checked: the core period, the COVID-19 pandemic and the war in Ukraine. The base period was set at 2 years back from the date of commencement of the state of epidemic in the territory of Poland. The epidemic period was set at two years from the date of commencement of the state of epidemic. The time of war

was set as one year after the end of two years after the introduction of the state of epidemic. One year from 24.02.2022, that is from the date of the outbreak of the war, was also examined. These periods are as follows:

- base: March 20, 2018 - March 19, 2020,
- COVID-19 pandemic: March 20, 2020 - March 21, 2022 – the state of epidemic in Poland began on March 20, 2020 (Regulation of the Minister of Health from 20.03.2020),
- war in Ukraine: March 22, 2022 - March 21, 2023, the period February 24, 2022 - February 23, 2023 was also analyzed.

In order to assess the profitability of alternative investments in selected ores in relation to traditional investments, the rates of return of these investments in the analyzed period were compared. The rate of return is a measure of efficiency. It expresses the level of investment income that the investor will achieve in a given period in exchange for resigning from allocating the invested capital for current consumption, in relation to the expenditures incurred for a given investment. The rate of return is a percentage measure and determines the income per unit of invested capital (Pera et al., 2014).

Simple rates of return were used, which are considered the basic measure of investment income. A simple rate of return is the ratio of income earned to expenditures incurred. It is comparable only for investments with the same time horizon (Pera et al., 2014). Simple rates of return were calculated using the formula (Bednarz-Okrzyńska, 2019):

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}, \quad (1)$$

where:
Rt – simple rate of return in period t,
Pt – price in period t.

Nominal rates of return were used, so rates of return that do not take inflation into account (Pera et al., 2014).

As Stankiewicz (2013) notes, two ways of calculating rates of return on investment can be distinguished. The first of them, called "New Year's Eve", consists in calculating rates of return based on the exchange rates from the last day of each year or the last day of the selected period. This way of calculating the rate of return is considered the simplest. It is used in calculations on the Warsaw Stock Exchange. It reflects the actual achieved rate of return on an investment purchased at one moment and sold at another. Therefore, it is used to calculate the actual, historical rate of return on a given investment. According to the second method, the rate of return on investment is the arithmetic average of the daily rates of return. This rate can be calculated using the formula (Stankiewicz, 2013):

$$\bar{R} = \sum_{t=1}^{n} \frac{R_t}{n}, \quad (2)$$

where:
$\bar{R}$ – arithmetic mean of rates of return,
n – number of quotations.

This method is more often used in scientific research and capital market analysis. It is used to present a hypothetical situation, that is what would happen if an investor for a given period of time sold and bought a given instrument every day at the closing price. The rate of return obtained in this way is a hypothetical average rate of return for a given period.

Calculating rates of return in individual ways usually leads to divergent results of the rate of return (Stankiewicz, 2013). The first method can be used to calculate the actual, historical rate of return, but only on the basis of two moments – buying and selling. Therefore, this method determines the real rate of return on investment, but does not take into account fluctuations in the price of the instrument over the life of the investment. The second method shows the average rate of return on investment, including fluctuations in the prices of equity instruments, but does not reflect the real rate of return on investment. Due to possible discrepancies in the results obtained in the level of return depending on the chosen method, the levels of return on investment calculated by both methods were analyzed.

4. Results and discussion

In order to check the profitability of individual investments in the examined period, simple annual rates of return (the first method) and simple average annual rates of return (the second method) were calculated. Daily data on the closing prices of ores, the WIG20 index and 10-year Polish treasury bonds available on the secondary market were downloaded from the stooq.pl website. Due to the fact that ores prices are quoted in US dollars per troy ounce, which is a measure usually used when reporting the weight of metals, before calculating the rates of return, the prices of metals were converted into Polish zlotys. For this purpose, the average exchange rate published by the National Bank of Poland was used. Thanks to this, the impact of fluctuations in the PLN/USD currency pair on the profitability of investments in individual ores was taken into account. This may be important because there is a negative correlation between the price of gold and the US dollar (Anasiewicz, 2021). Data on the average interest rate on bank deposits concluded for a period from 6 months to 1 year were downloaded from the website of the National Bank of Poland. The price evolution of individual instruments during the period under review is shown in figures 1 to 6. Metals prices per troy ounce (figures 3-6) are presented in both Polish zlotys and US dollars.

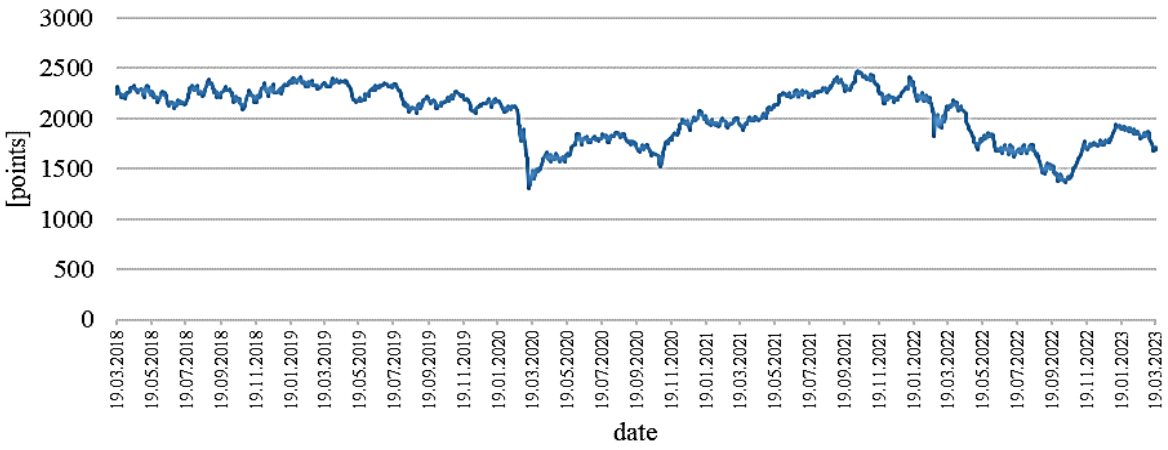

Figure 1. WIG20 index in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/

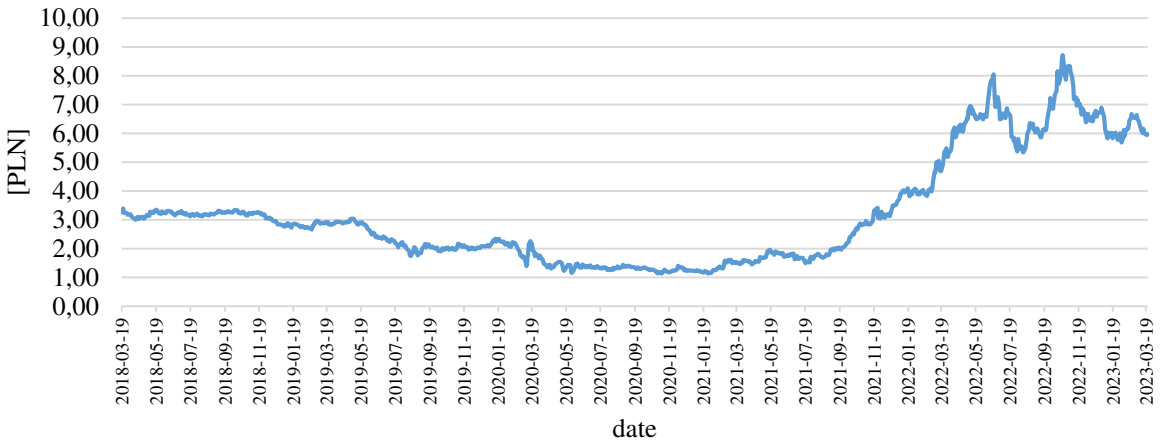

Figure 2. Bond prices in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/

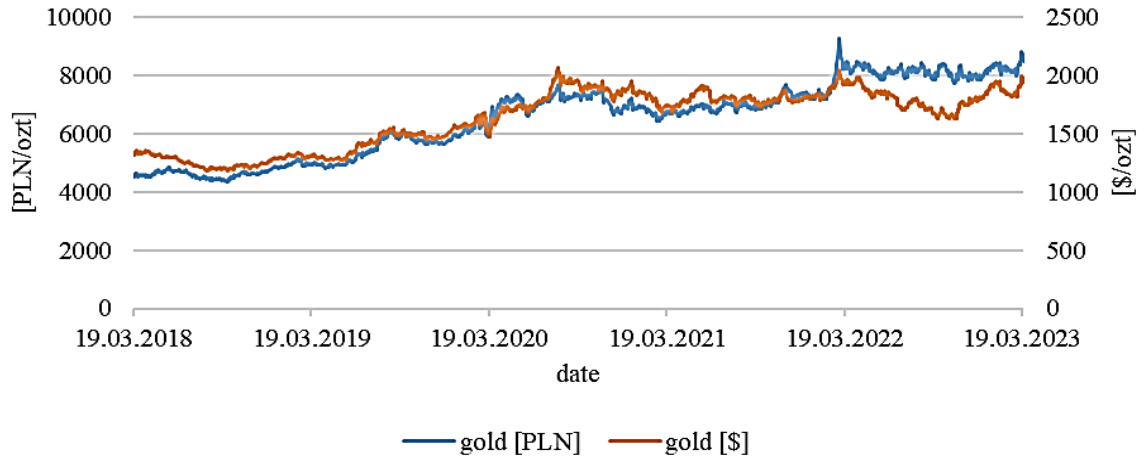

Figure 3. Gold prices in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

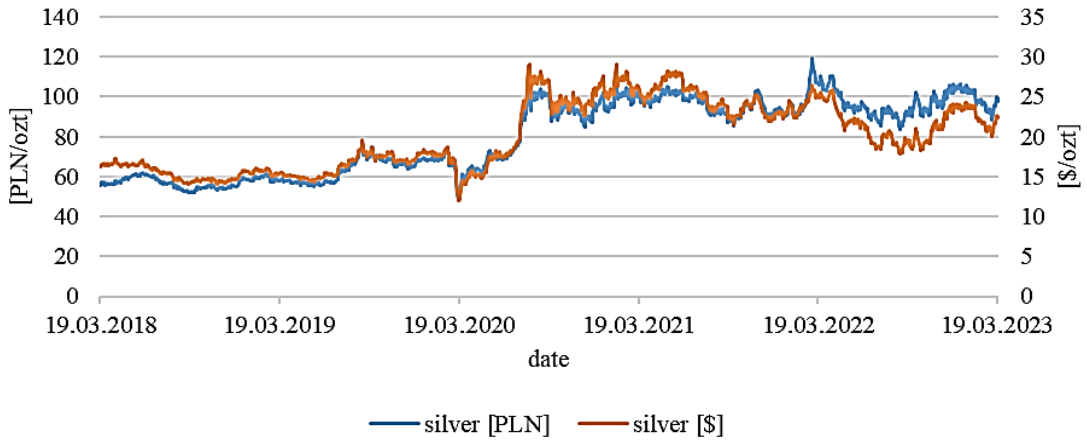

Figure 4. Silver prices in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

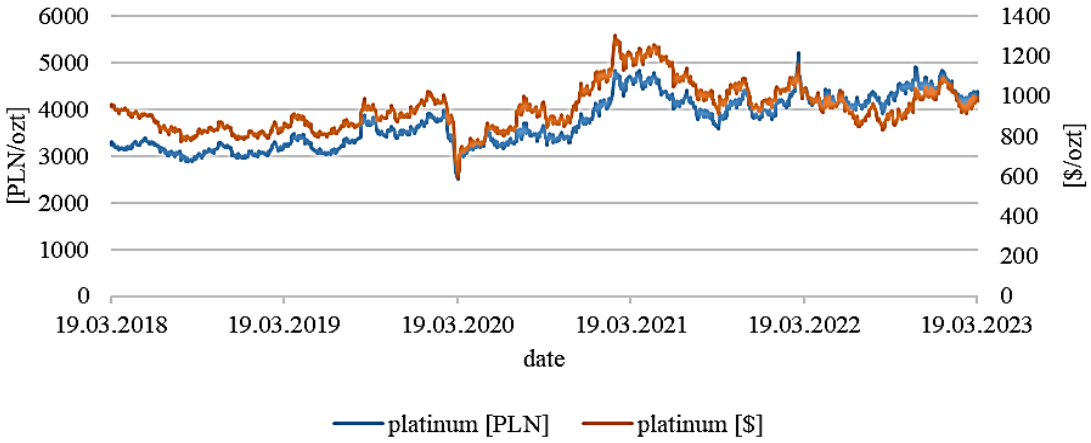

Figure 5. Platinum prices in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

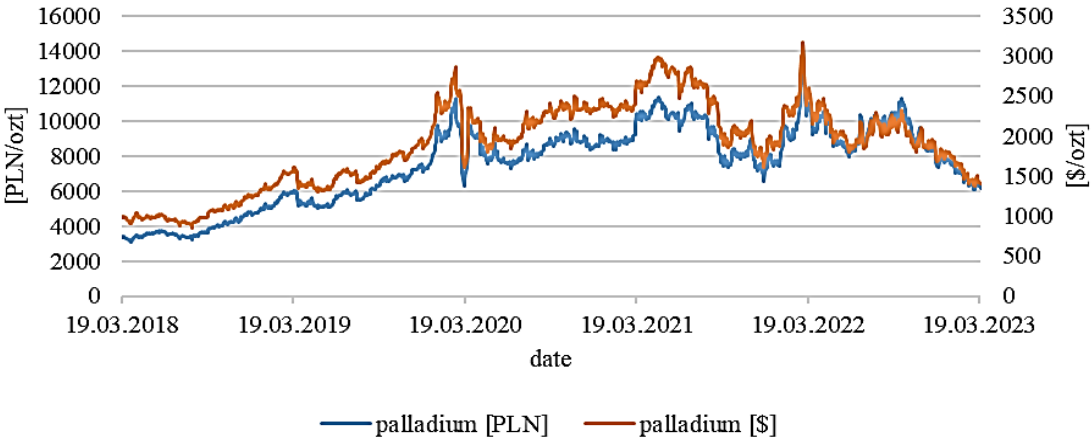

Figure 6. Palladium prices in the period between 19.03.2018 and 21.03.2023.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

As can be seen, the WIG20 index was sensitive to epidemic and geopolitical changes. In these periods, declines in the WIG20 index can be observed. The event to which bond prices reacted more strongly was the war in Ukraine. With the start of the war, bond prices began to rise. Both the pandemic and the war have increased the volatility of the prices of the tested ores. The level and volatility of metals prices expressed in Polish zlotys is slightly different from those expressed in US dollars.

Table 1 and Table 2, as well as Figure 7 and Figure 8, contain data on the level rates of return on an annual basis in individual periods, starting from March 20, 2018. The last period is presented in two variants: according to the next period, so from March 22, 2022, as well as according to the date of the beginning of the invasion of Ukraine, that is from February 24, 2022. Due to the days when there were no quotations, in 2021 one period ends on 19.03, and the next begins on 22.03.

Table 1.
Simple annual rates of return

date	gold	silver	platinum	palladium	WIG20	bonds	deposits
20.03.2018-19.03.2019	9.8508%	4.5656%	-0.4345%	78.9515%	3.5095%	-12.3494%	1.7200%
20.03.2019-19.03.2020	25.7886%	-12.1707%	-22.7926%	17.8147%	-37.5354%	-25.6849%	1.6200%
20.03.2020-19.03.2021	6.8223%	90.8913%	79.3527%	46.4946%	29.5038%	-23.3503%	1.2400%
22.03.2021-21.03.2022	21.8506%	7.1048%	-4.0966%	8.3977%	8.4971%	229.7297%	0.1400%
22.03.2022-21.03.2023	3.4111%	-7.5817%	-2.5870%	-42.3682%	-18.9656%	19.1235%	1.8500%
24.02.2022-23.02.2023	4.0355%	-4.3141%	-2.5246%	-34.6724%	0.4022%	62.8713%	1.8500%

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/statystyka-monetarna-i-finansowa/statystyka-stop-procentowych/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

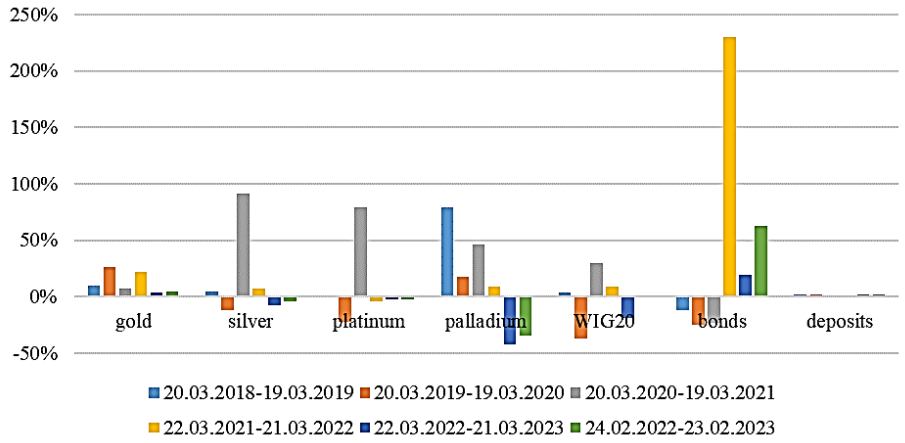

Figure 7. Simple annual rates of return.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/statystyka-monetarna-i-finansowa/statystyka-stop-procentowych/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

Based on the values of simple annual rates of return of individual assets, in other words calculated using the first method, it can be seen how profitable individual annual investments were, taking into account the moment of buying and selling.

In the base period, the most profitable investments were investments in palladium and gold. Palladium's rate of return was 78.95% after the first year and 17.81% after the second year, while gold was 9.85% and 25.79% respectively. During this period, the rates of return of gold and palladium were much higher than the rates of return on traditional investments. Moreover, investments in the WIG20 index after the second year brought a loss, while investments in bonds on the secondary market brought a loss after both the first and second year.

During the COVID-19 pandemic, investments in ores were the most profitable. During this time, both gold, silver and palladium brought a positive rate of return. Of the analyzed metals in the years of the pandemic, only platinum recorded a negative rate of return of -4.10% in the second year of the pandemic. This is consistent with the theory that ores are safer investments that can bring a positive rate of return also in conditions of uncertainty. At that time, the investment in the WIG20 index on the stock exchange was also profitable. After the first year of the pandemic, the rate of return on the index was 29.50%, and after the second it was equal to 8.50%. Investments in bonds became particularly profitable in the second year of the pandemic, after which the rate of return was 229.73%.

However, during the war in Ukraine, the profitability of individual investments changed again. At that time, only those considered the safest – investments in gold, bonds and investing capital on a bank deposit turned out to be profitable investments. Of all the analyzed ores, only the rate of return of gold showed a positive value. This rate was higher than the rate of return on bank deposits, but lower than the rate of return on treasury bonds purchased on the secondary market.

Table 2.
Simple average annual rates of return

date	gold	silver	platinum	palladium	WIG20	bonds	deposits
20.03.2018-19.03.2019	0.0370%	0.0199%	0.0011%	0.2322%	0.0248%	-0.0387%	0.1411%
20.03.2019-19.03.2020	0.0958%	-0.0313%	-0.0786%	0.0974%	-0.1754%	-0.0770%	0.1291%
20.03.2020-19.03.2021	0.0411%	0.3018%	0.2603%	0.1774%	0.1211%	-0.0996%	0.0276%
22.03.2021-21.03.2022	0.0809%	0.0322%	0.0023%	0.0777%	0.0449%	0.5002%	0.0478%
22.03.2022-21.03.2023	0.0203%	-0.0131%	0.0053%	-0.1745%	-0.0652%	0.1094%	0.4307%
24.02.2022-23.02.2023	0.0361%	0.0115%	0.0106%	-0.1016%	-0.0260%	0.2339%	0.4013%

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/statystyka-monetarna-i-finansowa/statystyka-stop-procentowych/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

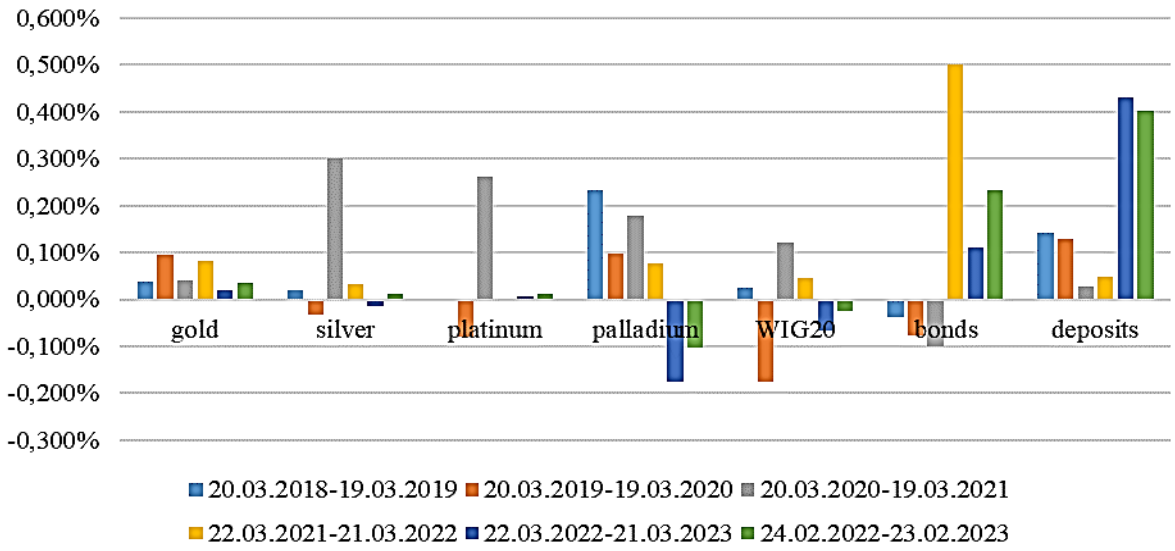

Figure 8. Simple average annual rates of return.

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/statystyka-monetarna-i-finansowa/statystyka-stop-procentowych/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

On the basis of simple average annual rates of return, in the base period, palladium turned out to be the most profitable form of investing capital. Its rate of return is at the level of 0.10-0.23%. After palladium, the most profitable was to invest capital in bank deposits, whose rate of return was at the level of 0.13-0.14%. At that time, a positive rate of return could also be achieved from investing in gold. On the other hand, investing in bonds on the secondary market was not profitable.

Despite the negative rate of return in the first year of the COVID-19 pandemic, investing in government bonds on the secondary market proved to be the most profitable during its duration. All other investments were also profitable, although some brought a loss in one of the two years of the pandemic. The profitability of deposits decreased significantly, as the level of return on them was at the level of 0.03-0.05%.

During the war in Ukraine, the level of rate of return on deposits increased to the level of 0.40-0.43%. At that time, it was the most profitable form of investing capital. Profitable investments also included bonds, gold and platinum. Investments in silver made in February were still profitable, but investments made a month later brought an average negative rate of return. The investment in WIG20 was unprofitable during the war. The profitability of individual investments is therefore consistent with the theory according to which investments in ores and bonds are safer investments in the times of geopolitical turmoil than investments in stock markets.

The level of rates of return calculated by the second method differs from the level of rates of return calculated by the first method, because it also takes into account changes in rates of return during the year. The level of average annual rates of return is lower than the level of annual rates of return calculated using the "New Year's Eve" method. Conclusions on the profitability of individual investments are also slightly different.

The rates of return on individual investments in the analyzed periods showed different characteristics (Table 3).

Table 3.
Rates of return statistics

statistics/date		gold	silver	platinum	palladium	WIG20	bonds	deposits
mean	20.03.2018-19.03.2019	0.0370%	0.0199%	0.0011%	0.2322%	0.0248%	-0.0387%	0.1411%
	20.03.2019-19.03.2020	0.0958%	-0.0313%	-0.0786%	0.0974%	-0.1754%	-0.0770%	0.1291%
	20.03.2020-19.03.2021	0.0411%	0.3018%	0.2603%	0.1774%	0.1211%	-0.0996%	0.0276%
	22.03.2021-21.03.2022	0.0809%	0.0322%	0.0023%	0.0777%	0.0449%	0.5002%	0.0478%
	22.03.2022-21.03.2023	0.0203%	-0.0131%	0.0053%	-0.1745%	-0.0652%	0.1094%	0.4307%
	24.02.2022-23.02.2023	0.0361%	0.0115%	0.0106%	-0.1016%	-0.0260%	0.2339%	0.4013%
standard deviation	20.03.2018-19.03.2019	0.0076	0.0111	0.0120	0.0151	0.0115	0.0118	0.0000
	20.03.2019-19.03.2020	0.0105	0.0176	0.0184	0.0251	0.0167	0.0295	0.0001
	20.03.2020-19.03.2021	0.0133	0.0268	0.0207	0.0272	0.0161	0.0299	0.0003
	22.03.2021-21.03.2022	0.0116	0.0163	0.0215	0.0314	0.0155	0.0260	0.0006
	22.03.2022-21.03.2023	0.0126	0.0210	0.0195	0.0325	0.0163	0.0239	0.0014
	24.02.2022-23.02.2023	0.0134	0.0206	0.0202	0.0350	0.0191	0.0251	0.0016
kurtosis	20.03.2018-19.03.2019	0.2214	1.2230	0.3778	1.7498	-0.3153	2.5992	-0.8280
	20.03.2019-19.03.2020	3.3674	10.9579	10.4838	14.1745	18.3866	10.7251	-0.3472
	20.03.2020-19.03.2021	3.2970	4.8464	1.5662	15.1109	0.9677	2.5292	4.5340
	22.03.2021-21.03.2022	3.4019	1.3730	1.9905	3.1710	12.4356	2.3258	-0.0465
	22.03.2022-21.03.2023	1.0324	0.8002	0.1589	3.6325	-0.2601	-0.0022	-0.1462
	24.02.2022-23.02.2023	2.0685	0.6441	1.1929	3.6988	4.5958	-0.0050	-1.2798
skewness	20.03.2018-19.03.2019	0.2872	0.2253	-0.1967	0.0938	-0.1256	0.6498	-0.3239
	20.03.2019-19.03.2020	0.3188	-1.7336	-1.6719	-2.0576	-2.1202	1.2101	0.2410
	20.03.2020-19.03.2021	-0.4129	-0.4114	0.2655	1.6964	0.1212	-0.2244	2.2128
	22.03.2021-21.03.2022	0.0715	-0.1643	-0.1118	-0.3204	-0.8403	0.0360	1.2544
	22.03.2022-21.03.2023	0.0041	0.3996	0.2229	0.4431	0.1683	-0.1573	-1.0800
	24.02.2022-23.02.2023	0.1283	0.4274	-0.0373	0.0063	-0.2626	-0.1013	-0.6580

Cont. table 3.

min	20.03.2018-19.03.2019	-1.8065%	-4.0532%	-4.0708%	-6.1136%	-3.3372%	-4.4248%	0.1350%
	20.03.2019-19.03.2020	-4.4938%	-12.4230%	-12.0862%	-18.7848%	-13.2774%	-14.7239%	0.1175%
	20.03.2020-19.03.2021	-5.7064%	-14.8712%	-5.6188%	-10.4250%	-5.5744%	-14.7059%	0.0117%
	22.03.2021-21.03.2022	-4.9161%	-6.7808%	-8.7642%	-15.4013%	-10.8652%	-9.9707%	0.0100%
	22.03.2022-21.03.2023	-4.6976%	-6.3172%	-5.2877%	-13.3222%	-4.2945%	-6.5359%	0.1542%
	24.02.2022-23.02.2023	-4.9161%	-5.1053%	-8.7642%	-15.4013%	-10.8652%	-6.5359%	0.1542%
max	20.03.2018-19.03.2019	2.4249%	3.3479%	2.8711%	6.0831%	2.7331%	5.0909%	0.1458%
	20.03.2019-19.03.2020	5.1514%	5.5977%	6.6517%	8.5646%	6.5402%	19.3370%	0.1425%
	20.03.2020-19.03.2021	5.3082%	9.3631%	10.0929%	21.1551%	5.1499%	9.3750%	0.1033%
	22.03.2021-21.03.2022	5.7271%	4.5187%	6.3027%	10.4346%	8.4365%	10.5960%	0.1575%
	22.03.2022-21.03.2023	3.9660%	8.1688%	5.9088%	16.9850%	4.5315%	6.4246%	0.5650%
	24.02.2022-23.02.2023	5.7271%	8.1688%	5.9088%	16.9850%	8.4365%	7.6037%	0.5650%

Source: Own study based on: https://stooq.pl/, https://nbp.pl/statystyka-i-sprawozdawczosc/statystyka-monetarna-i-finansowa/statystyka-stop-procentowych/, https://nbp.pl/statystyka-i-sprawozdawczosc/kursy/archiwum-tabela-a-csv-xls/

In the entire period under review, the interest rate on deposits was characterized by the lowest level of volatility (from 0.01% in the period between 20.03.2018 and 19.03.2019 to 0.41% in the period between 22.03.2022 and 21.03.2023). However, it should be borne in mind that deposits are the only over-the-counter investment under consideration. The highest level of volatility was characterized by palladium rates of return, which ranged from -18.78% in the period between 20.03.2019 and 19.03.2020 to 21.16% in the period between 20.03.2020 and 19.03.2021. Due to such a large range of rates of return, in most periods, palladium recorded both the lowest (except for the period 20.03.2020-19.03.2021, in which silver reached the lowest level of rates of return) and the highest levels of return (except for the period 20.03.2019-19.03.2020, in which the highest level was reached by bond returns). Apart from deposits, only gold showed positive average annual rates of return throughout the period under review. They ranged from 0.04% to 0.10%.

In the base period, gold, palladium and deposits had a positive rate of return, while bonds – negative. At that time, the smallest average deviations of individual values of rates of return from the average were shown by deposits. Generally, they deviated from the average by +/- 0.0001. Only the rates of return of gold and bonds were right-sided asymmetrical, while platinum and the WIG20 index were left-sided asymmetrical. Therefore, the rates of return of gold and bonds were usually higher than their average rate, and platinum and WIG20 – usually lower. During this period, almost all distributions of returns were leptocuric, so their values were concentrated relatively close to the average. Only the rates of return on deposits

during this period were platocuric, which means that their values were more distant from the average.

During the pandemic, a positive rate of return could be obtained from investments in all analyzed ores, deposits, as well as in the WIG20 index. During this period, the smallest average deviations of individual rates of return from the average were also shown by deposits. Generally, they deviated from the average from +/-0.0003 to +/-0.0006. The period 20.03.2020-19.03.2021 was the only one in which gold showed left-sided asymmetry, so its rates of return were usually lower than average. During the pandemic, the right-sided asymmetry was shown by the rates of return on deposits, which usually brought a profit higher than the average, while the left-sided one – silver. During the pandemic, all distributions were leptocuric, which means that the rates of return on these investments were concentrated relatively close to the averages. Only the rates of return on deposits in the second year of the pandemic showed a slight platokurtivity.

During the war (taking into account the period 22.03.2022-21.03.2023), gold and platinum, as well as bonds and deposits, showed a positive rate of return. Investments in other metals and the WIG20 index had a negative rate of return. During this period, the lowest deviation was shown by deposits, which deviated from the average by an average of only +/-0.0014. At that time, the highest average level of deviation from the average was characterized by palladium rates of return (+/-0.0325). The right-sited asymmetry was shown by the rates of return of ores and the WIG20 index, so these investments usually brought a higher rate of return than the average, while the left-sited asymmetry – bonds and deposits. At that time, the rates of return of ores and the WIG20 index were leptocuric, so they were concentrated relatively close to the average, and bonds and deposits – platokurtic.

However, the analysis of the last period from 24.02.2022 to 23.02.2023 indicates that at that time the investment in silver was also still profitable. During this period, deposits were also characterized by the lowest level of deviation (by +/-0.0016), and palladium rates of return – the highest (by +/-0.0350). In contrast to the war time counted from March, platinum and the WIG20 index showed left-sided asymmetry, so their rates of return were usually lower than average. Also in contrast to that period, the WIG20 index was characterized by leptokurtivity.

5. Summary

To sum up, the epidemic and geopolitical situation from 2020 to 2023 had an impact on the rates of return on raw materials, as well as on shares, bonds and interest rates on deposits. The pandemic has affected all countries' stock markets, but Harjoto, Rossi, Lee and Sergi (2021) point out that it has had a greater impact in emerging markets. However, Ashraf (2020) points out that investors' decisions were much more influenced by information about the number of

new cases of COVID-19 than deaths due to this disease. The war in Ukraine has contributed to the deepening of panic in the markets. It has contributed to problems with transport and ensuring the continuity of supply chains, which has affected commodity and equity prices (Shaik et al., 2023).

The analysis shows that only the average annual rate of return on deposits and gold throughout the period considered was positive. The lowest volatility was characterized by the rates of return on deposits, and the highest – palladium. Due to the high volatility of palladium rates of return, in the period under review they usually recorded minimum and maximum rates of return compared to other investments.

The profitability of individual investments changed during the period under review. Measuring the profitability of investments using the rate of return gave different results due to the chosen method of calculating the rate of return. The level of simple, nominal, annual rates of return differed from the level of simple, nominal, average annual rates of return. In this case, the level of average annual rates of return was lower than the level of annual rates of return. Therefore, the conclusions on the profitability of individual investments are slightly different. This means that the choice of the method of calculating the rate of return affects the results obtained, which translates into investment recommendations.

This article presents issues related to the profitability of particular types of investments and the impact of the selected method of calculating the simple rate of return on investment decisions, but it does not exhaust the examined issue. In subsequent studies, it is worth reviewing the literature not only of the most recent publications, but also of older ones, in order to identify changes in the approach to safe investments over the years, as well as the impact of crisis situations on the perception of the security of particular types of investments. It is also worth analysing other types of alternative investments, including cryptocurrencies. In future analyses, it is also worth considering the use of statistical tests.

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EFFICIENCY OF STOCK MANAGEMENT IN THE FISH PROCESSING INDUSTRY

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Purpose: The purpose of this paper is to demonstrate the role of stock management in the operations of fish processing enterprises and to analyse the impact of Covid-19 and the war in Ukraine on stock management efficiency.
Design/methodology/approach: Literature studies, the document research method, the economic analysis method, and expert knowledge, were used in the paper.
Findings: The stock structure of fish processing enterprises by company size was identified, and an analysis of stock management in the years 2019-2022 and its impact on the financial efficiency of these companies was carried out.
Research limitations/implications: In the future, it would be recommended to extend/specify the studies to the types of fish processing.
Originality/value: Evaluation of the 2019-2022 stock management policy (including Covid-19, the war in Ukraine) and verification of the impact of stock management on financial performance, taking into account the stock structure.

Keywords: stock management, fish processing.

Category of the paper: Research paper.

1. Introduction

The efficient and effective operation of manufacturing companies depends on stock management strategies regarding procurement, production and distribution (Wild, 2018). Stock management policy is a key element affecting both cost and revenue levels (Bose, 2006). This issue is also relevant to the food industry and the fish processing sector, where materials and raw materials represent a significant share of costs.

In an era of continuously changing market factors stemming from, among others, the COVID-19 pandemic and the hostilities in Ukraine, which have caused disruptions in the liquidity of the supply (Dimitry, 2020) of raw fish and materials as well as a significant increase in the price of components necessary for production, fish processing enterprises are forced to

constantly look for opportunities to improve their business processes, including stock management.

The subject of this article is the evaluation of stock management policies in the fish processing industry, by company size, taking into account the complexity of the stock structure in these companies.

2. The core business of fish processing enterprises

Fish processing is a branch of food industry classified in the Polish Classification of Activities as PKD 10.20.Z – the processing and preserving of fish, crustaceans and molluscs. Fish processing enterprises are mainly engaged in processes such as freezing, smoking, salting and preserving fish (Wang, 2018).

Fish processing enterprises can deal with (Krupska, 2016):

- pre-processing,
- proper processing,
- processing of fish raw materials and fish waste into feed and technical products.

Pre-processing (initial processing) aims to prepare raw materials for further processing. It includes operations such as heading the fish, gutting, flaying, filleting, skinning, defatting and portioning. Products of pre-processing do not have a form suitable for direct consumption without further treatment (Szulecka, 2020).

Proper processing, apart from the specific nature of the fish raw materials used, does not differ from other types of agri-food processing. It includes activities such as smoking, storage, production of delicatessen products, frying and production of other non-durable products, semi-permanent preserves and permanent preserves. This processing results in final products in ready-to-eat form (Zieziula, 2002).

The third type of fish processing is the processing of fish raw materials and fish waste into feed and technical products, in the form of fish meal, liquid feed, oils, fish oil and protein preparations (Niegolewski, 1979).

Fish processing is one of the fastest growing branches of the food sector in Poland, as well as the fish processing sector of the European Union. The turnover volume of this sector in 2021 reached PLN 15.07 billion (Hryszko, 2023).

The size of an entity in fish processing plays an important role, as it largely determines its business profile and production mix. Micro and small enterprises, most often operating in local markets, are mainly engaged in the production of preparations with a low degree of processing, e.g., salting, smoking and pre-processing of fish, which require lower financial outlays. On the other hand, large production facilities with adequate financial resources for investment are involved in the production of highly processed fish products requiring advanced processes

and complex technological lines, i.e., for example, the production of canned fish, some marinades, and frozen fish (Szultka, 2015).

In 2021, sole proprietorship is the predominant form of business (42%) among establishments processing and preserving fish and fishery products. Commercial law companies represent another prevalent organisational and legal form (38%), comprising mainly limited liability and joint stock companies, with civil partnerships accounting for 15-20% of all entities (Hryszko, 2023).

The share of micro enterprises in the total employment structure according to estimates for 2021 was only 2.2% and was 65%for large enterprises. The situation is similar taking into account the value of production, where micro enterprises have a 2% share in the structure of the value of production, while large enterprises have a 75% share of the value (Hryszko, 2023).

3. Importance of stocks in the operations of fish processing enterprises

One of very important areas of management in fish processing enterprises is stock management, while the efficient and effective functioning of this group of production enterprises depends on stock management strategies as concerns supply and production as well as distribution. Indeed, stock management policy is a key element affecting both cost and revenue levels in these enterprises (Munyaka,2022).

Guided by the principles of financial rationality, fish processing enterprises should develop their stock management processes in order to (Kardas, 2017):

- ensure continuity of production and the relevant level of customer service while maintaining the lowest possible stock cost,
- minimise expenditure on purchasing, supplying and maintaining stocks,
- prevent the build-up of excessive and, in particular, redundant stocks,
- counteract quantitative and qualitative stock losses.

In fish processing enterprises, stocks as an organic component of economic processes are a part of all phases of the enterprise economic activity. Representing one of the main items of current assets, they can arise in three areas of activity (Fikoń, 2008):

- supplies (in the form of raw materials, e.g., tomato paste, oils, spices, packaging),
- production (stocks of work in progress),
- distribution (stocks of finished products – e.g., preserves, canned, frozen, salted, smoked fish).

In the area of supplies, stocks are created mainly in the form of fresh fish raw materials as well as frozen raw materials. Imported fish and seafood form the basis of the raw material supply, which is supplemented by fish raw materials from a firm's own fishing as well as aquaculture (Gostomski, 2022). Stocks on the supply side also include materials and

components for production, such as tomato paste, oil, spices, vegetables, sauces. Packaging is also a significant component of supply-side stocks in fish processing enterprises, and includes, for example, tin and aluminium cans, plastic containers, cartons, stretch film, labels, and Euro pallets (Krupska, 2016).

Materials and raw materials represent a significant share (73.9% in 2021) of the operating costs of fish processing enterprises. In the period of 2010-2021, these costs showed the highest growth rate (as much as a 3-fold increase) compared to other types of operating costs (Hryszko, 2023).

Stocks of work in progress do not play a significant role in fish processing enterprises. However, they can occur in the form of prepared-sauces raw material after pre-processing (Sitaram, 2021).

Due to the nature of the processing performed, stocks of finished products may be, for example, in the form of smoked fish, canned fish, preserves, and salted fish. The storage period during which fish processing products retain their quality depends on many factors, including the species and the form of raw material, the fat content of the tissue, the storage temperature, the condition of the coating, the packaging method, the type and properties of the packaging material, including the stretch film's properties as a barrier against gases and water vapour and other factors. Thus, for example, the currently accepted standard is a shelf life of 2 years for vacuum-packed fish, the shelf lives of hot-smoked and cold-smoked products packaged without atmospheric modification and stored at 2 °C to 10 °C are, respectively, 4 and 10 days, while the shelf life of canned products is the longest shelf life where the quality preservation periods under standard conditions are: 18 months for canned oil-soaked products, 6 months for canned squid products and 12 months for other product groups of canned foodstuffs. In practice, producers adopt longer storage periods for canned food, usually 2 to 3 years (Szulecka, 2020).

Maintenance of stocks in fish processing enterprises depends on the type of fish processing performed and the type of stocks. In the case of stocks of fish raw materials (seasonality of supply, perishable raw material), materials, e.g., oil, tomato paste, spices and packaging, it stems from the need to ensure the regularity of production, to achieve potential economies of scale in production as well as supply, to minimise the impact of seasonality of supply as well as seasonality of demand and to reduce risks associated with uncertainty in the delivery of the goods and the time required for delivery.

In an era of continuously changing market factors, stemming from, among other things, the COVID-19 pandemic and the hostilities in Ukraine, which have caused disruptions in the liquidity of supplies of raw fish and materials as well as significant price increases, the imperative to reduce the risks associated with supply uncertainty and price increases is particularly important with respect to the stock management of fish processing enterprises (Barman, 2021).

On the other hand, in terms of stock management in the form of finished products, it is of paramount importance to ensure continuity of sales, the lack of which negatively affects the reputation of a company and reduces profits (Shiau Wei Chan, 2017).

However, it should be borne in mind that the maintenance of stocks is an important element of current assets and is a financial burden for companies from the moment of payment for raw materials, materials, and packaging until the finished products are received by the customer. The maintenance of stocks also involves various types of costs, e.g., storage, handling, movement costs, the cost of capital (opportunity costs) or costs resulting from stock losses (Iakovou, 2016).

Thus, stock management encompasses the demand and logistics aspects as well as the financial aspects related to the need to maintain the stocks and foot the costs that they generate (Zimon, 2015).

Stock management affects both costs and revenues and, consequently, financial performance, which in turn determines the need for continuous monitoring and evaluation of the effectiveness of stock management in fish processing enterprises (Kofi, 2021).

4. Stock management in fish processing – research results

To conduct the analysis, financial data from financial statements published in the EMIS database was used. The analysis covers the years of 2019-2022, which allows for an assessment of the impact of the Covid pandemic and the outbreak of war in Ukraine on stock management activities in the fish processing industry.

48 economic operators were entered in the survey, divided into (Official Journal of the European Union):

- micro enterprises – 12 entities (number of employees <10, annual turnover or annual balance sheet total ≤ EUR 2 million),
- small enterprises – 12 entities (number of employees <50, annual turnover or annual balance sheet total ≤ EUR 10 million),
- medium-sized enterprises – 16 entities (number of employees < 250, annual turnover ≤ 2 million EURO or annual balance sheet total ≤ 43 million EURO),
- large companies – 8 entities.

A study was carried out to analyse the structure, value and efficiency of stock management of fish processing enterprises.

In order to identify the specific nature of the stocks created in the fish processing industry, a vertical analysis of stocks (structure) was carried out. The results obtained are presented in Table 1.

The structure indicators were calculated according to the following formulas:

1. Share of total stocks in total current assets (%) = total stocks/total current assets x 100%.
2. Share of raw materials in total stocks = value of raw materials/value of total stocks with 100%.
3. Share of semi-finished products and work-in-progress in total stocks = value of semi-finished products and work-in-progress/value of total stocks with 100%.
4. Share of finished products in total stocks = value of finished products/value of total stocks with 100%.

Table 1.
Structure of stocks in fish processing enterprises

stock structure	2019				2020				2021				2022			
	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large
share of raw materials and supplies	0.30	0.31	0.68	0.56	0.29	0.16	0.71	0.54	0.57	0.16	0.72	0.61	0.63	0.48	0.76	0.56
share of semi-finished products in stocks	0.00	0.02	0.04	0.06	0.00	0.01	0.04	0.07	0.00	0.01	0.05	0.09	0.00	0.02	0.05	0.15
share of finished products in stocks	0.00	0.57	0.22	0.24	0.00	0.71	0.20	0.31	0.00	0.67	0.17	0.25	0.00	0.40	0.15	0.25
share of goods in stock	0.70	0.09	0.06	0.11	0.71	0.07	0.05	0.08	0.43	0.12	0.08	0.05	0.37	0.07	0.04	0.04
number n	11	12	16	8	11	12	16	8	11	12	16	8	12	12	16	8
share of stocks in current assets	0.05	0.39	0.35	0.44	0.14	0.36	0.34	0.44	0.10	0.46	0.33	0.42	0.07	0.47	0.37	0.50
min share of stocks in current assets	0.00	0.01	0.04	0.19	0.00	0.01	0.05	0.15	0.00	0.01	0.04	0.23	0	0.01	0.04	0.24
max. share of stocks in current assets	0.63	0.43	0.57	0.63	0.63	0.40	0.58	0.51	0.78	0.67	0.65	0.61	0.49	0.56	0.59	0.73

Source: Own studies based on financial data from EMIS database.

While conducting a vertical analysis of stocks (structure) for 2022, it can be seen that raw materials and other materials account for the largest share of stocks, with raw materials and other materials accounting for 63% of total stocks in large enterprises, as much as 76% in medium-sized enterprises, 63% in micro enterprises and 48% in small enterprises. The share of semi-finished products is low, which is due to the specific nature of production. Goods, on the other hand, account for the largest share in micro enterprises, although their share in stocks is decreasing in year-on-year terms (70% in 2019, and 37% in 2022). The share of stocks in current assets has also shown an upward trend. In 2022, stocks in large companies accounted for as much as 50% of current assets. The data presented imply that events such as the Covid-19 pandemic and the war in Ukraine, which contributed to disrupted supply chains and problems with access to raw materials and other materials, affected a change in the stock management policy, stockpiling in the form of raw materials and materials in order to protect fish processing enterprises from production stoppages and price increases of raw materials, as well as materials and components for production.

Table 2.
Stock growth ratio (value) in processing enterprises

	2022/2021				2021/2020				2020/2019				2022/2019			
	micro	**small**	**medium**	**large**	**micro**	**small**	**medium**	**large**	**micro**	**small**	**medium**	**large**	**micro**	**small**	**medium**	**large**
stocks in value terms	**1.41**	**1.20**	**1.44**	**1.63**	**0.60**	**1.41**	**1.25**	**1.19**	**2.36**	**0.88**	**1.01**	**1.02**	**2.00**	**1.48**	**1.81**	**1.94**
raw materials	1.57	3.56	1.58	1.58	1.16	1.42	1.22	1.14	0.99	0.45	0.96	1.06	1.80	2.30	1.85	1.92
semi-finished products	bd	2.08	1.27	2.61	bd	0.96	1.63	1.90	bd	0.84	0.95	0.87	bd	1.69	1.97	4.32
finished products	bd	0.72	1.27	1.77	bd	1.33	1.15	1.25	bd	1.08	1.07	1.07	bd	1.04	1.57	2.37
other stocks/goods	1.20	0.66	0.71	1.47	0.37	2.46	1.80	0.72	5.60	0.66	2.14	0.78	2.47	1.07	2.74	0.82

Source: Own studies based on financial data from EMIS database.

A horizontal analysis (dynamics) of the value of financial resources allocated to stocks showed that disruptions in supply chains caused by both the Covid-19 pandemic and the outbreak of the war in Ukraine translated into an increase in the value of stockpiling across all groups of enterprises. Over the period of 2019–2022, the value of total stocks doubled in micro enterprises, by increased by 94% in large and by 81% in medium-sized fish processing enterprises. The accumulation of stocks can protect fish processing enterprises against disruptions in the supply of raw materials and other materials as well as packaging, and consequently act as a deterrent against production downtime. In addition, it can provide a hedge against increases in the price of components required for production. In addition, the value of goods also increased in large companies in 2022, which may indicate that these companies had secured themselves against contractual penalties arising from contracts signed with food discount chains.

Another group of indicators illustrating the effectiveness of stock management are turnover ratios. The stock turnover ratio shows the number of days elapsed from the receipt of raw materials and supplies into the warehouse and the production and storage of finished products until their release to the customer (Serrano, 1994). The level of this ratio therefore indicates how long, on average, stocks wait to be sold, i.e., how long it takes for one zloty of capital employed in stocks to turn into one zloty of cash. Companies should strive to minimise this ratio (Jerzemowska, 2006). Due to the diverse structure of stocks, a deeper analysis can be performed using sub-indices, i.e., the turnover ratio of raw materials and materials or finished products and goods.

Stock management efficiency was assessed using the total stock turnover ratio and the sub-indices of material/raw material turnover, semi-finished product turnover, finished product turnover, and goods turnover. These ratios were calculated according to the following formulas (Pomykalska, 2007; Czerwińska-Kayzer, 2011):

$$\text{total stock turnover ratio} = \frac{\text{average stock level}}{\text{sales revenue}} \times 365 \text{ days} \quad (1)$$

$$\text{materials turnover ratio} = \frac{\text{average level of raw materials and materials}}{\text{operating costs}} \times 365 \text{ days} \quad (2)$$

$$\text{turnover ratio of finished products} = \frac{\text{average level of finished products}}{\text{operating costs}} \times 365 \text{ days} \quad (3)$$

$$\text{goods turnover ratio} = \frac{\text{average level of goods}}{\text{operating costs}} \times 365 \text{ days} \quad (4)$$

Table 3.
Stock turnover ratios in fish processing enterprises in 2019-2022 (in days)

	2019				2020				2021				2022			
	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large
stock turnover ratio	13	49	27	48	27	44	27	42	19	54	29	43	14	48	35	58
material/ raw material turnover rate	9	15	20	27	8	7	19	27	11	9	20	27	9	15	27	32
turnover rate of intermediate products	bd	1	1	3		1	1	3	bd	1	2	4	bd	1	2	8
finished products turnover rate	bd	28	5	12		31	5	12	bd	36	5	13	bd	28	5	17
goods turnover ratio	4	5	1	6	19	3	1	4	8	7	2	3	5	5	1	3

Source: Own studies based on financial data from EMIS database.

The stock turnover ratio is the product of the ratio of the average stock (average annualised) to the sales revenue generated by the unit and a value of 365, which is a conventional number of days per year. It represents the frequency of stocks renewal by a company in days. A low value for the indicator is postulated, which is usually evaluated positively. The data presented in Table 3 shows that, on average in 2019–2022, the stock cycle ranged from 40 days in 2020 to 55 days in 2022. The analysis shows that, on average, small and large fish processing enterprises had the longest stock turnover period. In the large ones the cycle ranged from 42 days to 58 days in 2022, in the small ones from 44 days to 48 days in 2022.

The shortest stock turnover period was recorded in micro enterprises, with 13 days in 2019 and 14 days in 2022. This is due, among other things, to the specific nature of production, micro enterprises process fish products with a low degree of processing, which have a short shelf life.

An increasing stock turnover ratio is not a favourable situation for the company, as it freezes cash for a longer period of time as well as incurs additional storage costs.

The rate of stock turnover is determined by the sub-cycles, i.e., the rotation of materials, semi-finished products, finished products and goods. The data presented in Table 3 shows that in fish processing enterprises, the stock holding period was mainly determined by the length of storage of raw materials and materials and, to a lesser but significant extent, finished products. The storage period of raw materials in large enterprises increased from 27 days to 32 days. Finished products, on the other hand, are stored longest in small enterprises, as long as 28 days in 2022.

Financial efficiency was also assessed using the return on sales and return on assets ratios, the levels of which were calculated according to the following formulas (Bieniasz, 2012; Sierpińska, 2004):

$$\text{ROS operating return on sales} = \frac{\text{EBITDA}}{\text{revenue from sales of products, goods and materials + other operating income}} \times 100 \quad (5)$$

$$\text{ROA} = \frac{\text{net profit}}{\text{average assets}} \times 100 \quad (6)$$

A preliminary assessment was performed of the impact of stock management on the financial performance of fish processing enterprises (e.g., reduction in stock cycle length), as measured by operating profitability of sales and return on assets. It was decided to examine the relationship between stock productivity and financial performance, taking into account their structures.

Table 4.
Selected financial indicators for 2019-2022

	2019				2020				2021				2022			
	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large	micro	small	medium	large
ROS	b/d	4.6%	5.1%	3.4%	b/d	4.8%	7.0%	4.0%	b/d	5.2%	9.2%	3.8%	b/d	5.1%	6.7%	2.7%
ROA	0.0%	1.4%	2.0%	1.2%	1.9%	–1.3%	5.3%	3.0%	3.6%	3.0%	10.6%	6.6%	1.4%	4.4%	7.2%	5.9%

Source: Own studies based on financial data from EMIS database.

The studies show that there is an impact of deteriorating stock management efficiency on the financial performance of the fish processing industry as measured by the operating return on sales and the return on assets. The lengthening of the stock turnover cycle affected the deterioration of financial performance in 2022, where the turnover ratio increased from 42 days in 2021 to 55 days, which translated into a reduction in the operating return on sales from 4% to 3.3% and the return on assets from 11% to 7%. In 2020, on the other hand, a reduction in the total stock turnover cycle from 45 days to 40 days resulted in an improvement in operating return on sales from 3.7% to 4.4% and ROA from 7% to 9%. The analysis showed that maintaining higher levels of stocks of both raw materials, finished products and goods in large fish-processing enterprises results in a longer rotation cycle of these stocks and translates into a deteriorating level of financial efficiency calculated using the operating return on sales. In the case of medium-sized enterprises, only a significant extension of the stock turnover cycle, i.e., by 6 days (year-on-year) with a simultaneous increase in the value of stocks by 44%, translates into a drop in operating return on sales from 9% in 2021 to 7% in 2022, and in return on sales from 3.4% in 2021 to 2% in 2022. In micro enterprises, where the rotation cycle is generally the shortest, the decrease in the stock turnover cycle in 2022 translated into a decrease in the sales deficit ratio, while in 2021 the lengthening of the material/raw material turnover ratio translated into a deteriorating of the deficit to 7%, and in 2022 the lengthening of the stock turnover ratio also resulted in an increase in the sales deficit.

5. Summary

Stock management is a key area in the management of fish processing enterprises, affecting the operational area of activity, its efficiency and effectiveness as well as the financial area, thus determining the level of financial results achieved, but also the marketing area, determining the timeliness and quality of finished product deliveries, and thus influencing the level of customer service and the competitiveness of the enterprise in the market.

The research conducted showed that events such as Covid-19 and the war in Ukraine had a significant impact on stock management in fish processing enterprises. A preliminary analysis of the relationship between stock management efficiency and financial performance showed a link between these economic categories. Deterioration of efficiency in the area of stock management, e.g., lengthening of the stock turnover cycle, translated into deterioration of financial results, i.e., the return on sales and return on assets. High stock levels mean high stock management costs. However, in a situation of a dynamically changing environment and uncertainty in terms of continuity of supplies and price stability, a high level of stocks means operational security, i.e., the possibility of maintaining continuity of production, but also a high readiness of supply (an important factor in the competitive game) where supply chains are again disrupted by a pandemic or warfare.

It can be concluded that efficient stock management is important for the financial situation of fish processing enterprises. Fish processing enterprises need to redefine their stock management strategy determining optimal economic performance.

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PRO-ENVIRONMENTAL ELEMENTS IN THE BUSINESS MODEL OF MEDIUM AND LARGE POLISH ROAD FREIGHT CARRIERS

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Purpose: The policy of sustainable development places requirements on businesses to reduce their negative environmental impact. One of the sectors of the economy that is responsible for greenhouse gas emissions is road transportation. Consideration of the European Union's environmental goals is forcing road carriers to have environmental measures built into their business models. The purpose of the study was to learn how road carriers can reduce their negative environmental impact so that they can fit in with the goals of the environmental policy and to learn about the regulatory tools that the road carriers expect to be able to support these activities.

Design/methodology/approach: Data for this study was collected in computer-assisted telephone interviews (CATI). The study was conducted in late 2021 and early 2022 by a Polish company that was responsible for the selection of the sample and the collection of the data. The survey was conducted on a sample of 146 medium and large Polish road freight carriers and was a continuation of a study carried out on the same sample of entities conducted in late 2019 and early 2020 using the same technique.

Findings: As part of their fleet policy, in order to fit in with environmental goals, carriers base their business models on the purchase of new means of transportation that meet increasingly stringent emission standards and reinforce environmentally friendly attitudes by buying means of transportation with smaller engine displacement that is tailored to the needs arising from their operations. Pro-environmental operational activities of medium and large Polish road freight carriers involve the use of solutions that change the composition of exhaust gases (AdBlue) and reduce fuel consumption (lowering rolling resistance – energy-efficient tires and lowering air resistance – fairings), and the acquisition of pro-environmental driving skills (eco-driving). Other environmentally friendly measures are to increase the utilisation of the vehicle capacity (cargo consolidation) and to eliminate empty runs by looking for cargo to be carried on the way back and using route planning software.

Originality/value: The paper indicates the methods to reduce the negative environmental impact considered in the business models of medium and large road freight carriers, so that they fit in with the environmental policy goals, and indicates their expectations associated with the support for the achievement of zero-emission transportation. The results can be useful in the adoption on both the European and Polish level of policies leading to a zero-carbon economy.

Keywords: sustainable business models, road freight transport.

Category of the paper: research paper.

1. Introduction

The policy of sustainable development places requirements on businesses to reduce their negative environmental impact. One of the sectors of the economy that is responsible for greenhouse gas emissions is road transportation. The combination of the organisation of road transport and the European Union's environmental goals forces road carriers to include pro-environmental measures in their business models. The paper indicates the methods to reduce the negative environmental impact that are taken into account by road carriers in order to meet the environmental policy goals and ensure their sustainable existence and expected economic efficiency.

Data for this study was collected in computer-assisted telephone interviews (CATI). The administration of the questionnaire by the interviewer ensures a higher response rate and more complete and accurate answers than surveys completed by respondents on their own. The study was conducted in late 2021 and early 2022 by a Polish company that was responsible for the selection of the sample and the collection of the data. The survey was conducted on a sample of 146 medium and large Polish road freight carriers and was a continuation of a study carried out on the same sample of entities conducted in late 2019 and early 2020 using the same technique. The design of the questionnaire, which is consistent with the purpose of the study, as well as the study's main objective, were developed by the authors of the study.

2. Sustainable business models of businesses

The organisation mechanisms in the activities of business entities boil down to the organisation of processes (the selection of resources and technologies as well as of the timing of the start of the activities), so as to bring about the achievement of the set goals in an efficient manner – one that results in the least possible undesirable effects, such as costs, if the economic dimension of efficiency is adopted. It is clear that the permanent nature of business activities in business entities results in a repetitive selection of resources and technologies, and only the factor of the timing of the begging of the activities depends on the market situation, for example, the timing of the receipt of a transport order in the case of a transport company. Repeatability contributes to the search for measures of efficiency, predictability of effects, and ensured sustainability of the entity's existence, including the identification of areas where competitive advantages can be achieved. Consequently, this gives rise to the need to identify the dimensions of efficiency in a context that is broad and, at the same time, tailored to each entity, through the short-term operational dimension on the one hand and simultaneously the long-term operational dimension on the other. Therefore, it can be said that the characteristic of efficiency is the ability

to repetitively implement the company's strategy and achieve certain long-term goals as part of the strategy. It should therefore be viewed and defined in the long term through (Fryca-Knop et al., p. 10):

- improved competitiveness of the company,
- quick response to the challenges and expectations of the market,
- development that covers the person and the organisation in the context of the phenomena occurring inside and outside the entity.

With such a perception of efficiency, the activities carried out cannot be random, therefore, the long time horizon in particular requires the identification of a model of activities (a business model) that can be called the 'dominant logic' of the performance of activities that guarantee the ability to exist and develop as well as achieve the set goals of the company (Leszczyńska, p. 40). The multiplicity of the definitions of a business model indicates the diversity of the understanding of this conceptual abstract, however, the common feature of the definitions is that they refer to two factors: creation of value and a long perspective, based on resources and operational activities carried out in the company (including those carried out with key partners), and an offer intended for the environment, customers, and finances – including costs and revenues (Janulek, 2022, pp. 60-61). All these components of the business model are correlated with the market model, and more broadly with the socio-economic system (Figure 1), which, as a system superordinate to companies, is able to set functional and market goals for enterprises that are in line with social policies and expectations, for example those relating to pro-environmental activities, and affects the efficiency of management and, consequently, the value of the entity.

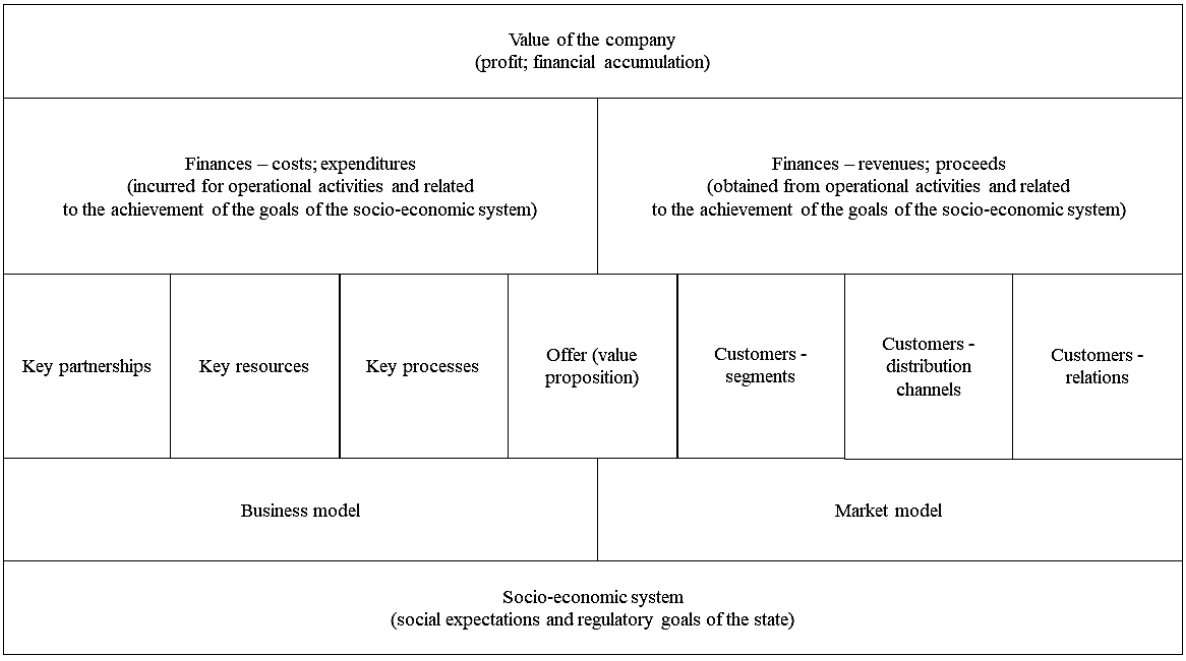

Figure 1. The business model as an element of creation of value of the company.

Source: Prepared by the author based on Janulek, 2022, p. 60.

The traditional concept of the business model is generally described as a tool for companies or organizations to create and add value to their products and services, before delivering them to their customers (Comin, Aguiar, Sehnem, Yusliza, Cazella, Julkovski, 2020, p. 2029) and the creation of company value should be perceived as a long term process (Kurznack, Schoenmaker, Schramade, 2021, p. 2). This process requires a non-random, structured approach that includes not only the identification of that part of the business model that is based on operational creation of value, but also the incorporation of the concept of Corporate Social Responsibility (CSR), that can also lead to improved management results (Dam, Lungren, Sholtens 2019, p. 244). This fits in with the concept of sustainable development and sustainable growth, forming the basis of a sustainable business model. The concept of a sustainable business model includes economic, environmental, and social factors. An entity operating according to a sustainable business model achieves economic results (creates its value), while creating social and environmental values in parallel. Therefore, sustainable organisations need to make a profit to exist, but they do not exist solely to make a profit. In other words, profit is a means to achieve sustainable results. Consequently, a sustainable business model 'helps to describe, analyse, manage, and communicate the sustainable value proposition offered by a company to its customers and other stakeholders, how that value is created and delivered, and how economic value is captured while maintaining or regenerating natural, social and economic capital beyond the boundaries of the organisation' (Szumniak-Samolej, 2022, p. 39), creating an integrated value that goes beyond the value of the entity in strictly financial terms. Thus, it is 'a promise of economic, environmental, and social benefits delivered to customers and the society in general through the company's offer, and takes into account both short-term profit and long-term sustainability' (Szumniak-Samolej, 2022, p. 39).

One of the planes for functioning according to the so-defined sustainable business model is the incorporation of pro-environmental solutions into internal processes – elements of the value chain and in the form of products/services (with pro-environmental characteristics) offered to the market. As a result, this allows entities to achieve economic and environmental benefits in the following form (Leszczyńska, pp. 42-43):

- achievement of favourable environmental results by minimising emissions, saving resources with similar (to other products/services) functionality and usability,
- regeneration, recycling of waste – which lead to a reduction in the demand for resources, closing material cycles,
- improved energy efficiency – including systems based on renewable energy sources, which is justified by high fuel prices and the climate change,
- optimisation of efficiency by using solutions that include the transmission, collection, and processing of data in electronic form (Information and Communication Technologies – ICT), which serves to control the consumption of resources, including energy, and allows the monitoring of resource consumption or redistribution.

3. Towards zero-emission road freight transport

In the second decade of the 21st century (2011-2020), the European Commission adopted a series of documents on strategies aimed to minimise negative environmental impacts. These documents include, among others, the 'White Paper: Roadmap to a Single European Transport Area' (2011), 'Clean Power for Transport: a European Alternative Fuels Strategy' (2013), the 'European Strategy for Low-Emission Mobility' (2016), and the 'Action Plan on Alternative Fuels Infrastructure' (2017). However, a decisive acceleration of energy transition activities, including electromobility, came after the European Commission adopted a strategic document titled 'European Green Deal' (2019). The document is an integral part of the European Commission's strategy to achieve the UN's 2030 Sustainable Development Goals and create a zero-emissions economy in 2050 (Transport 4.0…, pp. 20-21). The Green Deal is premised on the successful marriage of the EU's environmental and climate goals with its economic and social goals (Almeida, Zeben, 2023, p. 1).

As far as road freight transport is concerned, the first emission standards, including those applicable to CO_2, for lorries in the European Union were introduced on August 14, 2019, as part of Regulation (EU) 2019/1242 of the European Parliament and the Council of June 20, 2019. The Regulation set CO_2 reduction targets for new lorries. According to the Regulation, manufacturers are required to reduce the emission values of newly registered heavy vehicles by 15 percent in 2025 and by 30 percent in 2030 relative to the emissions of heavy vehicles first registered between July 1, 2019 and June 30, 2020. To ensure consistency with current environmental goals, on February 14, 2023, the European Commission proposed new greenhouse gas emission targets for new heavy vehicles for the period after 2030, under which it calls for the gradual introduction of stricter CO_2 emission standards compared to the 2019 levels. Thus, the reduction level for 2030 was changed to 45% and reduction levels were introduced for 2035 – 65% and 2040 – 90%. The Regulation is also intended to ensure a smooth transition to zero-emission mobility by 2050 (Miniszewski et al., 2023, pp. 9-10). This policy also includes the adoption of a new EURO 7 (European Standard for Exhaust Emissions) emission standard, scheduled to be introduced in 2025, with a delay of two years for lorries (permissible gross vehicle weight over 16 t) and buses (EURO 7 – nowa norma…).

In EURO 7, the biggest novelty compared to previous versions of the emission standards is the introduction of identical emission standards for all vehicles regardless of the type of fuel they use. The same requirements will therefore have to be met by gasoline and diesel engines, as well as hybrid and electric cars. In terms of diesel engines, which are by far the primary type of engines used in heavy-duty transport, nitrogen oxide emissions have been reduced from the previous 80 mg/km to 60 mg/km, the level set for gasoline units in EURO 6. In addition, another restriction will be imposed on lorries, this time on engine startup emissions. For the startup of a cold engine they are equal to 350 mg/kWh, and for a warm engine the value is 90 mg/kWh.

Provisions have also been added to regulate the emissions of formaldehyde and nitrous oxide for lorries, and ammonia for passenger vehicles, and tailpipe particle emissions are to be reduced by 13%. A surprising new provision is the restrictions on the abrasiveness of tires and brake components, which, after all, also emit particulate matter. The mileage and operating period during which the entire powertrain is expected to meet the new standards has also been extended. In EURO 7, it is supposed to be 200,000 km or 10 years, respectively. Vehicles are also to be equipped with electronic systems for monitoring emissions, so that it will be possible to check in an ongoing manner whether the vehicle still meets EURO 7 standards (Szczegóły normy Euro 7...).

Increasingly stringent emission standards and strategic EU policy goals are leading to a zero-emission economy in 2050 for road freight transport as well. For this type of business, this means first and foremost the conditions associated with the ability of road carriers to purchase zero-emission means of transportation. Vehicle manufacturers are analysing and trying to implement many alternatives leading to the replacement of diesel fuel. It is possible to replace diesel fuel supplied directly into internal combustion engines by using compressed or liquefied natural gas, biogas, biofuels, synthetic fuels, or alcohols, and to change the design of the powertrain by electrifying it (Brach, 2022, p. 56). The latter option – electrification of the powertrain – can take the following forms (Broadbent, Allen, Wiedmann, Metternicht, p. 2; González Palencia, Nguyen, Araki, Shiga, 2020, p. 5):

- hybridisation, or the introduction of an internal combustion – electric system (Hybrid Electric Vehicle – HEV and Plug-In Hybrid Electric Vehicle – PHEV),
- full electrification, based on an electric motor and a battery module (Battery Electric Vehicle – BEV),
- electrification linked to the introduction of an on-board source of electricity in the form of hydrogen fuel cells (Fuel Cell Electric Vehicle – FCEV).

Of the above-mentioned three options for electrification of the powertrain and the resulting reduction of the negative environmental impacts caused by means of transportation, the use of hydrogen fuel cells poses the most problems. The first two ways of electrifying the powertrain are already so technologically advanced that lorry manufacturers are already offering electric vehicles to carriers and are even declaring that they have plans to sell only electric vehicles. The planned levels of the share of the sales of electric lorries in the total sales of leading manufacturers are shown in Table 1.

Table 1.
The planned levels of the share of the sales of electric lorries in the total sales of leading manufacturers

Manufacturer	Years			
	after 2025	after 2030	after 2039	after 2040
Scania	10%	50%		100%
MAN		40-60%		100%
Volvo		50%		100%
Daimler		60%		100%
DAF			100%	
Renault	10%	35%		100%
IVECO				100%

Source: Miniszewski et al., 2023, p. 31.

It should be assumed that a fully zero-emission road freight transport can materialise 15 to 20 years after the introduction of electric-only vehicles, when all means of transportation manufactured before 2040 are taken out of service. However, there is still a long way to achieve that objective since, despite the availability of electric vehicles on the market, according to data from the European Automobile Manufacturers' Association (ACEA), currently about 97% of newly registered lorries run on diesel (New trucks…), while 2,903 electric lorries and 103 hybrid lorries were registered in the European Union between 2021 and 2022. The area is dominated by Germany (1,816 electric lorries registered in 2021–2022), followed by Sweden (226), the Netherlands (220), France (215), and Spain (179), which gives a total of 2,656 electric vehicles. The countries mentioned thus accounted for 91% of all registrations in the EU. In Poland, 11 electric lorries were purchased in 2021–2022: 5 in 2021 and 6 in 2022 (Miniszewski et al., 2023, p. 30). The current sales levels of new electric lorries are primarily due to the price of these vehicles. Even though some European Union countries (e.g., Germany and the Netherlands) have subsidy programs for the purchase of electric lorries, on average, when these are factored in, the price of a new electric lorry is three times that of a conventional, diesel-powered vehicle, although the definitely lower operating costs caused by high diesel fuel prices are emphasised (Ile kosztuje…). In Poland, the subsidies from the National Fund for Environmental Protection and Water Management under the 'My Electric Vehicle' program exclusively cover vehicles designed and built to carry freight and having a maximum gross weight not exceeding 3.5 tons – category N1. It is possible to obtain a subsidy of up to 20% of eligible costs, but not more than PLN 50,000, or up to 30% of eligible costs, but not more than PLN 70,000 if average annual mileage of more than 20,000 km is declared (Nabór…).

The difference in the operating costs is favourable to electric vehicles; however, the availability of infrastructure to replenish the 'energy agent' strongly favours liquid fuels, as the number of fuel stations in Poland, according to estimates by the Polish Organisation of Oil Industry and Trade (POPiHN), was 7,902 at the end of Q1 2023, compared to 7,898 at the end of last year. (Liczba stacji...). Each fuel station has several or even more than ten dispensers that allow simultaneous service of that many vehicles, with the duration of that service equal to from several up to twenty minutes. Assuming that on average there are 8 distributors per fuel

station, it can be calculated that this gives about 63,000 service points, while at the end of 2022 there were 5016 publicly available electric car charging points in Poland. This is 33 percent more than a year earlier, but despite this progress, it puts Poland in the fifth from last place in the European Union in terms of the number of electric car charging points, with less than 1 charger per 100 km of roads (Ciepiela, 2023). This disproportion, although also the speed of change in this area, can also be clearly seen if one considers the data from the integrated financial reports for 2020-2022 of the Orlen Group, which operates in the Polish, German, Czech, Slovak, and Lithuanian markets – see Table 2.

Table 2.
Number of stations by type, owned by the Orlen Group in 2020-2023

Station type	2020		2021		2022	
	ORLEN Group	of which in Poland	ORLEN Group	of which in Poland	ORLEN Group	of which in Poland
Petrol	2,855	1,811	2,881	1,819	3,097	1,920
Electric vehicle charging	114	84	454	372	598	493
Hydrogen charging	2	0	2	0	2	1

Source: Prepared by the author based on: Raport Zintegrowany Grupy Orlen za rok 2020; Raport Zintegrowany Grupy Orlen za rok 2021; Raport Zintegrowany Grupy Orlen za rok 2022.

The number of electric vehicle charging stations owned by the Orlen Group in Poland between 2020 and 2022 increased almost 6 times from 84 to 493. This, of course, fits in with the desired direction of change; however, not every entity has financial capabilities comparable to those of energy-sector corporation. Other entities looking to contribute to the electrification of road transportation expect financial support for the construction of charging stations in particular. As part of the support for the creation of zero-emission road transport in Poland, it is possible (the implementation period is planned for 2021-2028, including the contracting period until December 31, 2025 and the disbursement period until December 15, 2028) to obtain financial support for the construction of a charging station with a power of not less than 22 kW, other than a public charging station, and the construction of a public charging station with a power of not less than 50 kW, in which at least one point allows the provision of DC charging services and has a power of not less than 50 kW. (Infrastruktura…). However, it should be mentioned that the vast majority of the funds allocated for this purpose (PLN 870 million) have already been distributed or are in the process of verification of the submitted applications.

4. Pro-environmental activities in the business model of medium and large Polish road carriers

The unique characteristics of the management and the organisation mechanisms in road transport companies are due to the sector-specific characteristics of this type of business activity. First of all, a transportation company provides services, and second, the transportation

service is spatial in nature, which means that it is carried out outside the company's premises and involves traversing space. This results in the characteristic asset structure of these entities, in which means of transportation make up the vast majority of assets. According to Statistics Poland, in 2021, in companies employing more than 9 people, the share of the gross value of means of transportation in the total assets was about 71% (Figure 2). In absolute numbers, the value of these assets amounted to PLN 40.3 billion; however, much more important information is their wear rate of 53.4% (Road Transport in Poland in the Years 2020 and 2021, p. 26).

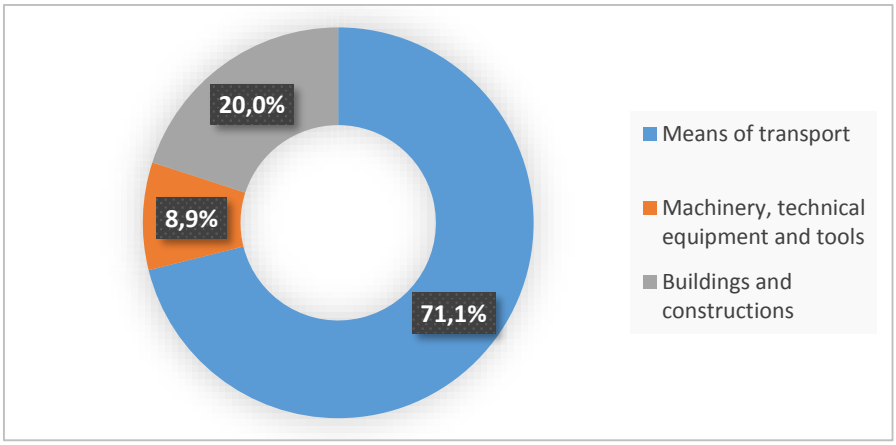

Figure 2. The structure of the gross value of fixed assets in road transport in 2021.

Source: Prepared by the author, Road Transport in Poland in the Years 2020 and 2021, p. 26.

Taking into account the provisions of the Accounting Act and the tax law that define the annual depreciation rates of 14% (tractor units) to 20% (all-purpose lorries) for means of transportation, and assuming a period of their use equal to 7 to 5 years, it is possible to determine the average 'economic' age of these assets as equal to about 3 years; however, one should bear in mind that these vehicles are also used after the end of the period when their depreciation is accounted for. According to data that takes into account the year of manufacture, the average age of lorries in Poland is 13.2 years, which is very close to the EU's average of 13.9 years (Przybylski, 2023). The percentage share of each age group of lorries is as follows (Road transport in Poland in the years 2020 and 2021, p. 52):

- up to 2 years – 5.2%,
- 3-5 years – 6.3%,
- 6-11 years – 14.9%,
- 12-15 years – 13.5%,
- 16-20 years – 15.3%,
- 21-30 years – 22.1%,
- 31 and over – 22.7%.

The transport capacity-building policy inherent in the business model of road transport companies should therefore take into account the age of their means of transportation, but it is also necessary to take into account the regulatory requirements for permissible exhaust

emissions, i.e. the EURO standard. Currently, the most stringent standard in force in Europe is EURO 6, however, the principles of the EURO 7 standard have already been defined, so businesses that provide road transport services in their business model function in a space determined both by the technical condition of their fleets and the legislative conditions that require the adaptation of their fleets to environmental constraints. The survey of a population of 146 medium and large road transport companies, which was conducted in late 2021 and early 2022, shows that for 68.8% of the respondents surveyed reason the means of transport were disposed of was mainly their age or mileage; for 16.7% it was their technical condition (degree of depreciation); for 12.5% it was their high operating costs, and for 2.1%. it was failure to meet EURO emission standards. These results are confirmed by an earlier study of fleet renewal policies conducted on an identical sample of companies. In the earlier study conducted in 2019-2020, a question was asked about pursuing a policy of regular fleet replacement. A regular fleet replacement policy was indicated by 113 respondents; the median number of years for fleet replacement indicated in that group was 3 years, which means that most of them replaced their transportation means after that length of time. Data from Statistics Poland show a positive trend in the renewal of fleets by road carriers, because nearly 48% of newly registered lorries in Poland are up to 2 years old, and thus meet the EURO 6 standard – see Figure 3 (Road transport in Poland…).

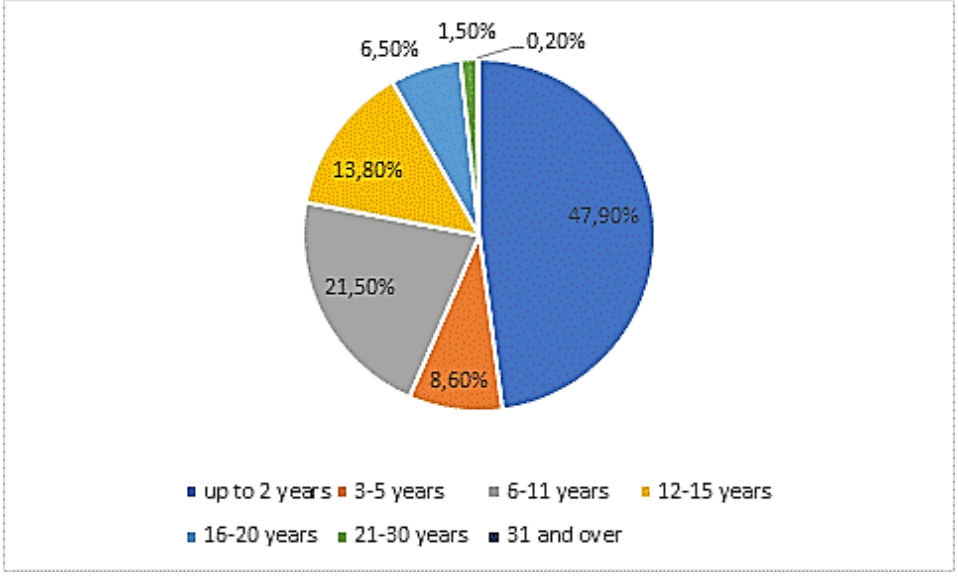

Figure 3. The structure of first-time registered lorries by age groups in 2021.

Source: Prepared by the author, Road Transport in Poland in the Years 2020 and 2021, p. 52.

The age of the vehicles purchased, and thus the compliance with the EURO standards, is one of the formal criteria, and the cost of operating these vehicles is another. In the 2021-2022 survey, one of the criteria considered by companies when purchasing means of transportation was operating costs: 70.5% of the businesses confirmed that they took that criterion into account. These are mainly costs related to fuel consumption: a 25-ton semi-trailer vehicle with a cargo of 25 tons that travels about 120,000 kilometres per year consumes

an average of 35 litres of fuel per 100 kilometres. This accounts for about 30% of the total cost of operation of the vehicle (Czy wiesz…), so one of the possible ways to reduce the negative environmental impact of the fleet purchasing policy is to choose vehicles with smaller engine displacement and consequently with lower exhaust emissions and at the same time lower greenhouse gas emissions. In the study conducted, 21.9% of companies declared that such was precisely the action they had undertaken.

Building a transport capacity compliant with the environmental requirements is a medium- to long-term dimension of the measures implemented by road transport companies. Of equal importance is the short-term dimension, expressed in the daily operation of the means of transportation and the organisation of transportation processes. The daily operation of means of transportation boils down to a direct reduction of the negative environmental impact by use of a fluid (AdBlue) that changes the chemical characteristics of the exhaust gas. AdBlue is a colourless and non-toxic liquid that consists of urea (32.5%) and demineralised water (67.5%). A small amount of AdBlue is injected into the exhaust gas in the exhaust system. Under the influence of heat and urea, harmful nitrogen oxides are transformed into ammonia and carbon dioxide. The exhaust gas then goes to a selective catalytic reduction (SCR) system, where most of the nitrogen oxides are converted into harmless nitrogen and water (Wszystko co musisz…). The use of AdBlue was declared by 61.6% of the surveyed entities.

Another positive direction for transportation companies is to strive to reduce exhaust emissions by reducing the resistance associated with vehicle movement (rolling resistance and air resistance) and using technical means to limit the maximum speed. Rolling resistance is mainly influenced by an efficient drivetrain and braking system. Tires are the component of the drivetrain that, depending on the composition of the rubber compound, can reduce rolling resistance. The use of this method of reducing greenhouse gas emissions was indicated by 43.2% of the surveyed companies. Another direction related to the technical conditions of vehicles that reduce exhaust emissions is the reduction of air resistance by using fairings above and sometimes on the sides of the vehicle's cabin. 65.1% of the respondents reported doing so.

Even tires with the lowest rolling resistance and the use of fairings cannot help achieve fuel economy if the driver has a so-called 'heavy foot'. Therefore, companies emphasising eco-driving in their business models as part of their operations. Eco-driving is a driving technique that limits rapid acceleration and braking, and includes analysing the situation on the road and anticipating the manoeuvres of other road users. The basic principles of eco-driving boil down to driving smoothly, working the gear ratios to keep the engine speed below 3500 rpm, and controlling and maintaining proper tire pressure (Caban, 2021). The primary player in eco-driving is the driver, hence the need to educate and train drivers in eco-driving techniques. Awareness of the positive impact of eco-driving on fuel consumption and the wear of the means of transportation can be observed in the surveyed companies, as 6.8% of the companies send their drivers to relevant training courses. It should be noted at this point that this is done in the smallest number of companies. The techniques used by the surveyed road freight transport

companies to reduce negative environmental impacts, ranked by frequency of occurrence, are shown in Table 3.

Table 3.
The techniques used by the surveyed road freight transport companies to reduce negative environmental impacts, ranked by frequency of occurrence

Techniques used	Share of indications
Buying new/newer vehicles	85.6%
Increasing capacity utilisation (cargo consolidation, carrying cargo on return trips)	81.5%
Buying vehicles that are cheaper to operate	70.5%
Fairings	65.1%
Ad Blue	61.6%
Buying energy-efficient tires	56.8%
Using transportation planning software	39.7%
Buying vehicles with smaller engines	21.9%
Eco-driving training courses	6.8%

Source: Prepared by the author.

The last of the dimensions of transport organisation considered in the environmentally friendly business models of road freight transport companies is the organisation of the transport process. As a general rule, a transport order involves the transportation of a cargo from the point of shipment to the point of destination, implicitly assuming that the principal, by paying the freight, pays for the transportation of the cargo, and the return of the means of transportation to the point of departure is the responsibility of the carrier and generates costs that it covers. Thus, one can imagine a situation in which the return of the means of transport generates a 'useless' negative impact on the environment, and therefore it is reasonable for carriers to search for cargo to carry on the return trip, to consolidate the cargo where the utilisation of the capacity or the cargo space is incomplete. From an environmental point of view, this rationalises the negative environmental impact and reduces it to the negative effects of an action that is useful from a socio-economic point of view. These measures were declared by 81.5% of the surveyed companies. In addition, the spatial scattering of the points of shipment and destination of cargo transportation, as well as of the times of expected pickups and, consequently, the times of the start of the transportation processes, requires planning the sequence and flow of the transportation processes. Humans (the dispatchers, sometimes referred to as fleet coordinators), their experience and knowledge of the road network and the road conditions play a considerable role here. Currently, however, artificial intelligence in the form of specialised software can support this process. In the surveyed group, 39.7% of the companies were using such software, which, according to one of the software's vendors, allows them to complete 30% more transportation tasks with the same fleet, save 80% of the fleet coordinator's time by automating the process, and reduce fleet labour costs by 30%, and enables 100% monitoring of fleet movement (Planowanie…).

Both the long-term and short-term dimensions of incorporating environmentally friendly elements into the business model of large and medium-sized road freight transport companies are part of the trends and conditions prevailing in the environment. One of these conditions for

road transport is the linear and nodal infrastructure, and another is the regulatory environment established by the state, understood as a legislative-administrative entity with the authority to impose the achievement of socially desirable goals (including pro-environmental ones) on the one hand, and to support these activities on the other. These dimensions are the factors affecting the carriers' decisions regarding obstacles on the one hand and expectations of the state on the other, regardless of what actions are taken by the state. As part of the 2020-2021 study, the carriers were asked to rank obstacles to the smooth achievement of environmental goals. The respondents' answers ranked the factors in the following order:

- lack of funding for vehicle purchases was indicated by 57 respondents as the most important factor,
- lack of assistance from the state was indicated as the most important factor by 47 respondents,
- lack of infrastructure (CNG stations, charging stations) was indicated as the most important factor by 42 respondents.

In the same survey, the respondents were asked to rank the state's actions that would motivate carriers to incorporate environmentally friendly measures into their business models. Investment in infrastructure was identified as the most important factor, followed by the introduction of tax systems that differentiate vehicle taxes based on exhaust emissions and by fleet renewal programs (tax reduction, subsidies).

5. Conclusions and discussion

One of the dimensions of environmental degradation is greenhouse gas emissions. The economic sectors with a significant negative impact on the environment include the road freight transport sector. Reducing greenhouse gas emissions from road transportation is one of the European Union's environmental goals, and, due to the share of exhaust gas emissions by motor vehicles in general, one of the goals is to reduce the carbon monoxide and nitrogen oxide emissions by introducing the EURO emission standards and, by 2030, stopping the manufacture of vehicles with engines powered by fossil fuels, specifically gasoline and diesel. In keeping with this goal, lorry manufacturers are already offering lorries with electric engines today, albeit to a limited extent, and are planning to offer only electric vehicles after 2040.

The environmental goals and the trends in the development of zero-emission transportation are not without an impact on road carriers, which must incorporate them into their business models in two areas of their operations. The first is the long-term dimension, related to the policy of replacing vehicles with new ones that meet increasingly stringent emission standards. This dimension requires carriers to make strategic decisions that take into account their

financial capabilities, including those that determine the efficiency resulting from the costs – the fuel costs and the environmental fees– of the operation of these vehicles in the future.

In the course of the survey, the respondents indicated that, as part of their fleet policy, they based their business models on the purchase of new means of transportation that meet increasingly stringent emission standards in order to fit in with the environmental goals. This is evident in the statistics, according to which almost 50% of newly registered lorries in Poland in 2021 were no more than 2 years old. The second measure is to make purchases of vehicles with smaller engine displacement to match the needs arising from the operations.

The operational activities of medium and large Polish freight carrier companies that lead to the satisfaction of transport needs are also characterised by activities that reduce exhaust emissions into the environment. They consist in the application of solutions that change the composition of exhaust gases (AdBlue) and reduce fuel consumption (lowering rolling resistance – energy-efficient tires and lowering air resistance – fairings), and the acquisition of pro-environmental driving skills (eco-driving). The final element is the organisation of processes that consists in an increase in the utilisation of the vehicle capacity (cargo consolidation) and the elimination of empty runs by looking for cargo to be carried on the way back and using route planning software.

Incorporating zero-carbon economy goals into a company's business model involves additional costs. The cost of pro-environmental solutions in the operational dimension of the road carriers' business model is relatively low; however, if one considers the fleet replacement policy, two fundamental barriers can be observed. The first is related to the lack of funding for the purchase of new zero-emission vehicles: currently, taking into account the subsidies available in some countries, their prices are on average three times higher than the prices of vehicles powered by fossil fuels. This results in the carriers' expectation of support for this activity by the state, which is not provided in Poland, as it applies only to cars and vans. The second barrier is related to infrastructure: Poland has one charging station per 100 kilometres of roads, and even if one considers that it is possible to obtain support for their construction, range limitations and charging times effectively limit, for now, the use of electric lorries for medium- and long-distance trips. Therefore, since the goal – a zero-carbon economy in 2050 – has been defined, the following question arises: How can the problem with the 'path to get there' be solved? Should carriers be left without support and should we wait another 10 to 15 years until vehicles powered by fossil fuels are naturally eliminated? Or should carriers be supported and should that time be shortened so that, for example, zero-emission road freight transport becomes a reality by 2050?

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RELATIONSHIP BETWEEN INSTITUTIONAL TRUST, INTRAORGANISATIONAL COLLABORATION AND COMMITMENT TO STRATEGIC BUSINESS DEVELOPMENT

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Purpose: The aim of this study is to identify the relationship between the two dimensions of institutional trust and collaboration and their individual and joint impact on the commitment to strategic business development.
Design/methodology/approach: The study included employees of innovative companies, in which collaboration is very important to create innovative solutions. The results obtained using structural equation modelling (SEM), confirmed the important role of institutional trust in the process of stimulating collaboration and the influence of both constructs, either directly or indirectly, on the commitment to the strategic enterprise development.
Findings: The research indicates that institutional trust, collaboration, and employee commitment to strategic business development are interrelated within organizations. Trust, particularly in terms of organizational assurance and a sense of security, serves as a foundation for collaboration, which, in turn, strongly influences employee commitment to the organization's strategic goals. These findings provide valuable insights for both researchers and practitioners interested in enhancing teamwork and commitment in organizational settings, particularly within innovative companies.
Research limitations/implications: By addressing these limitations and pursuing the suggested avenues for future research, scholars can continue to deepen their understanding of the complex interplay between trust, collaboration, and employee commitment in organizational settings.
Practical implications: The paper highlights the importance of trust, collaboration, and employee commitment in organizational contexts. Organizations that heed these findings and implement strategies to enhance trust and collaboration may experience positive outcomes in terms of teamwork, commitment, and ultimately, their competitive advantage.
Social implications: Research focuses on organisational dynamics. Its societal implications boil down to strengthening the social capital of the organisation and, as a result, strengthening the psychological capital of employees, improving their well-being in the workplace, fostering commitment and, as a result, the innovation and competitiveness of the organisation. Policy makers and organisations can learn from the research in order to implement human resource

policies oriented towards building social capital, which can finally contribute to improving the quality of life of employees and society as a whole.
Originality/value: The value of the paper lies in its contribution to understanding the relationship between the two identified dimensions of trust, collaboration and commitment in innovative organisations. The findings can also serve as a basis for the formulation of practical guidelines for managers.

Keywords: institutional trust, collaboration, commitment to strategic enterprise development, innovative enterprises.

Category of the paper: research paper.

1. Introduction

Institutional trust also called impersonal trust (T) creates the context for trust-based interpersonal relationships as it is necessary for interpersonal trust to emerge (e.g. DeOrtentis et al., 2013). Research indicates that institutional trust affects the formation of trust towards managers, as they implement the strategy of the organisation by making important decisions for employees (McKnight, Chervany, 2005). Institutional trust is based on the collective qualities of top executives, which cannot be reduced to those of individual members. However, they ensure continuity of action and direction in the organisation, even when members of top management are changing (Searle et al., 2011). Institutional trust also creates the framework and conditions for collaboration, from formal facilities that create a sense of security and stability and encourage initiative, through stimulating interpersonal trust, to an inter-organisational climate of trust. Institutional trust is an essential background for building trust between people in an organisation. Institutional solutions can therefore shape trust and reduce the risk of losing it. Although interpersonal trust is more decisive for the strength of collaboration, a certain role in this process cannot be taken away from institutional trust.

Research shows that institutional trust has a significant impact on behaviours or phenomena that are crucial for collaboration, such as: increased effectiveness and efficiency of communication (Blomqvist, 2002), knowledge sharing (Ford, 2004; Ahteela, Vanhala, 2018), job satisfaction (Shockley-Zalabak et al., 2000; Vanhala, Ahteela, 2011) or work efficiency (Robertson et al., 2013). Institutional trust is also positively linked to employee commitment and identification with the company (Ellonen et al., 2008), which should also have a positive impact on commitment to the strategic business development. Due to the fact that interpersonal trust becomes fragile, ephemeral and difficult to rebuild, institutional trust becomes important and becomes a serious source of competitive advantage (Schoorman et al., 2007; Vanhala et al., 2011). The results of the research indicate that institutional trust has a huge impact on the process of creating and sharing knowledge, which is very important for collaboration processes in the organisation. Trust helps to overcome the tension between the willingness to share

knowledge and the belief in the need to protect it (Bogers, 2011). That is why it is so important that there are mechanisms in the organisation that stimulate the dissemination of information and learning from each other, preventing distrust, cynicism and excessive caution in collaboration processes (Ford, 2004). Sharing knowledge can be risky behaviour, as it can have unpredictable consequences, including loss of professional position, use of knowledge for an inappropriate purpose, depreciation of its value and so on. A special role in the creation of knowledge is assigned to the process of its codification. In this case, institutional trust is a guarantee that the knowledge generated is properly stored and protected from persons who should not have access to it (especially in an external context) and that it will be used properly. In other words, it reduces the uncertainties and risks associated with this process by ensuring the protection of each party (Ford, 2004).

The results presented above confirm the important role of institutional trust in collaboration by creating a framework, a climate for collaboration and organisational learning, reducing fears and risks of opportunistic behaviour by colleagues (Lewicka, Zakrzewska-Bielawska, 2016). However, so far, little attention has been paid to institutional trust in the context of stimulating collaboration or commitment to strategic enterprise development.

Therefore, the main aim of this study is to identify the impact of two distinct dimensions of interpersonal trust on stimulating collaboration. In addition, to demonstrate that both institutional trust and collaboration has an impact on the commitment to strategic enterprise development.

The described assumptions are presented in Figure 1.

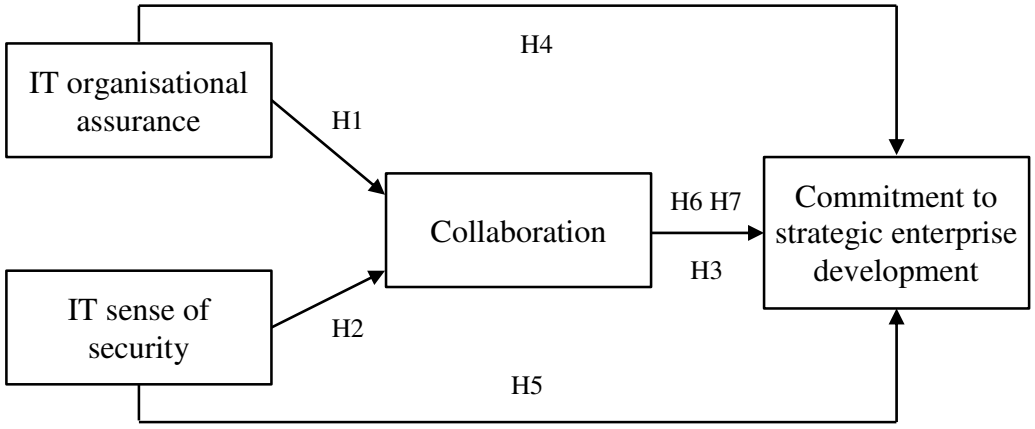

Figure 1. Relationship between institutional trust, collaboration and employee commitment to strategic enterprise development.

Source: Own study.

2. Collaboration and trust

Almost every organisation operating in a knowledge-based economy sets up teams of employees to achieve its objectives. Collaboration in often very complex projects is associated with the need to rely on the results of the work of others and entails a greater need for trust in teams (Tseng, Ku, 2011). Trust is therefore an essential condition for relations based on collaboration. Additionally, it increases the willingness to continue the relationship (Sankowska, 2011 p. 73). The relationship between trust and collaboration seems to be of a bilateral nature, i.e. trust is a prerequisite for the quality of collaboration, while collaboration and related past experience may be a factor in increasing trust. Trust affects the way the team operates and the results achieved (Gazley, 2008; Bryson et al., 2015). Collaboration can, of course, occur under conditions of constraint. However, there is a fundamental difference between voluntary and forced collaboration, especially in the long term. It seems that only voluntary collaboration based on trust can lead to above-average results. It is therefore important that collaboration should be based not only on positive interpersonal relationships, but also on a framework built on institutional trust. These include, for example, the conditions for taking risks, tolerating mistakes and failures, the willingness to learn from each other, the conviction of the possibility of sharing doubts, reporting a problem situation, and others (Lewicka et al., 2017).

This gives rise to the formulation of the following research hypotheses:

H1: Institutional trust in the dimension of organisational assurance is positively and directly linked to collaboration.

H2: Institutional trust in the dimension of sense of security is positively and directly linked to collaboration.

3. Commitment of employees to the strategic enterprise development

Researchers emphasise the link between institutional trust and employee commitment, pointing out that it gives employees an overall view of the meaning and benefits of the venture they intend to engage in (Vanhala et al., 2011). Institutional trust is built primarily through the effectiveness and fairness of the rules governing the operation of the entire company, also on the basis of the policies and practices of the HRM (Dietz, Den Hartog, 2006; Searle et al., 2011), and therefore provides a basis for commitment to the organisation. A number of studies have been devoted to the influence of trust on commitment (Lewicka, 2019). However, these studies were mainly concerned with interpersonal trust. It is believed that trust strengthens commitment to the organisation, which is particularly valuable when the organisation is experiencing

problems or crisis situations. This study tested the impact of institutional trust on one aspect of commitment to strategic enterprise development. The choice of this observable variable is related to the belief that commitment should have a specific behavioural dimension, and one of its most significant manifestations seems to be precisely the commitment to the implementation and development of the business strategy (Bashynska et al., 2023).

In this context, it is also worth pointing out that the identification of the observable variable of commitment to strategic enterprise development is related to the increasingly widespread concept of commitment relating to diverse facilities (Klein et al., 2012). Commitment is treated as a kind of bond that motivates further activities for the facility, i.e. the company, with increased spending of forces and resources. These may include initiatives aimed at clarifying the strategy or adapting it to the adopted goals and values, as well as taking action in line with the company's strategy. The authors of the model emphasise the relationship of trust with commitment, treating trust as its determinant (Klein et al., 2012).

It is difficult to imagine the implementation of complex projects without effective teamwork (Robbins, Judge, 2011). Research indicates that the experience of successful collaboration has the potential to build commitment in the implemented projects (Trespalacios et al., 2011). In this case, it is about commitment to strategic enterprise development. The above reasoning gave rise to the formulation of further research hypotheses:

H3: Collaboration is directly and positively linked to the employee commitment to strategic enterprise development.

H4: Institutional trust in the dimension of organisational assurance is positively and directly linked to employee commitment to strategic enterprise development.

H5: Institutional trust in the dimension of sense of security is positively and directly linked to the commitment to strategic enterprise development.

In the context of considerations concerning the relationship between trust and collaboration, it is pointed out that there is a close link between them, as trust creates conditions for collaboration, establishing and maintaining relations (Sankowska, 2011), making them more satisfactory and influencing the results of actions taken. Therefore, both these constructs are treated as determinants of organisational success. Thanks to trust, also impersonal, it is possible to cooperate and commit to the strategic development of the company and the achievement of its goals. The above reasoning gave rise to further hypotheses:

H6: Collaboration mediates the relationship between institutional trust in the dimension of organisational assurance and employee commitment to strategic enterprise development.

H7: Collaboration mediates the relationship between institutional trust in the sense of security and employee commitment to strategic enterprise development.

4. Method

To verify the theoretical model, structural equations modelling (SEM) was used, which is a statistical modelling technique including path analysis and regression analysis (Rodríguez, Pérez, 2007). Institutional trust was tested with 14 statements (Ellonen et al., 2008), on a five-step Likert scale. In this case, the exploratory factor analysis led to separating two dimensions: the organisational assurance and the sense of security. They both have satisfactory Alfa Cronbach factor: the sense of security: 0.87 and the organisational assurance - 0.90. The organisational assurance as a dimension of impersonal trust is a conviction about the clarity of rules and principles, open communication and the staff feels included in the organisational processes. In turn, the sense of security is largely shaped by the belief that, in the enterprise, employees are offered development conditions which are right for their needs. The collaboration construct, on the other hand, has also been examined by three statements on a five-step Likert scale. The reliability of the variable measured by the α-Cronbach coefficient is satisfactory and amounts to 0,70. The collaboration structure is associated with the existence of optimal conditions for collaboration at various levels, including between departments or departments, the willingness to help colleagues from other departments and share ideas with them and the awareness of creating a strong team. The "output" variable, i.e. the commitment to strategic enterprise development was a variable that was observed and measured by means of a claim: "I am committed to the strategic planning of my company's development" using a five-step Likert scale.

The survey was attended by 1769 people - employees - representing innovative companies selected in a quota manner. The recruitment criteria for selecting company's/employees for the survey were innovation diagnosed using an additional form and the sector (industry or services). The sample consisted of 50.4% women and 49.6% men. Most of them were in the 25-35 age group (42.2%). Production companies accounted for 56% of the sample and 44% of service providers. The majority of the respondents were recruited from companies employing up to 200 people, i.e. 53.1%, and the rest from companies employing over 200 people (46.9%).

5. Results

The results of the study indicate that the model of the impact of institutional trust and collaboration between employees on employee commitment to enterprise development is statistically significant. The parameters of the model's matching make it possible to conclude that the assumed relationships between the institutional trust of the other constructs correspond well to the collected empirical data. The main model parameters are: chi-quadrate = 642.44 at

95 degrees of freedom (p = 0.00), CMIN/DF = 6.76, GFI = 0.96, CFI = 0.96, RMSEA = 0.06, HOELTER (0.01) = 358.

The analyses carried out justify the acceptance of six research hypotheses and rejection of one - H5. Institutional trust in both dimensions - organisational assurance and the sense of security - creates conditions for initiating collaborative projects (H1 and H2), while the sense of security motivates employees to cooperate more strongly.

Table 1.
Standardized Regression Weights

	Relationships tested			**Estimate**	**P-value**	**Status**
H1:	Collaboration	←	Organisational assurance	0,36	0,00	Accepted
H2:	Collaboration	←	Sense of security	0,50	0,00	Accepted
H3:	Commitment to strategic enterprise development	←	Collaboration	0,63	0,00	Accepted
H4:	Commitment to strategic enterprise development	←	Organisational assurance	0,23	0,00	Accepted
H5:	Commitment to strategic enterprise development	←	Sense of security	-	0,06	Rejected
H6:	Collaboration mediates the relationship between institutional trust in the dimension of organisational assurance and commitment to strategic enterprise development.			0,22	0,00	Accepted
H7:	Collaboration mediates the relationship between institutional trust in the sense of security and commitment to strategic enterprise development.			0,31	0,00	Accepted

Source: Own study.

At the same time, collaboration between employees, even from different departments, is conducive to increasing commitment to strategic enterprise development (H3). It is worth noting that the impact of collaboration on this type of commitment is extremely strong. Additionally, it has been verified that there is a direct impact of institutional trust in the organisational assurance on commitment to strategic enterprise development. However, the direct impact of trust in the sense of security proved to be statistically insignificant, hence the H5 hypothesis was rejected.

In addition, the existence of a mediation effect was also confirmed, i.e. it was recognised that collaboration can strengthen the relationship between the institutional trust in both dimensions and the commitment of employees to strategic enterprise development. It turned out that, in the case of the organisational assurance, there is, apart from the direct, indirect relationship (through collaboration) with the commitment of employees to strategic development (see Table 2). The H6 hypothesis was therefore confirmed. In the case of trust in the sense of security dimension, the mediation of the construct turns the sign of dependence, i.e. the strength of the indirect relationship between this dimension of trust in the sense of security and commitment to strategic enterprise development becomes statistically significant. Thus, the H7 hypothesis about the mediation role of collaboration in the relationship between the sense of security dimension and commitment to strategic enterprise development was confirmed.

Table 2.
Standardised total, indirect and direct effects

	Sense of security	Organisational assurance	Collaboration
Total effect			
Collaboration	0,50	0,36	-
Commitment to strategic enterprise development	0,13	0,44	0,63
Direct effect			
Collaboration	0,50	0,36	-
Commitment to strategic enterprise development	-0,18	0,22	0,63
Indirect effect			
Collaboration	-	-	-
Commitment to strategic enterprise development	0,31	0,22	-

Source: Own study.

6. Discussion

The results of the study indicate that both dimensions of trust are strongly linked to collaboration, but with a sense of security with a little more strength. A sense of security in the workplace, by guaranteeing stability and sustainability, creates conditions for collaboration. Many authors stress that a supportive and secure climate is extremely important for collaboration (Erden, Erden, 2009; Bertels et al., 2011).

Organisational assurance i.e. the conviction of clarity of rules and principles in the organisation as well as open communication has a slightly weaker, but significant connection with collaboration. This relationship is also confirmed by the results of research by other authors (Bachmann, Inkpen, 2011; Hakanen, Soudunsaari, 2012; Nancarrow et al., 2013). The research also showed that variable collaboration is strongly linked to the commitment to strategic enterprise development.

Collaboration also turns out to be a partial mediator of this relationship, which means that it stimulates the impact of organisational assurance on the commitment to strategic enterprise development. In turn, the dimension of institutional trust sense of security does not significantly direct affect the commitment to strategic enterprise development, which does not allow to accept the H5 hypothesis. However, the introduction of variable collaboration as a mediating factor strengthens, although indirectly, the impact of this dimension of institutional trust. It can be argued that collaboration helps to decode the perceived trust in an organisation in the sense of security, towards a more active commitment with the company. It is worth noting that many studies indicate a stimulating effect of trust on commitment (Katou, 2013), which confirms the identified relationship.

As it results from the conducted research, trust should be classified in a category of exceptional importance in the modern business environment. Therefore, many authors point to the need to build organisational trust, which increases the effectiveness of the company's

competitiveness and improves its reputation (Nemiro et al., 2008). In particular, it is important to build impersonal trust, which so far has not been the focus of attention from researchers and practitioners (Searle et al., 2011). This is due to the fact that, similarly to the processes of introducing change, building trust in an organisation should start from the 'top', i.e. impersonal trust, which forms the basis for building interpersonal trust (Pennington et al., 2003). This article confirms the significant role of institutional trust in stimulating collaboration, as well as employee commitment to strategic enterprise development.

The results of this survey may provide managers with guidance to help them build teams of committed employees. It turns out that in order to achieve this goal, managers need support at the organisation level in addition to their own efforts to create optimal conditions for employees to cooperate. Institutional trust built at the level of the whole organisation through a system of procedures and creating a sense of security provides the necessary background for managers' actions. Managers based on institutional trust should effectively use the potential of a credible organisation. An interesting direction of further research could be to test these relationships in organisations that are diversified in terms of industry and work organisation.

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ACHIEVING SUSTAINABLE DEVELOPMENT THROUGH ORGANIZATIONAL ALIGNMENT: A CASE STUDY OF APTIV

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Purpose: Sustainable development has become a critical goal for organizations worldwide, with an increasing focus on environmental, social, and economic responsibilities. Companies are now expected not only to achieve financial success but also to contribute positively to the well-being of society and the environment. In this context, Aptiv, a global technology company, stands out as a beacon of sustainable development. This article explores how Aptiv integrates sustainable practices into its operations, with a particular emphasis on Organizational Alignment and the Theory of Planned Behavior. By examining Aptiv's sustainability documentation, authors delve into how the company addresses various aspects of sustainable development and aligns with specific United Nations Sustainable Development Goals (SDGs).
Design/methodology/approach: The research employs case study and company documents analysis to understand structural and perceptual aspects of Organizational Alignment in reaching SDGs.
Findings: The findings suggest that aligning organizational structures with SDGs, coupled with a comprehensive understanding of planned behavior factors, can serve as a strategic approach for fostering successful sustainability initiatives within organizations. This dual approach addresses both the structural and behavioral aspects, offering a more holistic framework for achieving sustainable development objectives.
Research limitations/implications: Research limitation lies in single source case study, suggesting the need for broader research encompassing a more extensive range of organizations. Future studies should consider both the size and the industry-specific characteristics of organizations to enhance the generalizability of findings.
Practical implications: The case study serves as a blueprint, demonstrating how successful organizations strategically integrate sustainability practices to achieve tangible and impactful results.
Originality/value: This paper contributes novelty by addressing a research gap through its focus on a limited number of case studies detailing specific organizations' successful implementation of SDGs. Its value lies in providing actionable insights and strategic guidance for organizations aiming to effectively integrate SDGs, particularly suitable for those seeking practical examples and success stories in the realm of sustainability initiatives.

Keywords: Sustainable Development, Organizational Alignment, Theory of Planned Behavior.

Category of the paper: Case study.

1. Introduction

The natural environment is constantly being polluted by the activities of the construction industry and the built environment as a whole. Likewise, finite natural resources that are used as raw materials for construction are increasingly being depleting due to continuous extraction. Waste generation resulting from human activities during construction is also on the rise, with little effort being made to minimize it (Ogunmakinde, 2022). In September 2015, the United Nations (UN) adopted a global plan of action for sustainable development named "Transforming Our World: The 2030 Agenda for Sustainable Development", with a broad scope incorporating 'Five P's' namely, planet, people, prosperity, peace, partnership. The 2030 Agenda is a global scheme incorporating 17 Sustainable Development Goals (SDGs) and 169 related targets addressing global challenges of climate change, social inequality and environmental degradation. The SDGs call for worldwide action among governments, businesses and civil society organizations to achieve shared and sustainable prosperity (Khaled, 2021).

The motivation for organizations to adopt sustainable development practices is multifaceted, encompassing environmental responsibility, regulatory compliance, financial considerations, and the recognition of the interconnectedness between business success and broader societal and environmental well-being. Organizations recognize the finite nature of many resources and the importance of using them efficiently. Sustainable development practices aim to minimize resource consumption, reduce waste, and ensure the responsible use of natural resources. By doing so, organizations contribute to the long-term availability of resources. Adopting sustainable practices is driven by the desire to mitigate the environmental impact of business operations (Yadaf, 2022). Organizations acknowledge their role in contributing to pollution and environmental degradation. Sustainable practices, such as waste reduction, eco-friendly manufacturing processes, and emissions controls, are implemented to minimize negative effects on the environment (Al-Shetwi, 2022). Increasingly stringent environmental regulations and standards require organizations to comply with specific sustainability measures. Adhering to these regulations not only helps avoid legal consequences but also demonstrates a commitment to responsible corporate citizenship (Bengo, 2022). Consumers and investors are placing a growing emphasis on corporate social responsibility. Organizations that demonstrate a commitment to Sustainable Development practices often enjoy enhanced reputation and trust among stakeholders. This positive perception can lead to increased customer loyalty and investor confidence (Fallah, 2022). Sustainable practices often go hand in hand with increased efficiency. For example, energy-efficient processes not only reduce environmental impact but also result in cost savings for the organization. Adopting sustainable technologies and practices can lead to long-term financial benefits (Zakari, 2022). Organizations recognize that environmental and social risks can impact their operations.

By integrating sustainable practices, they aim to mitigate these risks and build resilience against potential disruptions (Wang, 2022). This includes considering the impacts of climate change, supply chain disruptions, and reputational risks associated with unsustainable practices. Sustainability challenges present opportunities for innovation. Organizations that invest in sustainable technologies and solutions may gain a competitive advantage by tapping into emerging markets for green products and services. This fosters a culture of innovation within the organization (Aftab, 2022). Sustainable development practices are viewed as essential for ensuring the long-term viability of businesses. Organizations recognize that a focus on short-term gains at the expense of environmental and social considerations is not sustainable in the long run (Andersson, 2022). By integrating sustainable practices, they aim to build resilience and future-proof their operations.

In the literature, there is a research gap regarding how the private sector implements SDGs at the organizational level. In this paper, we analyze case study of Aptiv, one of the most sustainable companies in the automotive sector. This case study highlights: the key strategies that Aptiv has employed in engaging employees to achieve SDG, and how Aptiv integrates sustainable practices into its operations. These findings underscore the value of the SDGs as a common language in employees engagement and offer practical implications for the private sector to contribute meaningfully to the shared global agenda.

2. Literature review

Organizational Alignment is a crucial aspect of management because it influences an organization's ability to achieve goals, adapt to changes, maintain consistency in actions, and build coherence across different areas of the organization (Aldalimy, 2019). It may involve adjusting the organizational structure, human resource management, communication, strategic objectives, and many other elements to create a coherent and integrated whole (Conway, Andrews, 2020). According to Lumineau and Malhotra (2020) when the structural conditions of an organization is attractive and it has the resources and capabilities to carve out a viable competitive position, the structural alignment approach is likely to lead to better performance. Saffold (2019) points out that a solid culture has nearly been utilized as a main impetus to support the confidence of laborers and to improve employee self-confidence and engagement, reducing work stress and improving employee ethical behavior. The capacity to recognize the organization's cultural characteristics offers a platform for a better comprehension of the organization's activities including those which are connected to Sustainable Development (Anamanjia, 2022).

To emphasize key processes and identify best practices for the case study, this paper comes with a discussion on Theory of Planned Behavior (TPB). TPB (Ajzen, 1991) posits that an individual's behavior is influenced by their attitudes, subjective norms, and perceived behavioral control. The main assumptions of Ajzen's Theory of Planned Behavior are: (a) attitude toward the behavior: where individuals make subjective evaluations of a given behavior. These attitudes include positive or negative assessments of the consequences of the behavior and subjective values attributed to these consequences, (b) subjective norms: these are subjective evaluations, or an individual's beliefs about whether important people in their social environment (e.g., friends, family, co-workers, employees, leaders) approve or disapprove of a particular behavior. Subjective norms also include the individual's willingness to conform to these evaluations, and (c) perceived behavioral control: this involves assessments of whether an individual believes they have sufficient control over a given behavior. It considers whether they can control it, whether there may be obstacles, and what their skills are in controlling the behavior. These three factors (attitude toward the behavior, subjective norms, and perceived behavioral control) influence an individual's intention to engage in a particular behavior. These intentions, in turn, are considered direct precursors to actual behavior. Since its development almost three decades ago, the TPB has frequently been applied to understand the factors underlying various pro environmental behaviors (Yuriew, 2020): the use of alternative transportation (Ali, 2023), waste recycling (Ma, 2023), saving water (Si, 2022), energy conservation (Duong, 2023) or low carbon consumption (Jiang et al., 2019; Liu, 2022).

The United Nations Agenda 2030 (United Nation, 2015) for Sustainable Development, signed by all United Nation Member States, consists of 17 goals and 169 targets representing shared environmental, social, and economic aspirations commonly referred to as the Sustainable Development Goals (SDGs). With less than one decade left to achieve the SDGs and implement the 2030 Agenda, the United Nation called this period the “decade of action” and committed to mobilize financing, enhance national implementation, and bolster local action (Bandari, 2022). The adoption of the 2030 Agenda has demonstrated the need to change existing priorities for organizations, from quantifying economic growth at any cost to recognizing and rewarding sustainable economic development (Cojocaru, 2022). In general, sustainability refers to creating a condition that human and nature can co-exist in a productive harmony that allows the socioeconomic development of the current and future generations (Nodehi, 2021). The literature of sustainability development proposes three different perspective for sustainable development: a) strong sustainability, b) weak sustainability, and c) health-centered or social sustainability (Parsa, 2019). Each can propose a special and distinctive strategy for the development of transportation infrastructure, since each perspective sustainability assumes different importance to each pillar of sustainable development e.g., social, environmental, and economic (Taghvaee, 2021). Studies are increasingly focusing on assessing the interactions among specific SDGs (Van Soest et al., 2019). A exploration was conducted by mapping interactions between SDG 14 (i.e., life below water) and other SDGs (Dawes, 2022).

Biglari et al. (2022) undertook a study based on published evidence around interactions between SDG 7 (i.e., affordable and clean energy) and other SDGs. UN (2017) developed a comprehensive methodology to assess relationships between clean water and sanitation (SDG 6) and other SDGs using a systems thinking approach. A report by the International Council for Science (ICSU, 2017) evaluated key interactions between the targets of SDG 2 (i.e., zero hunger), SDG 3 (i.e., good health and well-being), SDG 7, and SDG 14 with other SDGs using a seven-point scale, without accounting for geographical context. Turcson et al. (2020) conducted a systematic assessment between SDG 7 targets and other SDGs by reviewing energy-related literature and assessing context dependencies. In addition to these studies, Anderson et al. (2022) discussed efforts towards SDGs 5 (Gender Equality) and 17 (Partnerships for the Goals) which may accelerate progress, while SDGs 10 (Reduced Inequalities) and 16 (Peace, Justice and Strong Institutions) were shown to create potential hurdles. Some studies have taken a more comprehensive approach to assessing SDG interactions, focusing at the global (Anderson et al., 2022) and national scales (Horal et al., 2022).

3. Methodology

A case study approach was employed. A case study (Glinka, Czakon, 2021) is a method of solving a cognitive problem, and its main intention is to understand the circumstances of the occurrence of phenomena, discover their causes, and the direction of dependencies between them. Yin (2009) recommends using the case study method to find answers to questions of an exploratory nature, thus addressing "how" and "why" a given phenomenon occurs. Such scientific research focuses more on a profound understanding of the phenomenon than on the analysis of variables. Therefore, the application of the case study method allows for discovering what quantitative research results can only suggest. Compared to other research methods, case studies offer the richest range of techniques and tools for data acquisition and analysis. Sources of data may include observations, interviews, company documents, press articles, surveys, databases maintained by various institutions. There are also no methodological limitations regarding the way data is analyzed. For this paper The Sustainability Progress Report (2023); Environmental, Health, Safety and Energy Policy (2022); Annual Report (2022), company documents retrieved from the company's website (www.aptiv.com), and official press releases were used for the analysis, and to characterize the organization. Conclusions drawn based on a case study method aligned with the assumptions of the phenomenological paradigm allow for explaining unique phenomena, which may be valuable in a different context and in another organization as an interpretation of phenomena but cannot be entirely predictable in the future (Goffin, Ahlstrom, Bianchi, 2019).

This research focuses on Aptiv – global technology company, recognized as one of most sustainable companies from automotive sector, where business strategy is intricately linked to company's commitment to sustainability. Aptiv provides advanced solutions in electrification, safety, autonomy, and connectivity within the automotive business. The company operates in the automotive technology sector, developing innovative systems and components that enhance safety, energy efficiency, and the overall driving experience. Aptiv focuses on advancing technologies related to autonomous (driverless) vehicles and integrated vehicle systems. This corporation is one of the largest in the industry involved in the production of parts for the automotive sector. It employs approximately 163,000 workers (around 50,000 in the USA). Aptiv operates in 46 countries, including Poland, with the biggest Research and Development Center in Krakow. In the year 2022, Aptiv revisited its materiality assessment to guarantee that its sustainability strategy remains closely aligned with the ESG (Environmental, Social, and Governance) topics that hold utmost significance for the business and its stakeholders. This routine engagement process yields valuable insights, which are employed to fine-tune the company's initiatives as its sustainability strategy progresses. Drawing from the insights gained in the 2019 analysis, Aptiv utilized input from independent experts for the assessment, encompassing feedback from both internal and external stakeholders.

4. Findings

Aptiv has a sustainability strategy based on the 2030 Agenda (UN, 2015). Aptiv is dedicated to delivering top-quality solutions that are designed, developed, and manufactured responsibly, contributing to a safer, greener, and more connected world. This commitment extends to taking care of people and the communities in which company operates, all while minimizing its carbon footprint. The foundational pillars of company sustainability are: people, products, planet and platform. Code of Ethical Business Conduct serves as the foundation for instilling values into action. In 2022, senior leadership actively engaged with employees, promoting a culture of speaking up and providing ethical education through various channels.

With reference to People, Sustainability Development Goals number 4 (Quality Education), 5 (Gender Equality), 8 (Decent Work and Economic Growth), and 13 (Climate Actions) are implemented by:

- Attract, develop & retain the best talent:
  To achieve year-over-year improvement in employee engagement scores, the company is implementing a comprehensive strategy. This involves conducting regular employee surveys and pulse surveys to gather feedback and insights into the employees' experiences. The aim is not only to identify areas for improvement but also to recognize and reinforce positive aspects of the work environment. Additionally, the company is

focusing on increasing the internal fill rate on open positions, emphasizing the importance of promoting talent from within the organization. This approach contributes to a culture of continuous development and growth.

- Health & safety:
  A proactive stance on mitigating risks and implementing health and safety best practices is a priority for the company. The goal is to ensure that 100% of manufacturing sites attain ISO 45001 certification, reflecting a commitment to maintaining high standards of occupational health and safety. Emphasis is also placed on improving workplace safety through the cultivation of a safe culture and the tracking of strong leading indicators. By focusing on these aspects, the company aims to create an environment where the well-being and safety of employees are paramount.
- Diversity, equity & inclusion:
  The company is dedicated to cultivating an inclusive workforce that not only reflects diversity but also actively engages and attracts the best talent to fuel innovation. Initiatives include conducting pay equality studies globally to identify and close gender gaps. Furthermore, there is a specific focus on increasing gender diversity across all levels of the organization. By fostering a culture of equity and inclusion, the company aims to create an environment where everyone feels valued and has equal opportunities for growth and success.
- Community engagement & wellbeing:
  The company is extending its commitment beyond its organizational boundaries by actively engaging with the community and promoting overall well-being. Initiatives include conducting vehicle safety education programs for children, with the ambitious goal of reaching 5000 children per year, totaling 30,000 children by 2025. Another environmental initiative involves planting 80,000 trees annually, contributing to a total of 480,000 trees by 2025. Additionally, the company is empowering girls in technology through workshops, dedicating 500 hours per year, with a goal of reaching 3000 total hours by 2025. These initiatives reflect the company's commitment to making a positive impact on society and the well-being of future generations.

With reference to Products, Sustainability Development Goals number 3 (Good health and Well-Being), 9 (Industry, Innovation, Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Actions) are implemented by:

- Safe, green & connected solutions:
  In company’s commitment to SAFE, GREEN & CONNECTED SOLUTIONS, Aptiv is dedicated to providing cutting-edge multi-modal human-machine interface solutions. These innovations aim to significantly reduce driver distraction and enhance convenience during interactions with the vehicle. Notable features include advanced driver monitoring systems, gesture recognition technology, and child presence detection

mechanisms. By incorporating these elements, Aptiv strives to create a safer and more intuitive driving experience. Furthermore, company's focus extends beyond immediate safety concerns. Company is actively involved in developing transformative, sustainable architectures that lay the foundation for feature-rich, highly automated, and electrified vehicles of the future. This strategic approach aligns with their vision of contributing to the evolution of the automotive industry, promoting environmental sustainability, and embracing the paradigm shift toward electric mobility.

- Product quality:
  Commitment to PRODUCT QUALITY underscores our dedication to developing and delivering products and solutions that consistently meet and exceed expected levels of performance. Through rigorous research, development, and testing processes, Aptiv ensures the reliability and durability of our offerings. This commitment extends across entire product portfolio, reflecting unwavering pursuit of excellence. To achieve these high standards, Aptiv employs state-of-the-art manufacturing practices, quality control measures, and continuous improvement initiatives. Their emphasis on product quality is not merely a goal but a guiding principle embedded in every stage of product development life cycle.
- Customer satisfaction:
  At the core of values is the pursuit of CUSTOMER SATISFACTION. Company strives to maintain their position as the customers' partner of choice by consistently delivering industry-leading products and solutions. This involves understanding the evolving needs of customers and adapting offerings to exceed customers' expectations. Customer-centric approach encompasses not only the quality and functionality of products but also the overall experience of interacting with brand. Aptiv actively seeks feedback, foster open communication channels, and prioritize customer support to ensure that every interaction with organization is marked by satisfaction and trust.

With reference to Planet, Sustainability Development Goals number 6 (Clean Water and Sanitation), 7 (affordable and Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Actions) are implemented by:

- Climate change:
  a) Innovative Solutions: Aptiv is committed to developing cutting-edge solutions that not only curb carbon emissions but also enhance energy efficiency. This includes a targeted approach to reduce electricity consumption at its top 10 most energy-intensive sites by obtaining ISO 50001 certification, a recognized standard for energy management systems.
  b) Renewable Energy: To further contribute to the fight against climate change, Aptiv aims to power its operations with 25% renewable electricity. This strategic shift toward cleaner energy sources aligns with global efforts to transition towards sustainable and renewable power.

c) Supply Chain Carbon Footprint: Aptiv is dedicated to an ongoing reduction of the carbon footprint within its supply chain. This involves implementing measures to curtail emissions and minimize waste throughout the entire supply chain process.
d) Environmental Management Certification: All manufacturing sites under Aptiv's purview are committed to achieving environmental management system certification (ISO14001). This ensures that these sites adhere to international standards, emphasizing the importance of environmentally sustainable practices.

- Waste & packaging:
  a) Circular Economy Approach: Aptiv sets a high standard for waste management by aspiring to achieve and maintain a waste recycling rate from manufacturing operations above 80%. This commitment reflects a dedication to a circular economy approach, where materials are reused, recycled, or repurposed to minimize environmental impact.
  b) Waste Reduction Strategies: Aptiv implements comprehensive waste reduction strategies that prioritize sustainable practices in manufacturing processes. By focusing on recycling and responsible waste management, Aptiv aims to contribute to the broader goal of minimizing waste generation.
- Water:
  a) Identifying Water Scarcity Areas: Aptiv is proactively addressing water conservation by identifying areas where water scarcity is a concern in locations where the company operates. This involves a strategic assessment of water availability to ensure responsible resource management.
  b) Annual Water Consumption Reduction: In high-risk areas with water scarcity concerns, Aptiv is committed to reducing water consumption by 2% annually. This targeted reduction aligns with sustainable water usage practices and demonstrates Aptiv's commitment to responsible water stewardship in regions facing water challenges.

These detailed actions illustrate Aptiv's holistic approach to environmental sustainability, outlining specific strategies and initiatives in the areas of climate change, waste and packaging, and water conservation.

With reference to Platform, Sustainability Development Goals number 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), 16 (Peace, Justice and Strong Institutions) are implemented by:

- Ethics & compliance:
  a) Code of Ethical Business Conduct: Aptiv aims to instill a strong ethical foundation within the organization. This involves the distribution of a comprehensive Code of Ethical Business Conduct to 95% of its salaried employees. This code serves as a guiding framework, outlining principles and standards to ensure that employees

conduct business with integrity, transparency, and in compliance with relevant regulations.

b) Compliance Training: To reinforce ethical behavior and regulatory compliance, Aptiv conducts mandatory compliance training for its salaried employees. This training is designed to educate employees about key legal and ethical considerations in the business environment. By ensuring that 95% of salaried employees undergo this training, Aptiv demonstrates its commitment to a workforce that understands and upholds ethical standards.

c) Annual Risk Assessment: Aptiv undertakes an annual risk assessment across all its sites globally. This comprehensive evaluation helps identify potential areas of vulnerability and non-compliance. By regularly assessing risks on a global scale, Aptiv can proactively address challenges and implement preventive measures, fostering a culture of continuous improvement in ethics and compliance.

- Sustainable supply chain:
  a) Aptiv Code of Conduct for Business Partners: Aptiv actively promotes ethical practices not only within its organization but also throughout its supply chain. The company encourages key suppliers to align with its Code of Conduct for Business Partners. This code outlines principles related to environmental sustainability, labor practices, and business integrity. Engaging suppliers in adopting these principles helps create a sustainable and responsible supply chain ecosystem.
  b) Third-Party Due Diligence Program: Aptiv is committed to expanding its third-party due diligence program. This initiative involves a comprehensive assessment of the ethical, legal, and sustainability practices of external partners. By ensuring that third parties share Aptiv's commitment to ethical conduct, the company mitigates risks associated with its supply chain and strengthens its overall corporate responsibility.
- Data security:
  a) Alignment with International Standards: Aptiv places a high priority on data security. The company is actively working to align all its data cybersecurity practices with appropriate international standards. This includes adhering to recognized frameworks and guidelines to ensure the confidentiality, integrity, and availability of its data assets.
  b) Rigorous Cybersecurity Standards: Aptiv is dedicated to maintaining rigorous cybersecurity, privacy, and data governance standards. This commitment involves implementing robust measures to safeguard sensitive information, prevent data breaches, and comply with evolving data protection regulations. By prioritizing data security, Aptiv demonstrates its responsibility in handling and protecting information assets.

Aptiv's Sustainability Strategy concentrates on areas such as:

a) employees education – Aptiv focuses on ensuring a culture of safety based on prevention, training, verification and risk mitigation in manufacturing plants, technical centers and offices. Standard training includes topics such as emergency preparedness and response, chemical material management and ergonomics. Goal for each employee is 4 training hours per year,
b) employees workplace - in 2022, Aptiv recycled 84 percent of the total waste that generated. Cost savings from supplier recycling programs help fund environmental projects in local communities, such as solar panel installation projects, freshwater conservation initiatives and reforestation efforts,
c) employees engagement – Aptiv supported the restoration of hydrological micro basins in the Sierra Tarahumara region of Mexico by planting almost 40,000 trees to help preserve the region's biodiversity and protect fresh water supplies. Planting was done by employees themselves.

The findings suggest that Aptiv recognizes the significance of social responsibility in its operations. The company emphasizes the well-being of its employees, promotes diversity and inclusion, and engages in community development projects. Through partnerships and outreach programs, Aptiv contributes to the enhancement of education, healthcare, and overall societal well-being in the regions where it operates. In the pursuit of Company Social Responsibility (CSR,) organizations are increasingly recognizing the importance of community engagement and wellbeing initiatives. This success in sustainable development can be attributed, in part, to effective Organizational Alignment, which is a crucial aspect of management because influences an organization's ability to achieve goals, adapt to changes, maintain consistency in actions, and build coherence across different areas of the organization. It may involve adjusting the organizational structure, human resource management, communication, strategic objectives, and many other elements to create a coherent and integrated whole (Conway, Andrews, 2020).

5. Discussion

Aptiv aligns its organizational elements to ensure a cohesive approach to sustainability and recognizes the significance of its workforce in achieving sustainability goals. Aptiv applies this theory by fostering a culture that encourages employees to embrace sustainable practices (Moslehpour, 2022). The company provides training programs to raise awareness about the importance of sustainability (Yuliantini et al., 2023) and equips employees with the knowledge and tools needed to contribute actively. Aptiv encourages employees to engage in behaviors that align with the company's sustainability goals (Algarni et al., 2022). By fostering a culture

that promotes environmental and social responsibility, the company aims to shape employees' attitudes and subjective norms, leading to a collective commitment to sustainable actions (Silva, 2023). The Aptiv case study illustrates practical implementations for managing a company in a way that takes into account key SDGs and overall implications for business operations. This paper provides a valuable insights for individuals within the private sector, enabling them to effectively involve their employees in supporting the SDGs initiatives. A potential limitation of this study lies in single source case study, but the findings from this research have the potential to shape future investigations into sustainable development models, broadening the range of variables considered and striving to formulate a comprehensive model. This would allow for assessing the effectiveness of organizations policies and strategies implemented and quantifying their medium- and long-term impacts.

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OVERVIEW AND PRIORITIZATION OF CRITICAL SUCCESS FACTORS IN NPD MODELS FOR THE CHEMICAL INDUSTRY

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Purpose: The purpose of the article is to review NPD models and identify critical success factors for new product development in the chemical industry.
Design/methodology/approach: The systematic review of the literature was applied in the paper and the AHP method was used to build a hierarchical model for determining the importance of CFSs.
Findings: The paper characterizes the concepts of new product development and general models of new product development. Older (pre-2000) and newer generation studies were included among the models described. Data analysis of new product development studies in the chemical industry was carried out. Based on the literature analysis, key factors determining the success of a new product were selected, with a division into general and typical elements of the industry in question.
Research limitations/implications: The prioritization of CFSs will allow in the next step the analytic hierarchy process of NPD models, on the basis of which it will be possible to determine which of the analyzed models is most suitable for chemical products.
Practical implications: Most chemical products are designed using trial-and-error techniques based on experimentation, making NPD in the chemical industry more iterative. This often involves generating a huge number of chemical components, and this means that the search area can be very large. It is therefore reasonable to look for decision support tools to facilitate the selection of necessary components. The selection of chemical product ideas should be based not only on an analysis of what is possible to produce, but also on an analysis of what the market would like to buy. The specifics of chemical products and changes related to 21st century trends are forcing the determination of appropriate CFSs for the chemical industry.
Originality/value: The chemical industry is one of the world's key industries, whose products are used in almost every area of life. Despite this high relevance, there has been no attempt to date to systematize the issues of developing new product lines or portfolios in this industry.

Keywords: new product development model (NPD), critical success factors (CFSs), analytic hierarchy process (AHP), prioritization, chemical industry.

Category of the paper: research paper, general review.

1. Introduction

Increasing customer demands related to the quality of services and products offered, and the consequent difficulty of maintaining a good market position, affect the need for businesses to continuously improve. This involves the necessity to monitor and analyze processes on an ongoing basis, as well as to react quickly, for example, by introducing a new type of product. Developing new products is one of the key factors for progress and competitive advantage in any country. Companies around the world are facing changes in both production technology and service organization. The product life cycle has never been as short as it is now, so developing a new commodity is one of the most important business tasks (Silineviča et al., 2016). From a macroeconomic perspective, new products are important for generating employment and economic growth, technological advances and generally higher standards of living (Bhuiyan, 2011). From a company's perspective, new product development is essential to remain competitive, survive and prosper (Guimaraes et al., 2019).

Product development is the process by which an organization transforms market and technical opportunities into valuable information for commercial production (Clark et al., 1991). Unlike business processes that have clear characteristics and are designed to produce predictable results, product development aims to create something new. It requires creativity, innovation, and is non-linear and iterative (Kline, 1985; Browning et al., 2006).

The process of bringing new products to market is a key area of research and business practice. First, while earlier literature research on new product development focused mainly on durable goods (Barczak, 2012), the global economy has shifted from being commodity-based to more service-oriented (Eichengreen, Gupta, 2013). Second, it is now common practice for companies to offer customers multiple options for accessing a product in order to meet different customer needs and maximize market potential (Shi et al., 2016).

The ability to manufacture a product from design through production does not always guarantee sales. In the age of the Internet, globalization and unlimited access to information, it is not only customers who define their needs, it is also designers who create new ideas in the mind of the customer. Hence, for example, the concept of design management plays an important role in the process of new product development (Dziadkiewicz, 2013). In addition, developing innovative products requires openness and flexibility, the ability to manipulate different perspectives, and control the direction to ensure that new information is effectively integrated and implemented to generate product solutions (Chiang, Hung, 2014). Accordingly, one of the indispensable processes of new product development is modeling. It is an activity that must be performed to create one or more process models for a specific purpose, e.g., design, specification, analysis or control of a particular process (Vernadat, 1996). Developing a new product each time requires the selection of an appropriate model (Aguilar-Savén, 2004).

2. Literature review

The beginning of literature reports on the issue of new product development (NPD) dates back to the 1960s (De Silva, Rupasinghe, 2016). To date, there are many different definitions of a new product (Cooper, 1999, 2001; Cooper et al, 1997; Ozer, 1999; Tracey, 2004). One of them, proposed by Cooper, defines it as a specific product that has been on the market for up to three years, which may be subject to further improvements and/or expansions. All definitions, however, have one thing in common, i.e., they define a new product as one that has not previously been produced by a company (Owens, 2009).

A product that is new to the manufacturer is characterized by a changed, improved design, construction, material composition, the use of a new material, a new technological process or a new way of serving the customer. A product perceived as new to the consumer is a commodity that satisfies a new need or better satisfies an existing need (Mruk, Rutkowski, 1999). A new product is undoubtedly essential to an organization's business continuity. Businesses are expected to innovate and develop new products in accordance with ever-changing customer tastes and needs (Doorasamy, 2017).

A new product offers the organization the greatest opportunity to increase revenue and profitability (Guimaraes et al., 2019). The main goals of the product development process are to minimize life-cycle costs, maximize product quality, and maximize customer satisfaction and flexibility, and minimize lead time (Mazumdar, 2001). The product development process can be divided into two main processes, i.e. product development and product production (Kušar et al., 2004).

NPD is a complex process. Its complexity and risks are due to the presence of multiple phases of the NPD process and its many stakeholders, the complexities of the product under development, changing consumer demands, increased market globalization, extended supply chains and design networks (Guimaraes et al., 2019).

Despite extensive research on how to achieve NPD success, products that fail continue to be developed. Approximately 46% of resources allocated to NPD are spent on products that are discontinued or do not provide an adequate financial return (Bhuiyan, 2011).

Among the biggest challenges faced by companies in the aspect of new product development are the pace (time), meeting the requirements of the approved budget, and determining the best possible project management method (Rawat, Divekar, 2014).

One of the main goals of any development program should be to get the right product or service to the market or to the customer as quickly as possible. However, this can limit the chance of a competitor gaining an advantage and thus gaining an early market position (Owens, 2009; Owens, Atherton, 2018).

The cost of development, whether large or small, puts a strain on an organization's cash flow (Hultink, Hart, 1998). For example, marketing functions can consume enormous resources determining which products should be offered in which markets and at what price. Imposed constraints on the scope of a new product, usually stem from a combination of the company's mission or strategy and the attractiveness of the market (Cooper, Kleinschmidt, 2000).

According to a research report published by the Product Development and Management Association (Pandey et al., 2019), despite the use of new methods and techniques, the success rate of NPD in marketing organizations in the US remains stagnant (about 58%). To overcome this stagnation and improve NPD success, marketing and management researchers have proposed solutions in the form of new practices. For example, some scholars call for greater emphasis on the design and commercialization of new products (Kaul, Rao, 1995; Srivastava et al., 2009). Others (Henard, Szymanski, 2001; Pattikawa et al., 2006) focus on the performance of new products. Change management is also addressed (Pandey, Jaiswal, 2014). In contrast to marketing researchers, management experts focus on product innovation, product development decisions, innovation terminology and NPD-related factors (NPD speed and new product performance) (Pandey et al., 2019).

Rosenfeld et al (2006) define the product development process as "a set of activities in which it seeks to meet market needs and the capabilities and limitations of the technology (...) to achieve the design specifications of the product and its manufacturing process (...) includes post-market follow-up activities". Several approaches can be identified for these activities, defined according to the type of company or product. Various models are thus characterized (Pereira, 2018). New product development is a complex process, involving high risk. However, the success of carrying out such a process is associated, as research shows, with a systematic product development process (Cooper, 2008b).

Product development aims to generate functional and productive products. The literature contains numerous frameworks for the product development process. These models are abstract descriptions of activities and recommendations that support the product developer. Process models are usually created in a generic and theoretical form to fit a wide range of possible development situations. Each model must be tailored to a specific situation (Riesener et al., 2019).

Process models consist of distinct phases and structured workflows defined at the beginning of product development. The starting point for product development is usually planning. This is followed by the conceptual phase, during which requirements are specified and ideas are refined. Determining the basic concept of a product concerns defining its function and structure. In the design phase, product elements are developed technically and economically. The final stage of the process is the development phase (Riesener et al., 2019).

Three concepts are inseparable from the product development process, i.e. innovation, development and novelty. Innovation can be considered a unit of technological change and invention (if any), which is part of the innovation process (Harborne, Johne, 2003). The development of a new product does not necessarily include innovation, meaning that new

products are characterized by the introduction of minor or major changes to existing products (Noke, Radnor, 2004). Novelty can include works (such as original innovations or products that are new to the world or to the company), additions, improvements and changes, repositioning of the product (such as innovative ways to use it in a different market segment or possibly the use of branding) or simply cost reductions (lower price or improved cost of living) (Owens, 2009).

Numerous examples of research on NPD models can be found in the literature. Based on the conclusions drawn from these publications, it can be said that it is not possible to create one definitive NPD model applicable to every situation. For this reason, many authors propose various classifications of the available models. For example, Saren (1984) in his work proposed five categories of NPD process models available at the time, grouping them into staged, activity stage, decision stage, conversion process and response. Other authors, on the other hand, propose various kinds of modifications, thus creating hybrids based on already known models, e.g. Noke, Radnor (2004) in their study used the staged (phase) development model from the 1960s as a starting point for comparison with some of the NPD process model ideas that developed from the late 1980s to the early 2000s. There are many different ways to model the NPD process, and each way involves its own strengths and weaknesses.

3. General models of NPD

We can find assessments of the implementation of both the new product development process itself and the application of various types of models as early as the literature of the 1990s (De Silva, Rupasinghe, 2016). Interestingly, most of the analysis is concentrated in the marketing or management domain, while little attention has been paid to product engineering (Cooper, 1994; De Silva, Rupasinghe, 2016).

There are three basic approaches in the implementation of deployed products, i.e., first-generation (functional structure), second-generation (integrated, concurrent process) or third-generation (model focused on speed, flexibility and customer requirements) processes. All three generations belong to stage-gate models i.e. processes of transition from idea to launch, consisting of separate stages, where each stage is preceded by a decision point to move to the next (go) or end stage (kill) or gate.

The stage-gate model developed by Cooper became fundamental to further developments, being modifications or extensions of it (Cooper, 1994). Virtually all models developed before 1995 were sequential, which is why they are referred to as "waterfall" in the literature. Product development is divided in them into a sequence of predefined phases, such as feasibility, planning, design, build, test, manufacture and support, with some overlap between each phase or stage. However, this type of work affects the appearance of delays between business requirements and technology delivery. Changing customer requirements during this

time, for example, results in final products that often no longer meet current needs (Ottosson, 2019). The latest approach related to the NPD issue is network models (Matusek, 2013). These models, not only design products, but take into account the needs of the consumer and make companies far more open to innovation (De Silva, Rupasinghe, 2016).

Table 1 presents the different generations of NPD models. The early generations of stage processes were largely driven by engineering, which in practice meant that they were based almost exclusively on physical product design and development. As an integral part of product development, next-generation systems incorporate the involvement of the marketing and manufacturing departments, and furthermore treat each stage as an interdisciplinary team effort. The first generation systems were sequential in nature, only the latest generation models assume parallel activities, process stages can overlap, which improves flexibility and reduces unnecessary time lapses between process stages (Cooper, 1994). In addition, third-generation models allow conditional transitions between stages (fuzzy stage-gate).

Different approaches can be found among the various generations of models described in the literature; for example, Peters et al. (1999) state that typical models are aimed at management, design or have been developed for specific industry needs. Modern models, on the other hand, assume a collaborative attitude (Yang, Yu, 2002). Some of them assume collaboration using information technology, mainly simulation methods and virtual prototyping, others, close cooperation between the end user and the inventor.

Table 1.
Review of NPD models in the literature

NPD models	Publications
Stage-gate: Cooper, 1994 1st-3rd generation	Cooper, 1983; 1990; 1994 De Silva, Rupasinghe, 2016
Bass diffusion model: Bass, 1969	Bass et al., 1994 Bass, 2004 Ansari et al., 2010 Wu et al., 2015 Peres et al., 2010 Mahajan, Muller, 1996 Chung, 2011 Shi, 2016
Concurrent process models	Hambali, 2009 Bhuiyan et al., 2006 Smith, Morrow, 1999 Nelson et al., 2016 De Silva, Rupasinghe, 2016
Total design model: Pugh, 1991	Pugh, Moreley, 1988a, 1988b Pugh, 1991 Owens, 2009
Design for Manufacture and Assembly (DFMA): Boothroyd, 1994	Matusek, 2013 Yin, Hou, 2019 Kishore, Arunkumar, 2020
Multiple convergent model: Hart, 1995	Hart, Baker, 1994 Owens, 2009 Owens, Atherton, 2018

Cont. table 1.

Generic model: Peters, 1999	Peters et al., 1999 Matusek, 2013
Product and cycle time excellence model	Pittiglio, Rabin, McGrath, 1994 Owens, 2009
Supplier integrated model: Handfield, 1999	Handfield et al., 1999 De Silva, Rupasinghe, 2016
Next Generation Idea-to-Launch System: The Triple A System	Cooper, 2008a; 2014
Open innovation model	Cooper, 2008a Chesbrough, Bogers, 2014 Bogers et al., 2017 Zhu, et al., 2019
Collaborative product development models	Nambisan, 2002 De Silva et al., 2018
Electronic NPD (E-NPD): Yang and Yu, 2002	Yang, Yu, 2002
Virtual customer integration	Füller et al., 2010 De Silva, Rupasinghe, 2016 Hemetsberger, 2007 Nambisan, 2002
Virtual New Product Development Team	Aubert, Kelsey, 2003 Martins et al., 2004 Badrinarayanan et al., 2008 De Silva, Rupasinghe, 2016

Source: own elaboration.

4. Overview of NPD research in the chemical sector

A review publication by Kalluri, Kodali (2014) on a review of new product development research conducted between 1998 and 2009 shows that most of the studies described then could be assigned to the categories of other, not applicable or general. In turn, the most favored research sector was the automotive industry (about 15%), while much less attention, only about 1-5%, was given to research in the aerospace, food, machinery, apparel or chemical sectors. The total number of publications on the chemical sector during this period was only 34 (Kalluri, Kodali, 2014). The literature analysis also shows that only a few of the publications address topics related in some way to NPD modeling in the chemical industry. Of which, the topics are more about systems, tools used in product development, rather than analysis of a specific NPD model that could be used throughout the process.

In the chemical industry, product development can be technology-driven and demand-driven. The selection of chemical product ideas should be based not only on an analysis of what is possible to produce, but also on an analysis of what the market would like to buy (Hill, 2009). From the consumers' point of view, the properties of the final product are more important than the chemical composition. To meet consumer expectations, both consumer needs and technologies must be transformed into new product design and development (Charpentier, McKenna, 2004).

Most chemical products are designed using trial-and-error techniques based on experimentation, making NPD in the chemical industry more iterative. This often involves generating a huge number of chemical components, and this means that the search area can be very large. It is therefore reasonable to look for decision support tools to facilitate the selection of necessary components (Lee, 2017).

In the chemical industry, NPD can be divided into three types. First, new products can be inspired by new chemical ingredients, information from exhibitions and conferences, market reports or published articles. Based on such information, product prototypes are created and then evaluated. The second type of products is created using reverse engineering. Third, products can also be marketed, and after studying customer needs, marketers redefine product concepts. One possible tool to support decision-making processes in the above three types of NPD is case-based reasoning (CBR). It allows searching for similar, previous NPD cases. Thus, it provides knowledge of problems that have occurred and reduces development time. One disadvantage of using CBR to solve NPD problems is that CBR lacks the ability to capture the ambiguity of human expression in product attributes, which are often described in qualitative terms (Lee, 2017).

It is believed that the subjective evaluation of sensory attributes of chemical products can also be managed through the Analytic Hierarchy Process (AHP), also known as Saaty's eigenvector method. It is a tool for making multi-criteria decisions when both qualitative and quantitative aspects of a decision need to be considered. It is an effective method for gathering expert knowledge in solving complex decision-making problems and has become one of the most widely used approaches for generating concepts and evaluations during NPD. However, the subjective evaluation, selection and preferences of decision makers affect the final results. A more accurate description can be obtained using an extension of this method, the so-called fuzzy analytic hierarchy process (fuzzy-AHP), where evaluation criteria weights are applied (Lee, 2017).

A method to solve the problem of ingredient composition in chemical product development was also proposed by Lee (2017). The knowledge-based product development system (KPDS), is a hybrid of CBR (case-based reasoning) and fuzzy-AHP. In this intelligent system, linguistic preferences for products are matched with similar comparisons, resulting in increased ease of formulating desired products. According to the author, compared to the pure CBR approach, the KPDS is more effective, as a systematic method for determining the relative importance of product attributes is provided. Moreover, the vagueness of human expression and quantitative values were also taken into account using fuzzy-AHP. In addition, KPDS is equipped with two functions to improve the sensitivity of the results (Lee, 2017). Another example of a hybrid model can be found in an article by Choy et al. (2016). Aimed at supporting sustainable consumption and production from product development to chemical product manufacturing processes, the model integrates an operational strategy model with artificial intelligence,

including CBR and fuzzy logic. The development of chemical products becomes more efficient, the number of trials and the amount of chemical waste generated are minimized.

The next example proposed by Sapuan concerns a concurrent engineering design system for polymer-based automotive composites (Sapuan, Abdalla, 1998). The system involves the integration of various concurrent engineering tools, such as a knowledge-based system (KBS), solid modeling, material database and design analysis tools. The material selection process is based on a set of specific criteria and constraints related to the specifications of the desired material and component design. Material selection must be dictated by meeting all of the set criteria/constraints. Violation of any of them determines the rejection of that material. According to the author's analysis, the selection of a polymer-based composite component system resulted in weight and cost reductions of 31 and 53%, respectively, compared to a steel counterpart (Hambali, 2009; Kalluri, Kodali, 2014).

In summary, numerous examples of various types of NPD models can be found in the literature. However, no model dedicated to the chemical industry was found. The analysis of the literature allowed only the identification of typical, for this industry, tools. Therefore, in the following part of the work, the models characterized above were evaluated for applicability to chemical product development processes. For this purpose, one of the techniques typical of the industry was used. Based on general and key factors in the NPD process, it was determined which of the models could best serve as a benchmark. The results obtained were related to a selected example of NPD in the chemical industry.

5. Key factors determining the success of new product development

There are many factors that affect the performance of a company. However, only a few enable success, so they are fundamental to the company and are called critical success factors (CSFs). The process of identifying CSFs is based on the manager's current point of view. By aggregating CSFs from an individual's point of view and identifying existing relationships, it is possible to discover exactly which areas and activities require attention due to their criticality (Rocha, Delamaro, 2012).

The AHP method was proposed by Saaty in the early 1970s. It is classified as one of the best known, safest and most widely used multi-criteria decision analysis. AHP can use both qualitative and quantitative factors to create a hierarchical structure in the decision-making process. This can help select the best option based on the selection criteria presented in the model (Chan et al., 2019). These factors determine which model is more appropriate for the industry under study. The evaluation criteria are determined with expert support and are also based on literature research, pertaining to the industry sector under study.

Thus, first, based on literature data, an attempt was made to identify CSFs specific to the chemical industry. Only one publication addressing this topic was found in the literature. Namely, Cooper, Kleinschmidt (1993) analyzed 21 major chemical companies in 4 countries (the United States, Canada, the United Kingdom and Germany). The data was collected over a period of two years. The performance of a new product was evaluated on a variety of measures, including an assessment of profitability, technological success, annual sales revenue and market share (domestic and international), and the impact of sales and profit on the company. Based on this data, the authors determined six main factors affecting the success of new product development. Table 2 shows their characteristics.

Table 2.
CSF characteristics of NPD process in the chemical industry

Critical success factors	Characteristics
Quality of execution of the activities that make up the innovation process (Q)	The quality of chemical project implementation, where key activities include: - detailed market research, - pilot production, - analysis of pre-commercial activities, - preliminary market assessment, - trial sales, - preliminary review
Early and clear definition of the project and product (P)	- definition sets clear objectives for the development phase, - defining the product and project early in the project and before entering the development phase (target market, product concept, benefits to be delivered, positioning strategy and product requirements)
A strong team leader with a responsible, multidisciplinary team (L)	- project leader – timely implementation of a project from idea to launch, successfully completed, - a cross-functional team drawn from different functions within the company (as opposed to each function or department doing its own part of the project) – project implementation from start to finish
Close link between sources of ideas and project results (S)	- the most effective projects are based on ideas that come from customers or are technology-based, where the idea comes from the technology and/or lab (the most popular), - projects based on concepts are slightly less effective - taken from competitors
Elements related to marketing – qualitative and quantitative (M)	- the quality of the formal launch including customer service and technical support, - the quality of the sales force, - product availability (reliability of delivery and sufficient available production), - lack of importance of advertising and promotion in industrial, higher technology, large products
International orientation (G)	- global product (designed for the world market), - foreign competition, - least successful new product strategy – nearest-neighbor approach, i.e., products targeting the domestic market and one or more neighboring markets

Source: elaboration based on Cooper, Kleinschmidt, 1993.

Based on their research, Cooper, Kleinschmidt (1993) noted that the success of a new product is predictable and largely controllable. It is the project leader and the team who exercise control over the key variables that determine success. Significantly, the success factors for a new product are fairly universal. Most of the results of this chemical industry study were consistent with previous studies of new product success and failure. The author also noted how

critical product innovation is to business success. With increasing competition at home and abroad, more and more companies are being forced to treat product development as a major component of their overall business strategy.

However, the CSFs presented here refers to research conducted almost 30 years ago. Thus, in the next step, general success factors specific to the new product development process were identified, based on an analysis of the literature compiled between 2005 and 2022. Table 3 presents their characteristics.

Table 3.
Characteristics of the critical success factors in NPD process (selected literature examples)

Critical Success Factors	Publications
- high product quality, - increased design capabilities, - short product development cycle time, - market responsiveness, - cost management, - advanced technology applications, - innovation	De Silva, Rupasinghe, 2016
- a clearly defined target market, - implementation of quality standards, - clear project objective, - solving problems at an early stage, - internal communication within the team, - on-time delivery, - adequate time for launch, - competitive cost of the product	Sun, Wing, 2005
- timely completion, - cost, - quality, - customer preferences, - technical advantage, - strategic alignment, - proper execution of projects, - coordination between projects, - company reputation and ethical conduct, - correct definition of project scope, - customer relations	Iamratanakul et al., 2014
- top management support, - the link between new product strategies and business visions, - cross-functional teams with flexible and mutual support, - timing of new product launches, - satisfaction of customer demand, - creativity and innovation, - cost of production, - integration and application of R&D-related equipment and technology, - application of database management system, - excellent planning and monitoring, - complete quality management system, - use of management tools	Yeh et al., 2014
- shorter time in the development process, - lower product manufacturing cost, - products with greater customization, more relative benefits and added value, - companies with greater internal coordination and external cooperation, - product introduction time, - competitors with less aggressive responses	Chi-Jyun, Shiu, 2008

Cont. table 3.

- marketing skills, - product strategy, - technology sources, - company skills, - project leader skills, - functional integration, - project team organization, - product development performance	Öztürk, 2018
- cost and budget management, - time and deadline management, - product positioning, - customer needs fulfillment, - organizational alignment, - characteristics of the development team, - work process (development process), - organization and management of the work environment	Rocha, Delamaro, 2012
- senior management involvement, - early customer engagement, - external cooperation beyond customers, - alignment between NPD and strategy, - appropriate degree of formalization, - cross-functional and cross-departmental cooperation, - creative organizational culture, - project management capabilities	Florén et al., 2018

Source: own elaboration.

6. Results and discussion

Analysis of the collected data made it possible to select the five general CSFs most frequently mentioned in recent literature, i.e. time (T), cost (C), innovation (I), technology (E) and integration (N) – understood as coordination of tasks, cooperation or good communication. Organizations need to work at very high levels of efficiency, optimizing existing resources, in order to achieve and maintain their position in the market. This is due to increased competitive pressures caused by technological advances. Consumers are increasingly demanding and aware, and their expectations, needs and tastes are changing very rapidly. Today, companies are reinventing their development processes to become faster (including shorter time-to-market) while constantly innovating even in the smallest components. This involves increasing R&D costs and rising capital costs. In order to optimize the product success rate, marketing, manufacturing and design functions must also be integrated.

Using the basic 9-point scale (Table 4) defined by Saaty (1980) in the next step, the value of CSF priorities typical of the chemical industry was determined first (Table 5). The assumption was made that the importance of each criterion decreases in the order Q > P > L > G > M > S (cf. Table 2).

Table 4.
AHP scale for pairwise comparisons

Significance level	Definition
1	equally importance
3	moderate importance
5	strong importance
7	very strong importance
9	extreme importance
2, 4, 6, 8	moderate values

Source: Saaty, 1980.

Table 5.
Prioritization of CSFs concerning the chemical industry

	Q	P	L	G	M	S	Criteria weights (%)
Q	1	3	5	7	8	9	47,40
P	0,33	1	3	5	6	7	25,60
L	0,2	0,33	1	3	4	5	13,20
G	0,14	0,2	0,33	1	2	3	6,40
M	0,12	0,17	0,25	0,50	1	2	4,30
S	0,11	0,14	0,20	0,33	0,50	1	3,00

Note. Q – quality, P – project and product, L – leader and team, G – globalization, M – marketing, S – sources.

Source: own elaboration.

In the next step, taking into account the factors relevant to the chemical industry, the CSF priority value was determined along with the parameters selected based on the analysis of recent literature (Table 6). The following assumptions were made:

- the most relevant CSF for the chemical industry (Q = 9) has a higher value compared to the most relevant general CSFs (T, C, I = 8)
- the next two factors, i.e., technology (E) and integration (N), are slightly less important (4) than project and product definition (P = 7) or leader and team (L = 5), important in the chemical industry
- the least importance was assigned to the parameters G (3), M (2) and S (1).

Table 6.
Prioritization of CSFs

	Q	I	T	C	P	L	E	N	G	M	S	Criteria weights (%)
Q	1	2	2	2	3	5	6	6	7	8	9	23,40
I	0,50	1	1	1	2	4	5	5	6	7	8	15,70
T	0,50	1	1	1	2	4	5	5	6	7	8	15,70
C	0,50	1	1	1	2	4	5	5	6	7	8	15,70
P	0,33	0,50	0,50	0,50	1	3	4	4	5	6	7	10,70
L	0,2	0,25	0,25	0,25	0,33	1	2	2	3	4	5	5,50
E	0,17	0,2	0,2	0,2	0,25	0,50	1	1	2	3	4	3,70
N	0,17	0,2	0,2	0,2	0,25	0,50	1	1	2	3	4	3,70
G	0,14	0,17	0,17	0,17	0,2	0,33	0,50	0,50	1	2	3	2,60
M	0,12	0,14	0,14	0,14	0,17	0,25	0,33	0,33	0,50	1	2	1,90
S	0,11	0,12	0,12	0,12	0,14	0,20	0,25	0,25	0,33	0,50	1	1,40

Note. Q – quality, I – innovation, T – time, C – cost, P – project and product, L – leader and team, E – technology, N – integration, G – globalization, M – marketing, S – sources.

Source: own elaboration.

It should be noted that the weight of the quality criteria is clearly more relevant than the other criteria, as it is an important characteristic associated with the chemical industry. Nevertheless, given current trends and conditions, innovation processes, time and cost are also of great importance. One of the least important meanings is globalization due to the fact that the introduction of modern information technology makes the process almost automatic. Likewise, the importance of the elements involved in bringing a product to market and the source of ideas in developing new projects/products are not as significant in relation to the other factors selected. The importance of these criteria shows the evolution of NPD and the adaptation to the actual needs of companies in making faster decisions in a competitive market.

7. Summary

An analysis of the existing literature shows that despite the creation of many general models for new product development, there is no single, specific one that can form the basis for product development in any industry. Each company, deciding to develop and introduce new products, should define its needs and choose the most suitable model for the process. In the literature one can find examples of models dedicated to, for example, the apparel industry, the furniture industry or the automotive industry. However, no attempt has been made to verify models defined for the chemical industry.

The chemical industry is part of the processing industry sector and one of the world's key industries. The current structure of the chemical industry can be characterized by various products starting from oil and gas through petrochemicals, chemicals, polymers, special additives or active ingredients. These products are used in almost every area of life. Product life cycles are often longer compared to other industries and products. Products developed decades ago are still important raw materials sold on the market today. The chemical industry serves many other industries as a supplier of raw materials and often acts as a good indicator of overall economic development.

For a good understanding of the requirements and drivers of the chemical industry, the development of the chemical market and the trends involved must be carefully analyzed. Among the biggest changes associated with 21st century trends are globalization (the growth of global trade), consolidation (the rise of ever larger and more complex corporations), commoditization and margin pressure (cost reduction e.g. through restructuring or outsourcing), innovation (use of new technologies, such as biotechnology, nanotechnology, artificial intelligence), legislation (mainly EU legislation, precise documentation, compatibility of standards) and sustainability (e.g., efficient management of natural resources).

In general, chemical products are primarily not designed and developed as a single product, but as product lines or portfolios. Commodity chemical products (e.g., petrochemicals, basic chemicals and some polymers) tend to be manufactured and sold to mass markets in large volumes and at low unit values. In contrast, specialty products, such as nutritional and agricultural products, are sold in specialized markets, in smaller quantities and at higher unit values.

Both the literature data and the results of the analysis conducted indicate that there is no single, ideal NPD model that can be applied to different industries and products. In this paper, two approaches were used, i.e. using CSFs general and specific to the chemical industry. The results also indicate several trends that should be taken into account in further analysis of the models for their application to specific industries or products, i.e.:

- the number of different types of models described in the literature indicates that it would be beneficial to carry out a classification of them, e.g. by creating a database of models, taking into account their characteristics, or different groups of products or industries. For example, among the models discussed, some were strongly oriented on the quality parameter and the product definition process, others on the use of various types of new technologies. This would make it easier for managers to look for specific solutions;
- the analysis of the results shows that a better solution in the NPD model selection process is to use CSFs dedicated to a particular industry. Which suggests that a more precise specification of CSFs would allow more accurate matching of the appropriate NPD model. It is therefore advisable for companies wishing to conduct this type of analysis to define CSFs according to their own guidelines in each case.

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ASSESSING THE COMPANY'S STRATEGIC DECISIONS IN THE CONTEXT OF ITS ABILITY TO CONTINUE BUSINESS AS A GOING CONCERN – THE CASE OF X COMPANY

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Purpose: The objective of the study is to determine the degree of prediction of the discriminant function on the example of a household appliance company.
Design/methodology/approach: The objective of the study is to be achieved by verifying the discriminant function as an instrument for assessing the company's strategic decisions in terms of its ability to continue business as a going concern.
Findings: Discriminant models in terms of their application in the household appliance company are presented in the theoretical part whereas the company's ability to continue operations is analyzed in the empirical part. Based on the prepared scientific material, the following research question was formulated: Is it possible to determine the degree of prediction of the discriminant function on the example of a household appliance company.
Originality/value: The problem of assessing the company's ability to continue business as a going concern is not new. However, it is still very important and up-to-date with regard to the impact on making strategic decisions in enterprise management.

Keywords: decision-making, ability to continue business as a going concern, discriminant models.

Category of the paper: literature review and case study.

1. Introduction

The development of business management processes has created the need for the continuous updating of information about the endogenous and exogenous environment of the enterprise (Lichtarski, 2007; Skowron-Grabowska, 2015). Providing reliable information forces managers to search for new (Stabryła, 2010), effective solutions and instruments that will allow them to make the right decisions in the enterprise. Effective assessment of the company's strategic decisions in terms of its ability to continue business as a going concern provides an opportunity to stay on the competitive market (Chan Kim, Mauborgne, 2007). The application of

discriminant models is an effective instrument for identifying the symptoms of risk of corporate bankruptcy (Dudycz, Osbert-Pociecha, 2012). It should be emphasized that discriminant models are a valuable instrument for assessing the financial condition of enterprises, and additionally they are characterized by the ease of use due to computer programs (Mosionek-Schweda, 2014). The objective of the study is to determine the degree of prediction of the discriminant function on the example of a household appliance company. Based on the prepared scientific material, the following research question was formulated: Is it possible to determine the degree of prediction of the discriminant function on the example of a household appliance company.

2. Instruments for assessing the ability to continue business as a going concern and decision-making

An effective instrument facilitating managerial decision-making is the Altman model. Altman's concept belongs to the group of multi-factor discriminant methods indicating the signs of corporate bankruptcy. The concept consists in examining the information contained in the financial statements of the entities under study using specific indicators. E.I. Altman proposed several versions of the so-called Z function. Altman's original concept was created in 1968 and had the following form (Altman, 1968):

Formula 1.

The first formula of the Altman model

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 1.0X_5 \quad (1)$$

Source: Own study based on: Altman, 2007, pp. 229-239.

where:

X_1 – working capital/total assets,

X_2 – retained earnings/total assets,

X_3 – earnings before interest and tax/total assets,

X_4 – market value of equity/book value of foreign capital,

X_5 – net sales/total assets.

When carrying out the empirical study using the Altman index, the information is obtained indicating companies at risk of bankruptcy and solvent ones in the research group. The research result refers to the adopted boundaries of enterprise classification and to individual groups of categorization (Table 1).

Table 1.
Classification of risk of bankruptcy according to E.I. Altman

Z-score value	Bankruptcy risk level
1.8 or less	Very high
1.81 – 2.99	Unspecified
3.0 and more	Low

Source: Stabryła, 2002, p. 359.

Table 1 shows that enterprises for which the value of the Z index exceeds 2.9 are characterized by a low risk of bankruptcy, thus their financial situation is good. On the other hand, when the value of the Z index is below 1.8, there is a high level of risk of bankruptcy. Another concept used in this study was created in 1983 and comes down to the following form:

Formula 2.

The second formula of the Altman model

$$Z' = 0.717X_1 + 0.847X_2 + 3.107X_3 + 0.420X_4 + 0.998X_5 \quad (2)$$

Source: Own study based on: Altman, 1984, pp. 171 et seq.

The presented model is called the *Zeta* function or the *Z-Score* model and is based on the parameters of Altman's original concept, except for the X_4 variable, which took the following form (Altman, p. 171 et seq.; Altman, Hotchkiss, 2007, pp. 229-239):

Formula 3.

The formula of the X_4 variable in the Altman model

$$X_4 \text{ – balance sheet (book) value of equity/book value of foreign capital} \quad (3)$$

Source: Own study based on: Altman, Hotchkiss, 2007, pp. 229-239.

Redefining the *Zeta* function brought about that more companies could benefit from Altman's concept. Its original version required the knowledge of the market value of the equity of the company under investigation (Gnysińska, 2013). The Z-Score model, based on the balance sheet (book) value of equity, was addressed to enterprises that could not determine the market value of equity.

Another version of the *Z-Score* model consists in eliminating the last variable of the Z' function, which is the X_5 parameter. Such a change is dictated by the fact that the X_5 asset turnover ratio strongly depends on the market in which the surveyed company operates. Eliminating the X_5 variable made the Z' function a universal and cross-sectoral method of early warning of bankruptcy in the surveyed enterprise, and the Z'' function took the following form:

Formula 4.

The third formula of the Altman model

$$Z'' = 6.56X_1 + 3.26X_2 + 6.72X_3 + 1.05X_4 \quad (4)$$

Source: Own study based on: Altman, Hotchkiss, 2007, pp. 229-239.

The presented concepts of E.I. Altman illustrate only a selected excerpt of the scientist's research and are to present exemplary concepts of forecasting bankruptcy of enterprises.

Formula 5.

The fourth formula of the Altman model

$$Z''' = 6.56X_1 + 3.26X_2 + 6.72X_3 + 1.05X_4 + 3.25 \quad (5)$$

Source: Own study based on: Altman, Hotchkiss, 2007, pp. 229-239.

The fourth formula of the Altman model, referred to as the EM Score, was created in 1990 and was to serve as an instrument for assessing the risk of bankruptcy for investors and lenders operating in much less stable markets than in the US. In this formula, the return on assets ratio was omitted and the intercept of 3.25 was added. The result of this formula is interpreted as follows (Table 2):

Table 2.

Classification of risk of bankruptcy according to the EM Score formula by E.I. Altman

EM Score value	Bankruptcy risk level
(0-5.5>	High
(5.5-∞)	Low

Source: Stabryła, 2002, p. 359.

An important instrument for evaluating the alternatives of choice to make a specific decision is the model by A. Hołda. It is a correction of Altman's model adapted to Polish conditions. Hołda's model is used to forecast the bankruptcy of enterprises (Malinowska, 2001, p. 46; Nita, 2007, p. 23; Maćkowiak, 2009, pp. 24-25). A linear discriminant function was applied in the model. The concept of the Hołda model is presented in the form of the following formula (Hołda, pp. 306-310):

Formula 6.

The formula of the Hołda model (ZH)

$$ZH = 0.605 + 0.681X_1 - 0.0196X_2 + 0.00969X_3 + 0.000672X_4 + 0.157X_5 \quad (6)$$

Source: Own study based on: Hołda, 2001, pp. 306-310.

where:

X_1 – current assets/current liabilities,

X_2 – total liabilities/balance sheet total,

X_3 – net profit (loss)/average annual total assets,

X_4 – average annual current liabilities/cost of products, goods and materials sold,

X_5 – total revenue/average annual total assets.

When using Hołda's model as an assessment instrument being part of decision-making models, one obtains the concise description of the company's operations. In addition to numerous advantages of the implementation of the ZH function in decision-making models, its application also brings the following disadvantages:

- "no possibility of substantive interpretation of the value of the discriminant function,
- not considering qualitative factors affecting the financial situation of entities,
- a high degree of generalization and synthesis, which is not always sufficient to diagnose the financial situation, which is a multi-faceted category,
- problems with the comparability of empirical data concerning various entities which have some freedom as to the methods of accounting and preparing financial statements,
- difficult access to empirical data, especially in relation to those entities which are at risk of bankruptcy,
- problems with estimating the discriminant model based on empirical data concerning one specific economic entity (relationship between the number of financial ratios and the number of observations)" (Nowak, 2005, p. 255).

The study conducted using the *ZH* function is an objective way to assess the actual financial situation of the studied entity (Siemińska, 2002; Kędzierska, 2012). The difference between Altman's and Hołda's models consists in using the constant value in the *ZH* function, which is independent of values of the other parameters of the Hołda model (Jerzemowska, 2006; Nowak, 2013). The interpretation of the results obtained in Hołda's model is presented in Table 3.

Table 3.
Classification of risk of bankruptcy according to A. Hołda

ZH value	Bankruptcy risk level
(- ∞; - 0.3)	**Very high**
(- 0.3; - 0.1)	**"Grey area"**
(- 0.1; ∞)	**Low**

Source: Hołda, 2001, p. 306.

In conclusion, it should be noted that Hołda's model is based on the discriminant function and requires more research work than Altman's model developed in the conditions of a mature economy. Scoring models make it possible to predict bankruptcy of enterprises. The main difficulty in the course of the development of scoring models is the lack of appropriate economic and financial documentation that would allow comparing companies, the short period of occurrence of given economic conditions and the quality of empirical materials from the conducted bankruptcy procedures. It is worth emphasizing, however, that the use of discriminant models should enable the analysis and assessment of the decision-making situation.

3. Research methodology

The research tool used to accomplish the objective of this study is a case study, which allows the presentation of an accurate and in-depth image of the phenomena and relationships under study (Gibbert et al., 2008). According to W. Czakon, the case study, as a research method, has a probabilistic possibility of scientific cognition, and its limitations include high time consumption, intuitiveness, subjectivity of judgments and high costs of research, as well as low representativeness of results (Czakon, 2015). However, the attention is drawn to the fact that the empirical verification carried out based on the case study method makes it possible to find answers to questions of an original nature, which enables more thorough explanation of the studied phenomenon (Yin, 2009; Eisenhardt, Graebner, 2007).

For the purposes of assessment of the ability to continue business as a going concern a Polish household appliance company, which has been operating on the international market for many years, was selected. The surveyed company was chosen based on purposeful sampling according to the following selection criteria: empirical data were available in the Notoria database, surveyed entities were listed on the Warsaw Stock Exchange (WSE) throughout the research period, surveyed entities could be assigned based on the Polish Classification of Activities: PKD-47.54.Z - Retail sale of electronic household appliances, individual financial statements were available on an annual basis, allowing for the calculation of discriminant models, Polish manufacturer of household appliances. Such assumptions brough about that only one household appliance company met all the criteria. The research period was the years 2017-2021. The choice of the Altman and Hołda models to assess the ability to continue business as a going concern was dictated by the information capacity of these parameters (Stachowicz, Machulik, 2002), as they characterize organizational and financial phenomena (Kościelniak, 2008; Bednarski, 2005) and constitute an effective research instrument enabling parameterization of information channels. The presented models of Altman or Hołda are not models of the latest generation, however, they are characterized by simplicity and speed of measurement as well as practical applicability, which shortens the time of decision-making.

4. Verification of the discriminant function in the assessment of the ability to continue business as a going concern - the case of the X company

The assessment of the ability to continue business as a going concern of the X enterprise was carried out in two stages, i.e., all four formulas by Altman were analyzed first, and then those by Hołda. The results of the analysis of Altman's formulas are presented in Table 4.

When analyzing the results obtained using the Altman model for the Z, Z' and Z" formulas in the years 2017-2021 for the surveyed household appliance company, it is noted that the entity only in 2020 indicated the level of bankruptcy risk, referred to as "unspecified" for the Z formula. In all the other periods examined, the Z, Z' and Z" formulas indicated values below 1.8, which means that the risk of bankruptcy was very high. Similar results were obtained on the basis of the latest version of the Altman model, EM Score. Here, also the highest score was obtained in 2020. In the remaining years under study, the values of the discriminant function indicate a high risk of bankruptcy. When analyzing the ratios in 2020, it is noted that EBIT recorded a high value in contrast to other periods. The conclusion is that 2020, when the Covid-19 pandemic began in Europe, brought much better financial results to the household appliance industry. The period of the pandemic was associated with forced isolation, during which many people focused on renovations related to the replacement of household appliances. Nevertheless, the results of all four examined formulas of the Altman model show that the strategic decisions of the surveyed household appliance company may be wrong since the level of bankruptcy risk was very high almost throughout the entire research period. In terms of the company's ability to continue business as a going concern, it is recommended to conduct a detailed analysis aimed at indicating what factors cause such low financial results. Failure to implement strategic recovery decisions in the studied enterprise may contribute to its bankruptcy.

Table 4.
Results of the Altman model for the household appliance company

The Altman models					
	2017	**2018**	**2019**	**2020**	**2021**
x1	0.10	0.12	0.13	0.19	0.17
x2	0.11	0.09	0.07	0.08	0.05
x3	0.07	0.10	0.09	0.09	0.06
x4	0.02	0.03	0.03	0.03	0.02
x5	1.12	1.08	1.12	1.09	1.15
Z	**1.65**	**1.68**	**1.69**	**1.74**	**1.63**
Z'	**1.52**	**1.54**	**1.56**	**1.58**	**1.51**
Z"	**1.52**	**1.75**	**1.75**	**2.13**	**1.70**
EMS	**4.77**	**5.00**	**5.00**	**5.38**	**4.95**

Source: Own calculations.

The assessment of the household appliance company’s ability to continue business as a going concern based on Altman's four formulas showed that the level of bankruptcy risk in the years 2017-2021 was very high. Therefore, in the second stage of the research, it was decided to conduct an additional analysis regarding the identification of symptoms of risk of bankruptcy of the examined enterprise, using the Hołda discriminant model, and the results of this analysis are presented in Table 5.

The results obtained based on the Hołda model provide information about the situation of the surveyed household appliance company in a much better light compared to Altman's models. In the enterprise under study, in all the surveyed years, the value of the ZH index reached a level above zero. The values are also not in the range (-0.3;0.1), i.e., the company does not belong to the "grey area". This means that the company is not at risk of bankruptcy.

Table 5.
Results of the Hołda model for the household appliance company

	2017	2018	2019	2020	2021
x1	1.28	1.38	1.45	1.64	1.52
x2	47.12	41.39	37.41	36.17	39.35
x3	10.56	8.92	7.42	7.99	5.23
x4	117.31	112.20	101.73	103.64	104.98
x5	1.12	1.08	1.12	1.09	1.15
ZH	**0.91**	**1.07**	**1.18**	**1.33**	**1.17**

Source: Own calculations.

When referring to the individual factors affecting the value of the discriminant function of the Hołda model, it is noted that the X1 index, reflecting the level of liquidity, was steadily increasing until 2021, when it decreased, and thus the positive trend was stopped. In turn, the X2 index, reflecting the company's debt level, was systematically decreasing until 2021, when it increased again, which also confirms the stopping of the positive trend for the X2 index. The situation was slightly different with the X3 index, reflecting the company's effectiveness in generating revenue from its operations, which initially decreased, then increased in 2020, and then significantly decreased in the following year, which indicates that the company's situation in this area was deteriorating. The X4 index, reflecting the period of rotation of short-term liabilities, was decreasing for the two examined years, then it started to increase. The last X5 indicator, reflecting the company's ability to generate profit based on its resources, alternately decreased and increased, which indicates the lack of stability of the company in this respect.

The above analysis indicates that despite the good results of the Hołda model, a certain breakdown of the indicators affecting the discriminant function is noticeable in 2021. In addition, the trend changes and unstable results of individual indicators should be a warning signal for managers making strategic decisions.

5. Discussion

When considering the discriminant function in terms of its verification as an instrument for assessing the household appliance company' ability to continue business as a going concern, it is noted that various discriminant models provide different information about the ability to continue business as a going concern. When verifying the discriminant function based on the

Altman models, one may observe the occurrence of symptoms of a threat to the continuity of operations of the examined entity. The verification of the discriminant function using the Hołda model does not indicate the risk of bankruptcy. The results of the analyzes carried out using the Altman and Hołda models presented above prove that when assessing the risk of bankruptcy of enterprises, one cannot rely on the results of only one model. When referring to the results obtained in this study, one can therefore adopt the position presented by the authors of other studies, who indicate that the application of the Hołda model is adequate to Polish conditions, and the use of the Altman models is inadequate to these conditions (Kitowski, 2018; Micherda, 2006; Hamrol, 2013; Iwanowicz, 2018).

The conducted analyzes show that the Hołda model reflects the studied company's ability to continue business as a going concern better compared to the results obtained using the Altman model. However, when considering the financial results published on the WSE website for 2022, it is noted that the company under study had problems with both profitability and liquidity, which may suggest that its ability to continue business as a going concern is at risk. This may mean that Altman's models are more sensitive to the effectiveness of strategic decision-making in the surveyed enterprise, whereas Hołda's model is focused on assessing the results of the analyzed period. In this context, it is worth emphasizing that the task of discriminant functions as an instrument for assessing the company's strategic decisions is not only to analyze the results of the current period, but also to signal about the deteriorating financial condition (Wojnar, 2015, p. 209), which is a contribution to the research on the assessment of the company's strategic decisions in terms of its ability to continue business as a going concern.

When considering the results obtained on the basis of the analysis of the discriminant function conducted based on the Altman and Hołda models in the surveyed household appliance company, the conclusion arises that the mechanisms protecting this company against internal threats resulting from the low quality of management should be looked into (Obłój, 2002). The future direction of research should focus on examining the decision-making process which, in the surveyed enterprise, may lead to the destruction of value created by improper configuration of resources, which does not contribute to their optimal use.

6. Conclusions

The conducted case study allows for verifying the discriminant function as an instrument for assessing the company's strategic decisions in terms of the ability of the surveyed household appliance company to continue business as a going concern. To sum up, the results of the research conducted using the Altman and Hołda models to determine the degree of prediction of the discriminant function on the example of a household appliance company indicated that

the financial condition of the surveyed entity is largely determined by the effectiveness of managers' strategic decision-making. The assessment of the entity's ability to continue business as a going concern using the multidimensional discriminant analysis provides information on retrospective decisions taken in the enterprise. The empirical studies conducted in the field of verification of the discriminant function using the Altman model show the symptoms of a threat to the continuity of operations in the future despite the fact that, in the analyzed period, the enterprise was not at risk of bankruptcy in the Hołda model.

The main contribution of the article is an in-depth explanation of the possibility of using the Altman model to assess the company's strategic decisions in the context of the occurrence of signals about the deterioration of the financial condition. It is worth emphasizing that the financial results of the studied enterprise obtained in 2022 show the presence of symptoms of a threat to the continuity of operations as a result of not taking into account risk factors in future periods when making strategic decisions.

It is worth noting that the use of discriminant functions is an important instrument for assessing strategic decisions of the enterprise. Discriminant models make it possible to assess the ability to continue business as a going concern, but they should also enable signaling about the deteriorating financial condition.

It should be remembered that the use of discriminant models has both advantages and disadvantages. The advantage of scoring models is the ease of understanding and simplicity of application as well as high accuracy of classification in terms of analyzes of risk of bankruptcy of enterprises. The main disadvantage of discriminant models is their rapid obsolescence, which is the result of changes in the economic conditions of enterprises.

A clear implication from the theoretical and empirical assumptions of the conducted study is that several discriminant models should be considered when conducting the discriminant analysis of the enterprise. These results confirm that it was Altman's models that turned out to be more effective, as they earlier detected symptoms of threats to the continuity of operations, which the Hołda model did not capture.

The further direction of research will be aimed at testing discriminant models in early detection of symptoms of a threat to business continuity. On the other hand, the recommendation for managers making strategic decisions in enterprises is to monitor the enterprise and its results on an ongoing basis, especially in the face of competition on the international household appliance market.

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ETHICAL DETERMINANTS OF MARKET BEHAVIOR OF CONTEMPORARY ENTERPRISES

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Purpose: Increasingly, consumers and competitors are reviewing business behavior in the context of ethics. Ethics and ethical business strategies are becoming important factors in the success of modern business entities. The research objective of the article is to identify (on the basis of the cited cases) some of the ethical determinants of market behaviour of the enterprises in the conditions of modern economy.
Design/methodology/approach: The study is based on a review of the literature on ethical issues in the economy, particularly the requirements for companies by the wider environment and stakeholders. An important element of the study is the presentation of specific cases of entities that change their market behaviour under the influence of these requirements.
Findings: The main conclusion that can be drawn from the research presented concerns the increasing involvement of ethical aspects in the decision-making processes of companies operating in today's market. The environment's expectations of companies are changing - it is no longer enough to provide specific products or services to meet needs or to generate profits for shareholders. What matters more and more are the ways in which these products or services are created, as well as the willingness to accept profit limits in the context of the sustainable development of the entire socio-economic system.
Social implications: The social impact of the issues raised in this study is revealed in two aspects. Firstly, by analysing the business cases presented in the study, it is possible to realise that ethical and economic objectives need not be and are not in conflict. Secondly, showing ethical aspects that are also important in business activities can lead to the development of public awareness of the relevance of issues that have so far often been overlooked in discussions on the economy.
Originality/value: A valuable element of the study is to point out that it is possible to successfully combine the ethical aspects of businesses with the desire for financial success.

Keywords: functioning of enterprises, market behaviour of enterprises, ethical requirements.

Category of the paper: viewpoint, case study.

1. Introduction

Enterprises, regardless of their size, organisational and legal form, level of development or industry, are constantly subjected to environmental pressures. The aforementioned characteristics matter to what extent this pressure influences the activities of these entities, but the influence of the environment itself is indisputable. It conditions all business processes and is a source of opportunities and threats for economic actors. A condition of increasing importance for enterprises are the expectations of society at large towards them. These expectations towards business entities have their source in, broadly speaking, society's changing perception of the world and its problems.

This is compounded by worrying signals from the environment (e.g. depletion of non-renewable energy sources, climate change causing unexpected challenges for agriculture and industry, and affecting the comfort of living in a particular area of the world). From a different perspective, it can be seen that (in developed societies) there is beginning to be a different perception of time spent at work, with people increasingly reporting the need for a balance between work and simply life and leisure. Individual members of society are becoming more sensitive to the world around them, including the world of animals, and are no longer treating them merely as a source of food, but rather as co-inhabitants of the world.

All of this results in changing standards of living, or at least the aspiration to change these standards - which often goes hand in hand with a re-evaluation of life attitudes and expectations. Modern man wants to live better, with dignity and respect for where he lives. Paying more and more attention to and acting in accordance with humanistic values is also a challenge for the wider economic sphere.

In every industry, companies have to deal with a kind of 'new customer', but also a 'new employee'. Business stakeholders are changing, their expectations are changing and they require businesses to take their expectations into account in their business activities. This process is not entirely new, nor is it surprising for business stakeholders. For many years now, they have been trying to advance the idea of sustainability - economic development with respect for environmental and social values. However, nowadays, the pressure from the values, ethical attitudes of members of society, is growing and should prompt enterprises to change their attitudes and, consequently, their market behaviour.

Expectations of the environment actors towards enterprises, precisely in the context of ethics, are revealed, for example, in the fashion, in hairdressing services, production of food, gastronomy or tourism industries.

2. Ethics in the socio-economic space

When ethical issues are considered in relation to business processes, inevitably both management practice and theory focus on business ethics. It can be argued that this is currently the most common association of the terms ethics and economics – although, sometimes (in 1993 e.g.) business ethics was described like business fads of the late twentieth century (Trevino, Nelson, 2021). However, it is worth noting that this business ethics has emerged as a tool for enhancing the competitiveness of enterprises. By contrast, it is not ethics in general, it is part of it. Value creation in economic processes is studied by economics as a social science. It is based not on business ethics, but simply on ethics (so business ethics should be considered as a special case of ethics in general) (Sójka, 2007).

At the core of general ethics are considerations of the concepts of goodness, right, duty, obligation, courage, freedom, rationality and choice (Blackburn, 1997). All these concepts are also relevant in the socio-economic sphere, but not only. Ethics is divided into descriptive ethics, which is interested in the actual moral beliefs and conduct of people and the functioning of organisations, including economic ones. The second type of general ethics is normative ethics. It is concerned with the construction of general standards and norms for human conduct, defining what someone should and should not do for the sake of the good in a moral sense.

The life of society, but also of individuals, is largely made possible by the results of human economic activity. On the one hand, this refers to labour as a source of income, which then serves to meet people's needs. On the other hand, economic activity provides the goods and services necessary for life. In doing so, it is worth mentioning the hierarchy of human needs. When considering today's important needs, they cannot be reduced - in many areas of the world - to just basic needs. Increasingly, the ability to fulfil higher-order needs is a prerequisite for life - because a large proportion of global society is concerned with well-being rather than the physical survival of the organism. There are, of course, regions of the world and societies that this physical survival is hindered, but also the offer and involvement of economic actors in these regions takes place on a different basis than in the highly competitive markets of developed countries. For the sake of clarity, these aspects will be omitted from further discussion - although the analysis of the phenomena occurring there may be an extremely interesting area of research. Research that should also focus on ethical issues.

It is worth posing the question at this point - how do these two seemingly contradictory areas of human involvement, which are the economic sphere and ethical issues, relate to each other. The basis of the classical type of thinking about the economy is the assumption that economics and ethics are two different perspectives for describing and evaluating human activity and are generally in conflict with each other. In the new way of thinking, a reasonable compromise is needed between these fields of human activity and the interference of ethical norms in the realisation of profit or efficiency. It can be argued that the task of economics in

an ethical perspective is to create ethically and ecologically sound economic progress. Such an assumption reflects a common-sense approach to shaping the future of humanity. A different attitude may lead to the accumulation of social problems in the future. The value of looking at the ethical aspects of economics in this way continues to grow as the stakes at stake have dramatically increased in recent years, when the entire world has been destabilized by financial crises, worsening climate change, the development of artificial intelligence and global health crises (Bohm, Carrington, Cornelius et al., 2022).

Taking into account the assumptions of a sustainable economy, therefore, the objectives of the economy and individual enterprises must be assessed not only according to market outcomes, but also according to whether they create conditions for future generations to live decently. Ethical principles should be respected in all human activities, and in business in particular, and the behaviour of organisations should be assessed not only in terms of economic efficiency, but also in terms of moral efficiency, i.e. concern for social issues. It is not, and cannot be, indifferent to who benefits and who is harmed by these activities, what objectives the various actors have and by what means these objectives are achieved (Penc, 2008).

Introducing ethical issues into the space of farming, it should be stated that economic ethics examines the morality of a farming society and has a value-based character. From this perspective, an assessment can be made of what is right, morally acceptable, and what is not. By translating business ethics into a useful tool for evaluating the activities of individual economic units, business ethics is formed. It is a more specific discipline and is only part of business ethics as it only relates to ethics as applied to business.

Business ethics, however, is not unambiguous and can be interpreted in different ways (Filek, 2001). Observing the manifestations of business activity, one can encounter an interpretation of business ethics as a mere façade phenomenon, lacking a deeper, humanistic sense - business ethics in this case is merely a veil hiding the immanent unethical nature of business. It is merely a substitute measure, a prosthesis serving to superficially improve human behaviour in the face of a lost natural sense of what is good and what is bad, morally reprehensible.

Business ethics can also be a tool for increasing profit. It can be treated as a new, effective method of competitive struggle, allowing to increase profits in a situation where competitors have reached a similar level of technological and organisational development. In this case, it is important to distinguish between two different attitudes of companies - some may use the ethical context instrumentally, without creating real value. Others, on the other hand, may seek to fight for their competitive advantage by offering genuinely ethical solutions that will attract more customers.

The emergence of business ethics is linked to the growing need for a holistic view of the problems besetting modern societies - business ethics is therefore a response to the process of globalisation of the economy. With such a view, business ethics is meant to be a real help in solving increasingly difficult socio-economic problems, fulfilling the role of a guide without

which further development of humanity will not be possible. Underlying such a treatment of business ethics is the assumption that without certain values - agreed and shared by different societies - humanity cannot survive in the conditions it has created for itself. This is particularly relevant in view of the development of artificial intelligence, which is already widely used in business. In contrast, the numerous publications that are potentially relevant to the ethical debate on artificial intelligence are quite heterogeneous and include reports and positions of advisory bodies; guidelines and white papers as self-commitments of companies and research institutions. It is difficult to find a single guiding thought in them that describes the issue of business ethics supported by artificial intelligence (Heilinger, 2022).

It is also worth noting the culture-creating role of ethical values. Actors in the economic sphere are increasingly shaping a new system of values. The business world is increasingly creating a way of life, a way of thinking and a valid system of values, all of which are becoming weaknesses and pathologies of modern man. By contrast, relying on ethical values in business can lead to the moral development of all mankind. Modern organisations are taking over the role of the earlier institutions of opinion and control of compliance with the rules of social coexistence.

The dimensions of ethics become apparent in the various relationships that emerge in the economic sphere, including within the enterprise, in the market and in the wider environment:

- co-owners of enterprises,
- contractors with the enterprise
- competitors with each other,
- employers - employees,
- entrepreneurs - customers,
- economic operators - society,
- economic agents - authorities,
- economic agents - state institutions,
- economic operators - environment.

"Ethics are a company's best calling card when dealing with customers, suppliers and all the other actors that make up the company's environment. (...) Ethics should be at the heart of business - beyond the pursuit of money, we must remember that there are always people and their families on the other side of any contract. Therefore, when we transact with a company, we are choosing to support it and to influence its development to some extent. After all, it should not be forgotten that it is people who make companies. By respecting others, we respect ourselves and know that we can rely on someone. Today's market is changing so fast and is so competitive that nothing is permanent. That is why it is worth treating business partners the way we would like to be treated ourselves" (Kowalski, 2016).

Relationships in the socio-economic space are most fully revealed in the market. The market satisfies human needs - but only those that can be satisfied through economic means. In doing so, it is worth remembering that even the most efficient market cannot replace ethical behaviour - love, family and community (John Paul II, 2018). But it is important not to contrast ethics and the market on a disconnected basis. The market and the phenomena within it are to be shaped ethically. And they are increasingly being evaluated in an ethical perspective.

However, there is no single right concept to describe all market relations and corporate attitudes. Even if one assumes that enterprises are socially sensitive, it should be noted that there are two different models of social responsibility (Rybak, 2004):

- *after profit obligation* - in this model, the fundamental importance is attributed to the economic responsibility of the enterprise, other types of social responsibility are treated as additional obligations,
- *before profit obligation* - this model recognises the priority of moral principles over other values, which should be subordinated to them (including profit).

In this second model, the ethicality of economic action is the primary norm determining the internal and external morality of economic action. Economic efficiency, understood through effectiveness and economic efficiency (expressed in monetary units), is a secondary norm in the order of norms constituting the social order of economics (Gasparski, 2007).

The objectives of ethics therefore boil down to:

- evaluating human actions, referring to moral norms,
- answering the question: how to act morally in given situations.

In pursuing the goals of ethics in the socio-economic space, individuals, based on certain moral standards, seek acceptable ways of behaving. This includes determining what behaviour on the part of economic actors they are able to accept - an assessment by reference to moral standards. And, realising the many diverse needs, not only those that can be easily satisfied through goods and services, ethical requirements pose a considerable challenge for businesses. Their behaviour is constantly being assessed - which, in the age of ubiquitous electronic media, is extremely easy. And the final assessment is influenced by so many rapidly changing factors that it makes doing business increasingly difficult. Nevertheless, businesses must try to act in accordance with the moral principles professed and accepted in their environment in order to survive (e.g. Bhatt, 2022; Jakesch, Bucinca, Amershi, Olteanu, 2022; Behera, Bala, Rana, Kizgin, 2022).

Increasingly, survival is realised not only through profits, but especially through:

- an appropriate corporate image,
- satisfying the diverse (not only economic) needs of the environment,
- environmentally acceptable behaviour, e.g. for environmental protection, supporting a community in particular need of help or supporting local environments through sponsorship.

3. Enterprises behaviour inspired by ethics in business - case studies

One of the industries where the impact of ethical requirements on businesses can be seen is the fashion industry. Many players are introducing eco-friendly materials and accessories into their offerings. They are trying to emphasise ethical production processes - taking into account the fact that production costs may rise, but the overall activity will be better appreciated by customers. One example of an entity operating in the industry in Poland is the company Nago. It is a manufacturer of clothing made from good quality materials, using natural materials and recycling. The entire production process (from design, through strictly production, to packaging and delivery of the final product to the customer) is subordinated to the values professed by the owners.

The mission of this company's activities is summed up in the words: "A brand whose creators see it as a step towards a better world". And the entire philosophy of this entity is encapsulated in the following description: "More than fashionable patterns and designs, what matters is the origin of the fabrics, the methods of production and the conditions under which, thanks to extremely important human labour, it is transformed into a final product. At NAGO, we create lines in which you will look good and feel good. Our clothes are environmentally friendly, produced in a conscious and sustainable way. We optimise the use of raw materials, the entire production process of our collections is strictly controlled and in accordance with fair trade principles. We choose solutions that minimise damage to the environment, while striving to maximise our customers' comfort, creating the best garments we can" (https://nago.com/pages/misja).

Another example, indicating that not only profit maximisation matters, but also social sensitivity, is the behaviour of the owners of Polish hairdressing establishments and nail salons in the context of the wartime migration of the Ukrainian population. In these entities, there are currently a large number of Ukrainian women working in Poland, who, having fled the war, sought opportunities to live and work in Poland. Of course, one can focus on the fact that being in a difficult material situation, many of these people are able to work for the lowest wages. Which obviously translates into the possibility of lowering the business costs of the entrepreneur in question. But in many situations, it was simply concern for the other person that mattered. One concrete example is the hiring of a hairdresser from the Ukraine for a salon used by long-standing, loyal clients. At first, they were distrustful of the skills of someone they did not know. This may have led to some women leaving the hairdressing salon. However, the owner of the establishment took a risk, explaining her attitude as follows: "This is the right thing to do. This is the only way I can help people in difficult life situations". This attitude is undoubtedly a consequence of the entrepreneur's values, which are not only based on the desire for profit at any price.

In terms of the impact of changing ethical attitudes among consumers on business behaviour, many examples can be found in the food industry. The general trend in nutrition is leading to a reduction in the consumption of meat and meat products, paying attention to how

animals are raised. The number of people who are flexitarians, vegetarians or vegans is also increasing. Increasingly, society's eating habits are changing precisely for ethical reasons. This has led, for example, to changes in product ranges at traditional sausage producers. An example of a company that offers a whole range of products for vegetarians is Tarczyński S.A. - the company has created products based on vegetable protein (https://tarczynski.pl/kategorie). This company has been followed by others, which also create alternative products for people who do not eat or limit their consumption of animal protein. According to specialists, this is a very dynamically developing market segment.

Changes in the public's attitude towards the eating process have also been noticed by caterers. In recent years, a large number of vegetarian and vegan bars and restaurants have sprung up, which are used by a variety of consumers (including those who limit their consumption of meat products). Many of these operators cite a change of life philosophy as the basis of their existence. Often, the owners of these businesses seek to live in harmony with nature, trying to reduce their negative impact on the environment. They conduct their business by offering a new lifestyle to others. In turn, the emergence of many people who advocate this lifestyle has also prompted traditional restaurants to change their product range. Such players include McDonalds, which has introduced dishes made with plant-based protein. On top of this, since 2018, in Poland, the company has been introducing global standards for the use of closed-loop packaging - which is met with very positive customer reviews (McDonald's, 2023a). McDonalds has been followed by KFC and Burger King, introducing plant-based nuggets into their range (Nowy Marketing).

In the economic space, it is increasingly common to find companies implementing Corporate Social Responsibility (CSR) programmes. However, this mainly applies to corporations, which are usually large entities with an international reach. The next stage in the development of companies based on ethical values is the introduction of ESG programmes, which include an environmental, social and organisational management component respecting ethical values. Important in this respect is the transparency of the entities' activities achieved through compliance with performance reporting standards, e.g. McDonalds Poland in 2022 announced its first ESG report for 2021 (McDonald's, 2023b).

An important industry that has changed much of its behaviour under the influence of changing attitudes and, consequently, customer demands is the hotel industry. On the website of practically every hotel, and the largest chain ones are all of them, one can find information about a number of measures taken as part of environmental care. Hotels are changing their cleaning methods, washing bed linen and towels, changing cosmetics and the crockery used (e.g. replacing disposable plastic cutlery with wooden ones, and water in rooms in most hotels is available in glass containers). An example that very accurately demonstrates the ethical stance of hoteliers is Hilton, which shows in great detail all its corporate social responsibility activities and ESG programmes (https://esg.hilton.com/our-reporting/).

4. Conclusion

To summarise the behaviour of modern business entities, which has been presented in a simplified manner due to the nature of the study, it can be said that all of them are under the constant watchful eye of society, which expects ever higher ethical standards to be met. Society is changing, re-evaluating its expectations and, as a result, directing demands towards businesses to behave appropriately in all spheres of their activity. Appropriate behaviour means acting in accordance with the values currently held by a given community. The dynamics of changing needs, the ease of making observations and judgements in the media space, to which there is wide access, make the business environment more complex. Ethical issues are certainly not the only ones that need to be taken into account in the strategies of modern businesses. But they are undoubtedly a strong determinant of their market success and ability to survive.

In conclusion, it is worth pointing out one more thing. Well, to a certain extent, economic organisations attempting to meet the expectations directed towards them are a kind of creation of these expectations. Thus, the observation of economic entities and their attitudes suggests what the community that creates such organisations is like and what values it possesses. Organisations are a kind of mirror of the attitudes and values present in a given society.

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EDUCATION IN THE ERA OF ARTIFICIAL INTELLIGENCE – NEW QUESTS AND POSSIBILITIES

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Purpose: The article's primary goal is to analyze artificial intelligence's (AI) development in the educational system.
Design/methodology/approach: In the article, deep analysis of the consequences of technological progress For process teaching, identifying challenges and opportunities related to dynamic AI development. Underlined the necessity of facing changes in education appearances the AI and valuable looking at the implications for ways driving lessons, content teaching, and self-education.
Findings: AI is a new way of solving problems, especially during crises. The new technologies determine the way and the speed of problem-solving. The new era of education requires modern methods concerning AI.
Research limitations/implications: The surveys discussed in this article may contribute to further empirical studies, including but not limited to initiating works to improve innovation in artificial intelligence.
Practical implications: Education in the age of AI demands a holistic approach, connecting modern technologies with traditional teaching methods and considering the ethical and social aspects of technological development.
Originality/value: Originality work is about a consistent approach based on research literature, which can be a basis for further empirical research regarding the impact of AI on education and modification of learning methods.

Keywords: educational technology, artificial intelligence, future education, education 4.0.

Category of the paper: General overview, Research paper.

1. Introduction

In today's world dominated by technology, the development of artificial intelligence (AI) brings revolutionary quantitative and qualitative changes, touching critical areas of our lives (Banasik, Kempa, 2023; Czupryna-Nowak, 2023). One area that feels the impact of AI is the education system. It seems reasonable to attempt an in-depth analysis of the consequences of

technological progress for the teaching process, identifying the challenges and opportunities related to this dynamic phenomenon.

In the face of the emergence of AI, education cannot remain in its actual state. The changes must be made promptly. A valuable look at this phenomenon requires a detailed understanding of the implications for teaching methods, content, and self-education. It is necessary to reflect on the current state of education, identify threats, and determine opportunities related to AI development's dynamic nature. The need to introduce innovations in the teaching process, including learning programming and developing technology-related skills, may help personalize the learning process and adapt it to the student's individual needs.

Special attention has been paid to the role of education in the new type of society, construction of knowledge, and shaping of the primary job skills and abilities, semi-learning activities of individuals in lifelong learning processes in public and private education sectors during formal and informal education, and new methods and tools in education (Juszczyk, 2006). It is also worth paying attention to significant challenges related to AI, such as threats related to data privacy and the need to prepare teachers to use modern educational tools effectively. The role of the teacher-appropriate preparation of teaching staff for teaching in the AI era is focused on the need to adapt the teaching system to the new reality, taking into account both existing threats and potential benefits. In this context, reflection on adapting both the methods and content of teaching becomes a critical element of the response to the challenges posed by the era of artificial intelligence. Analysis of the current state of education is necessary to identify strategies that effectively adapt the teaching system to the new, dynamic reality shaped by technological progress.

Education in the age of AI requires a holistic approach, combining modern technologies with traditional teaching methods. The effective use of AI can contribute to developing students' creativity and analytical skills while considering technological development's ethical and social aspects. The success of OpenAI 's ChatGPT is sparking scientific discussions about the potential applications of new technologies, including generative artificial intelligence. During the Conference "Artificial intelligence, cybersecurity, technological innovations. Challenges for the development of competencies", organized by the Sectoral Council for Competences - IT and the Sectoral Council for Competences - Telecommunications and Cybersecurity, the modern education system was debated. as well as the use of artificial intelligence to build personalized learning paths[1].

The text is based on the latest publications in the field of education published in recent years. It presents a summary of important topics regarding the challenges facing the educational system in the context of technological progress. The first of the analyzed issues is the implications of the development of artificial intelligence in education. Then, the concept of

[1]Discussion panel Artificial intelligence supporting the development of digital skills of students and teachers of vocational schools, https://konferencje.radasektorowa.pl/

artificial intelligence as a teaching tool is discussed. The next area focuses on the current state of education, presented based on the latest research using Big Data analysis. The last part of the article also analyzes trends in the currently changing educational reality, emphasizing both the opportunities and threats related to these transformations.

2. Implications of the development of artificial intelligence in the field of education

This dynamic intersection of technology and education holds promises and challenges that demand our attention and understanding. The development of artificial intelligence is inevitable, and its impact on various areas of life, including education, is becoming more and more noticeable. In today's reflections, we will focus on how these technologies can change the face of our educational system. One of the key benefits of using artificial intelligence in education is the ability to personalize the teaching process. Thanks to data analysis and machine learning algorithms, we can adapt the teaching material to the student's individual needs, allowing him to develop at the pace that suits him.

The introduction of artificial intelligence opens the door to the creation of innovative teaching tools. From virtual assistants to interactive learning programs, these modern solutions have the potential to revolutionize the way we teach and learn.

However, the development of artificial intelligence in education also brings challenges. One of them is the issue of fairness of algorithms. How can we ensure that AI-based systems are free from bias and treat all students fairly?

The introduction of new technologies also requires appropriate preparation of teaching staff. Teachers must be aware of the potential, but also of the limitations, of artificial intelligence. Therefore, it is crucial to invest in the development of teachers' digital competencies.

Another aspect that requires our attention is the role of artificial intelligence in the student assessment process. How can we protect against excessive automation and loss of a human perspective on a student's development? Introducing new technologies must also go hand in hand with attention to accessibility for all students. How can we avoid widening educational inequalities and ensure that the benefits of artificial intelligence are available to all? Ethics in the applications of artificial intelligence in education is an issue that cannot be ignored. How do we protect students' privacy and maintain ethical standards in the use of data? Cross-sector cooperation is necessary to use the potential of artificial intelligence in education effectively. How can we build bridges between academia, business, and government to jointly shape the future of schooling? Introducing artificial intelligence into education is a technological change and a cultural one. The vision for the future of education should include a balanced approach that considers technical benefits, ethical principles, and concern for the development of each student.

Implications of the development of artificial intelligence (AI) in education refer to the various effects, influences, and changes this technology can cause in teaching systems. Research on artificial intelligence (AI) in education has found its central place in the trends of intelligent tutoring systems. This dynamic area of research focuses on using the potential of artificial intelligence to transform educational processes and adapt to students' individual needs. (English: intelligent tutoring systems – ITS), systems supporting the teaching process (Conati et al., 2018). The intelligent tutoring systems that are the subject of this research represent an innovative approach to teaching, using advanced algorithms and technologies to deliver personalized learning experiences. The purpose of these systems is not only to provide information but also to actively adapt to each student's abilities, learning pace, and preferences. Thanks to research on artificial intelligence in education, it has become possible to create interactive educational platforms that enable students to approach learning individually. Intelligent tutoring systems analyze student progress data, identify areas requiring additional attention, and then adapt learning materials to meet the learner's needs better. A personalized approach supports skills development, strengthens students' motivation, and promotes more effective knowledge acquisition. Moreover, they can help teachers diagnose students' difficulties, adapt teaching strategies, and improve the teaching process's quality.

3. Educational possibilities of artificial intelligence

(…) *The time has come for artificial intelligence to appear openly in schools* (Sysło, 2022). The education sector can certainly benefit from the use of artificial intelligence. However, already at a very early stage of implementing innovative solutions, it is necessary to consider the educational environment's specificity, especially considering this system's mission (Fazlagić, 2022). Artificial intelligence (AI) is a key future technology, according to the European Parliament in 2020. In the context of the development of AI in Poland, the Committee of the Council of Ministers for Digitalization (KRMC) adopted the "Artificial Intelligence Development Policy in Poland" in 2020, which sets specific goals and actions for the short, medium and long term. One of the important areas of this policy is education, covering a wide range of activities from primary schools to universities, including training programs for people at risk of losing their jobs due to the ongoing development of technology. It is worth noting that the document mainly focuses on the role of education as a tool for shaping human capital in the context of the economy but does not provide specific guidance on the potential applications of AI in the education system. The IBE report "Artificial Intelligence (AI) as a megatrend shaping education" (2022) focuses on the analysis of the connections between the field of education and the dynamic development of artificial intelligence. The document identifies current and future trends and presents how society can be prepared for the opportunities and challenges related to

technological progress. It emphasizes the key role of digital competencies in developing artificial intelligence. The report provides a comprehensive look at how education can adapt to the changing digital landscape while providing society with the tools to use the potential of artificial intelligence effectively.

Table 1 presents an overview of the possibilities of using artificial intelligence in education. There are several subcategories among the applications:

- artificial intelligence supports the learning process,
- artificial intelligence as teacher support in administrative processes,
- artificial intelligence in managing the education system at its various levels.

Table 1.
Overview of the possibilities of using artificial intelligence in the field of education

Application	Description
Artificial intelligence supports the learning process	
Artificial intelligence as a teacher's assistant	Artificial intelligence can act as a tutor/tutor. AI is better at teaching the basics of specific knowledge disciplines and cannot develop higher-order skills in students, such as unity of thought and creativity. However, it cannot be ruled out that AI educational programs will also be able to develop higher-level skills in the future. When assessing the reliability of the results of educational experiments, the existence of the confirmation effect must be considered. The researcher tends to subconsciously experiment in such a way as to confirm their expectations. Moreover, in social research, the reliability of results is achieved by repeating the experiment many times. Teachers don't practice this. Artificial intelligence should, in principle, be deprived of the ability to fall into thinking traps typical of humans. Therefore, it should have an advantage over a living teacher.
Artificial intelligence as a teacher's replacement	Solutions already enable intelligent teaching – smart tutoring systems (e.g., Carnegie Learning). These include Amazon's Alexa, Apple Siri, and Microsoft Cortana. Voice assistants allow students to discuss the material they have learned without engaging the teacher. Educational institutions also use voice assistants to provide students with organizational information. For example, Arizona State University's Cognilytica offers students a freshman tutorial using Amazon Alexa software.
Artificial intelligence as a space ensuring emotional safety in the process of suffering educational failures	Learning is inextricably linked to trying and failing in the process. Many social and emotional barriers in a traditional school discourage students from trying. As a result, the learning process is less effective due to fear of public ridicule. Therefore, the opportunity to practice skills in isolation and the intimacy provided by artificial intelligence may be an advantage over the student's work in the classroom or the presence of a teacher.
Application to the individual needs of the student (personalization)	The teaching and upbringing system in a traditional school is, by nature, focused on averaging and standardizing the learning process. Artificial intelligence offers opportunities to personalize the learning process. Personalization should primarily concern detected knowledge deficits, which in a traditional classroom may be neglected by the teacher as a compromise to meet the educational needs of other students. For example, artificial intelligence can increase the intensity of test tasks in areas it considers needing improvement and reduce the number of test tasks in areas the student has already mastered. This way, the total time spent on testing can be equal for many students in a class, but the structure of testing tasks will vary. This approach allowed for a faster transformation of society from an agrarian economy towards an industrial economy. Other countries around the world followed suit.

Cont. table 1.

Giving feedback	Teachers in the classroom often do not have enough time to provide feedback to students about their learning progress and knowledge and skill deficits. Artificial intelligence can solve this problem. Analysis of knowledge deficits combined with a feedback library can allow AI to generate personalized, reliable, and detailed feedback in a given area. An additional advantage of using artificial intelligence may be depriving it of the accusation of subjectivity ("The teacher doesn't like me, that's why he gave me an F"). If the student cooperates with AI, then based on the collected historical data, AI can help the student make decisions regarding the selection of further stages of education. A separate issue is the honesty of feedback. You can expect an AI algorithm to be fair and objective, whereas a "live" teacher is not always able or willing to provide honest feedback. Although he acts unethically, he nevertheless, in passing, prepares the young man for life in a world of injustice and deceit. So, can this function also be simulated using artificial intelligence? Theoretically, yes, you can program the algorithm sometimes to be unfair/racist/biased/ discriminatory towards a given student - but this will cause even more moral problems than teachers' unethical behavior.
Artificial intelligence as teacher support in administrative processes	
Assessing students	Artificial intelligence can reduce the burden on teachers in the grading process. Assessment can be automated entirely (assessment based on tests) or partially automated, e.g., AI can analyze the results of the student's work and provide suggestions to the teacher but leave the final decision to the teacher himself. In the future, we can expect the development of systems for qualitative analysis of students' work. Other related tasks that AI can perform include entering grades at the end of the semester, completing employment-related reports and documentation, preparing study materials, organizing school trips, communicating with parents and solving problems of international students, matters related to sick leave, and others. Teachers spend a significant amount of their time on tasks unrelated to direct work with students. Therefore, relieving them of this type of task may automatically translate into increasing the effectiveness of the education process if the saved time is allocated to teaching or recreation. The burden of administrative tasks also significantly impacts the level of motivation to work and often results in burnout. Artificial intelligence can also suggest who the teacher should meet with and about what.
Checking student attendance and activity	This is one of the simplest tasks that simple software can perform.
Methodological support	The system can support the teacher in the teaching process. For example, suppose AI detects a disproportionately high number of incorrect student responses in a given area. In that case, it can provide the teacher with suggestions for improvement or, for example, content knowledge to impart to students. Currently, the tasks of a methodological advisor are entrusted to teachers by the education superintendent competent for the seat of the public training institution where the advisor is to be employed after consultation with the principal of the school or institution where the teacher is employed. AI may replace the functions of a methodological advisor in the future.
Relationship management	Teachers are obliged to maintain ongoing relationships with parents. AI could replace teachers with related tasks, especially if AI allows for direct feedback about the student to parents without involving the teacher.

Cont. table 1.

Artificial intelligence in the area of managing the education system at its various levels	
Teacher evaluation	Education systems in many countries worldwide have implemented various rules for teachers' assessment and professional advancement. They are based on analyzing specific predefined achievements and activities of teachers. As with student assessment, artificial intelligence could also assess or provide information to people evaluating a teacher. By linking - within appropriate algorithms - information on students' learning progress (educational added value) with the results of the analysis of teacher involvement, with the work of the school, cooperation with other teachers and the local environment, the algorithm could issue periodic evaluations to teachers in an objective manner. They could be devoid of substantive or political elements often accompanying a teacher's work. As a result, objectifying teacher evaluations in the education system could lead to a general increase in the quality of teaching if it were possible to eliminate the influence of substantive factors on the professional situation of teachers in the system.
Big data analysis about the education system	Appropriate algorithms with access to data generated based on student behavior can provide information allowing for the proper allocation of funds in the education system, predicting trends, and anticipating threats, for example, during a pandemic and distance learning. With such data, the Ministry of Education and Science could determine the scale of possible losses caused by the decline in the quality of teaching caused by the pandemic. Research on education systems on a macro scale has been conducted for some time, including by the CERI center within the OECD structures. By using artificial intelligence, the quality, scale, and frequency of measurements could increase significantly. As is currently the case, there would also be no need to rely on data from teacher surveys. Artificial intelligence could also answer many questions that are presently the subject of political debate in Poland and worldwide. In the case of Poland, for example, is increasing/lowering the age of compulsory pre-school education beneficial or not for a child's emotional and intellectual development?
Data analysis at the managing body and regional level	Analysis of regional differences at the level of large local governments (e.g., urban communes) could allow for optimizing the use of resources and monitoring the effectiveness of their use. For example, student and teacher activity data could be correlated within an AI algorithm with spending on information technology in education.

Source: Fazlagić (2023).

The educational possibilities of artificial intelligence are also described in the book Big Data in Education. The Digital Future of Learning Policy and Practice (Williamson , 2017). Among its many applications, the following stand out: data collection and processing, control of the learning process, creation of predictions of students' progress by an AI program, introduction of software that adapts to students' activity, analysis of progress in real-time, possibilities of implementing a learning management system) and teaching bots (teacher bot) and cognitive tutors (cognitive tutors).

Artificial intelligence can efficiently collect, analyze, and process large amounts of data, helping to identify patterns, trends, and student needs. Artificial intelligence-based systems can monitor students' progress in real time, identify areas of difficulty, and adapt teaching material individually to the needs of each student.

By analyzing data, AI can predict students' future progress, which allows them to adapt teaching strategies and support students. Individual learning programs generated by artificial intelligence can adapt to each student's preferences, pace, and learning style. Artificial intelligence systems can provide teachers and students with real-time information on learning progress, enabling quick intervention when needed. Artificial intelligence can support advanced

learning management systems, helping to organize teaching materials and lesson schedules and monitor student progress. AI-powered bots can act as teachers by answering students' questions, providing additional explanations, and offering one-on-one support. Artificial intelligence-based systems can serve as cognitive tutors, providing personalized learning assistance, solving problems set by students, and adjusting the difficulty level of tasks. Research on using robots in foreign language teaching confirms their effectiveness by increasing children's vocabulary and stimulating more significant interest in learning (Movellan et al., 2009; Belpaeme et al., 2018). Moreover, research has shown that this technology accelerates solving cognitive problems and positively affects students' perception of tasks (Belpaeme et al., 2018).

Introducing these solutions may contribute to a departure from the traditional model in which educational institutions dominate the teaching and learning process. Artificial intelligence can increase individualization and adaptation to students' needs and enable more effective use of educational resources. However, at the same time, there are challenges related to ethics, the fairness of algorithms, and the need to ensure access to new technologies for all students. The PARP report Artificial Intelligence in Education – Prospects and Threats (2023) presents an up-to-date look at artificial intelligence (AI) use in education. In the face of the digital revolution, AI is becoming an essential element of many sectors, including science, with huge potential for use in education. The report emphasizes that AI can significantly facilitate and improve the learning process at every level, from students to entire educational systems. Teachers can use AI to monitor student progress in real-time, identify learning difficulties, and adapt teaching methods to meet individual student needs. Introducing new tools, such as text, voice, video generators, and Learning Experience Platforms (LXP), significantly improves the efficiency and accessibility of education while introducing elements of gamification and improved online discussion forums, increasing student engagement. The report also points to the growing popularity of AI in education due to new tools such as ChatGPT introduced by Open AI and Bing by Microsoft. Research shows that teachers use these technologies more actively than students, and most recognize that AI introduces changes to the traditional teaching model.

The report also raises issues regarding Poland's role in the global context of AI, forecasting the potential automation of up to 49% of working time by 2030. The challenges of adapting employee skills to the requirements of the changing labor market are mainly targeted in the education sector. Cross-sector collaboration is critical to the effective implementation and use of AI in education. The report suggests that developers, teachers, and students should work together to create AI tools tailored to real learning needs. In addition, ethical, security, and privacy issues must be constantly monitored and regulated. However, the report also identifies barriers such as concerns about losing natural human relationships, privacy and data security issues, and technology addiction. There is also a need to transform the skills of workers in the education sector to meet the new demands of the labor market.

Artificial intelligence (AI) is currently an up-and-coming tool supporting the teaching process at many levels. AI allows you to adapt the teaching process to students' individual needs. Algorithms analyzing data on student progress will enable you to create personalized teaching plans, taking into account differences in learning pace and learning style. Modern education faces the imperative of individualizing the education process, an important research issue and an essential element of educational practice. Delving deeper into the problem, it turns out that it is becoming an inevitable requirement of educational reality while at the same time constituting an opportunity to improve the quality of education. One of the central authors dealing with this issue is Hłobije (2015), who emphasizes that the individualization of the education process is not just a luxury but a necessity to meet the growing demands of civilization. The author points out that this form of teaching is a tool that improves the quality of education and promotes students' creative and comprehensive development. He also points out that attempts at various treatments to individualize work with students in terms of adapting the content, methods, forms, and means of teaching to the psychophysical abilities of students have not yet brought the expected results.

In the context of research on the individualization of the education process, the question arises about effective strategies for achieving this goal. These considerations include adapting teaching content to the individual needs of students but also issues related to various learning styles. Research on this issue also focuses on using modern technologies, such as artificial intelligence, to adapt educational materials to each student's skill level and learning pace. The practical aspects of individualizing the education process have decisive consequences for the role of the teacher. In the new teaching paradigm, the teacher becomes not only a guide in acquiring knowledge but also a mentor who adapts his approach to the individual characteristics of each student. Supporting students in developing their strengths while focusing on eliminating difficulties is becoming a vital element of a modern approach to education.

Individualization of the education process is not only a theoretical postulate but a practical tool introducing a revolution in education. It is an opportunity to create a more adaptive and flexible teaching system that better responds to the changing needs of students while preparing them for the challenges posed by modern civilization. Open Learner concept Modeling develops based on research on educational technology and systems supporting the learning process. In this research, various researchers, research teams, and educational institutions contribute to developing the OLM idea, exploring multiple aspects of its implementation and potential benefits for the teaching process. Open Learner Modeling (OLM) is one of the leading trends in research on using artificial intelligence algorithms in the context of individualizing teaching. OLM is an approach that focuses on creating and sharing an open learner model that can be accessed by students, teachers, and other stakeholders alike.

The main features of Open Learner Modeling are:

- Transparency of Educational Data: OLM collects data from the learning process, such as progress, test results, preferences, and learning style. This data is transparently presented in the form of a model that can be available to the student, teacher, and sometimes other participants in the educational process.
- Customization of Educational Materials: OLM allows you to customize educational materials to meet the individual needs of your students. Based on data analysis, artificial intelligence algorithms identify areas where the student needs additional support and then deliver personalized educational content.
- Self-Development: OLM focuses on developing students' self-regulation skills. By accessing their learner model, each learner can better understand their learning process and identify strengths and areas for improvement.
- Student Engagement: OLM can increase student engagement by making the learning process more transparent and tailored to their preferences and learning styles.
- Teacher Support: Teachers have access to information about student progress, enabling them to adapt their teaching methods more effectively. OLM supports teachers in an individual approach to each student.

As a result, OLM is an attempt to create an open and accessible learning model that supports the individualization of teaching and promotes transparency, student involvement, and adequate teacher support. This approach applies to various educational contexts, including e-learning, online training, and traditional educational settings.

AI-based systems can efficiently handle administrative tasks such as grading, tracking progress, and generating reports. These systems allow teachers to focus more on direct contact with students. SI can provide custom educational materials tailored to students' advancement levels and interests. This approach promotes more effective learning by providing content that matches individual skills.

AI algorithms can identify areas where students are struggling. Thanks to this, teachers can react quickly, adapting teaching methods to the needs of specific students. The use of AI in education can support the development of skills crucial in the digital era, such as programming, data analysis, and understanding the basics of artificial intelligence. AI-based systems can create interactive learning environments that engage students in learning. Educational games, simulations, and virtual lessons are examples of interactive tools. It is worth emphasizing, however, that introducing artificial intelligence into education requires simultaneous consideration of ethical issues, data privacy, and appropriate preparation of teachers for the effective use of these technologies. However, integrating SI as a tool supporting the teaching process opens new perspectives, allowing education to be adapted to the contemporary needs of students and the challenges posed by technology development. AI can enable the teaching process to be tailored to the student's individual needs. AI algorithms can analyze student progress data and adjust learning materials and the pace of learning, fostering a more

personalized approach. The development of AI opens the door to new, innovative teaching methods. Using intelligent systems to create interactive lessons, educational games, or e-learning platforms can make learning more attractive and practical. AI can support the process of student diagnosis and assessment. Advanced algorithms can analyze test results, homework grades, and student interactions with educational content, enabling a better understanding of progress and possible adjustments to teaching methodology. Integrating AI into education can help develop skills essential in the digital age, such as programming, data analysis, and the ability to use modern technologies. This approach can better prepare students for future career challenges. Introducing AI into education also raises ethical issues, such as protecting student privacy, the fairness of algorithms, and the responsible use of student data. It is necessary to define clear moral and legal standards related to the use of AI in education.

The introduction of AI requires appropriate preparation of teaching staff for the effective use of modern educational tools. As scientific researchers rightly emphasize, acquiring new competencies, mainly digital, social, communication, and intercultural competencies, and online access to digital open educational resources is in the context of preparing teachers to develop media culture (Tanaś, Galanciak, 2020). Teachers must formulate technology-related skills to effectively cooperate with intelligent systems in teaching (Education of the future. Report by Wasyluk, Kucner, Pacewicz, 2020).

In summary, the implications of the development of artificial intelligence in education include some opportunities to improve the quality of teaching, personalize the educational process, and develop new skills in students, but also pose challenges related to ethics, data security, and appropriate preparation of teachers to use new technologies.

Considering that modern education is intended to prepare students for the challenges of the contemporary and future world and can be implemented in various ways, it is worth dwelling on the topic of inclusive education, also known as inclusive education. This approach is recommended by the Ministry of Education and Science, which ensures high-quality education for every student. Nowadays, when technology constantly evolves, artificial intelligence (AI) is becoming a key factor supporting educational processes, especially in inclusive education. AI opens up new perspectives, enabling us to create a more adapted and flexible educational environment.

As previously written, one of the main advantages of artificial intelligence in education is the ability to personalize teaching. This process includes adapting teaching materials, pace, and teaching style to students' skills and needs. By analyzing data, AI-based systems can identify each student's strengths, which allows them to focus on developing specific skills.

Adaptive learning is another area where artificial intelligence plays a key role. AI-based technologies adapt to students' progress, providing appropriate challenges as they acquire new skills. Such flexibility helps to maintain students' motivation and increases the effectiveness of the educational process. Speech and text recognition is vital in supporting students with various difficulties, such as dyslexia and reading problems. Advanced natural language processing

algorithms enable speech and text recognition, which allows access to educational content tailored to individual needs. Assistive technologies, such as image recognition programs and special math applications, are vital in eliminating barriers for students with various difficulties. These tools help you fully participate in the educational process.

Another advantage of artificial intelligence is the ability to detect students' weaknesses. Analyzing data from tests or tasks allows AI-based systems to indicate areas requiring additional support, enabling teachers to tailor their approach to each student individually. Developing social, cooperation and communication skills is extremely important in inclusive education. Artificial intelligence supports these areas by providing tools for remote communication, collaboration on projects, and sharing educational resources. In summary, using artificial intelligence in inclusive education creates a more adapted and flexible learning environment. However, it is equally vital that we supervise the development of these technologies and ensure their ethical and safe use, minimizing potential risks. From a science perspective, this is a fascinating period in which modern technology and education meet, creating new horizons for future generations.

4. Conclusions

The impact of AI on education is evident and significant. Ways of learning are changing, and traditional teaching methods are giving way to new, technology-based approaches. The challenge for educational communities and policymakers is creating regulations allowing for AI's controlled development in education. In education, artificial intelligence (AI) is a powerful tool to support various aspects of the teaching and learning process. AI has the ability not only to automate many processes but also to personalize and adapt to the individual needs of students. From the perspective of inclusive education, which aims to create an environment that supports the participation of all students, the use of AI can bring significant benefits. Artificial intelligence enables the personalization of the teaching process, which means adapting teaching materials, pace, and teaching style to students' abilities and needs. Thanks to data analysis, AI can identify each student's strengths, allowing it to focus on developing specific skills. AI-based technologies have the potential to adapt to students' progress, offering them appropriate challenges as they acquire new skills. Adaptive learning allows for dynamic adjustments to curricula, which helps maintain student motivation and increases the effectiveness of the educational process. Thanks to advanced natural language processing algorithms, AI can recognize speech and text, which opens up new opportunities for students with various difficulties, including dyslexia or other reading problems. These tools can support the reading process by enabling access to educational content in a way tailored to individual needs. Artificial intelligence can support students through various assistive

technologies, such as image recognition programs or unique applications that help with math tasks. These tools aim to eliminate barriers, enabling students with multiple difficulties to participate more fully in the educational process. AI can also help identify areas where students are struggling. By analyzing data from tests or tasks, AI-based systems can indicate areas that require additional support, enabling teachers to approach each student individually. In the context of inclusive education, a key element is developing social, cooperation, and communication skills. AI can support these areas by offering tools for remote communication, collaboration on projects, and sharing educational resources. However, at the same time, it is essential to supervise the development of these technologies and ensure their ethical and safe use, minimizing potential risks. When developing the topic of threats related to introducing artificial intelligence (AI) into education, there is a need to focus on two key aspects: the lack of critical thinking and empathy among students and potential addiction to technology. These threats require not only attention but also specific intervention to ensure that the impact of AI on education is positive and sustainable. Introducing artificial intelligence into the educational process may create a situation where students rely too heavily on algorithms and automation, impacting their critical thinking ability. Too much trust in machine-generated content or evaluation algorithms may inhibit the development of analysis, reflection, and independent thinking skills.

Furthermore, there is a risk that students may lose the ability to empathize when interactions replace interactions with teachers or other students with technology. Virtual learning environments, although offering modern tools, may limit the development of social skills that are key to understanding other people's perspectives and building the ability to cooperate and empathize. Including elements in curricula that develop critical thinking, encourage independent thinking, and emphasize social skills is essential. Additionally, monitoring students' interactions with technology, supported by teachers, can help maintain a balance between using digital tools and developing social skills.

The second significant threat is students' potential addiction to technology. Introducing artificial intelligence into teaching creates the risk that students may become too reliant on interacting with computers, which can lead to problems with concentration and the ability to solve problems independently and cope with situations without technology. It is necessary to consciously design educational programs that integrate technology with traditional teaching methods to prevent this. It is also important to develop independence and time management skills early so that students can use technology effectively while maintaining the ability to think independently and solve problems. Ultimately, to effectively manage these threats, it is necessary to constantly monitor the impact of artificial intelligence on students, adapt curricula, and develop appropriate training programs for teachers.

Collaboration between educators, educational technology specialists, and policymakers is crucial to successfully integrating AI into education while minimizing potential risks.

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CLUSTER ANALYSIS OF EPIDEMIC CURVES OF THE THIRD COVID-19 EPIDEMICS WAVE IN DIFFERENT REGIONS OF POLAND

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Purpose: The purpose of the analysis was to divide Polish regions (as a single region we mean "powiat") into categories according to the way in which their population passed the third wave of COVID-19 epidemics and the attempt of linking the resultant classifications with other factors.
Design/methodology/approach On the basis of data about daily COVID-19 cases per 10,000 inhabitants in regions, weekly averages in every day were calculated. The curves of these averages for each region were approximated by a polynomial function. Then, for the majority of created functions, five characteristic "points" were determined: a maximum of the function together with a maximum and a minimum of its first derivative and two maxima of its second derivative, which are all located the closest to the function maximum. On the basis of coordinates of these points, regions were grouped by using of K-means method. Finally, the mean levels of various factors in obtained categories were analyzed as well as different classification models determined on this basis.
Findings: The performed analysis allowed to construct predictive models of the approximate shape of the epidemic curve in a given region. These models can be used in more-depth analysis of epidemics evolution.
Research limitations/implications: These models can be used in more-depth analysis of epidemics evolution.
Originality/value: By using cross-validation test, the number of clusters equal to five was determined. Mean values of the mentioned coordinates in each cluster allowed to determine an approximate shape of characteristic epidemic curve for a given group of regions. Only among some clusters there was a significant difference in population density, the percentage of population living in cities and the approximate percentage of inhabitants vaccinated after the third wave of COVID-19 epidemics. Nevertheless, on the basis of these factors and the age structure of the population, decision trees which classify most of the wave categories with a satisfactory accuracy were determined.

Keywords: Cluster analysis, decision tree, epidemic curve, method of K-means, region.

Category of the paper: Research paper.

1. Introduction

The COVID-19 pandemic was one of the greatest challenges for the entire world, individual regions, countries and societies in the 21st century. The powerful crisis that it caused both in the area of health care as well as in the sphere of economy and economy is and will certainly be the subject of numerous analyzes, studies, publications and discussion forums for a long time. It can be safely said that both on a global scale, i.e. worldwide, and locally - at the level of countries and regions - there is virtually no area where the pandemic would not leave its mark. Even a cursory bibliographic query allows to quickly realize that the number of studies on the impact of the COVID-19 epidemic on various aspects of life, business or social relations is already huge. At this point, it is difficult to try to distinguish any specific sphere or area of human activity affected by the pandemic without omitting another. The following brief bibliographic study therefore aims to provide an overview of those areas where the impact of the pandemic is currently being intensively studied. One can find the analysis of the impact of COVID-19 disease on environment and health in (Sneha et al., 2020; Verma et al., 2020), on agriculture in (Siche, 2020), on firm performance in (Shen et al, 2020), on globalization in (Shad et al., 2020), on mental health in (Banerje, 2020), on cancer care in (Richards et al., 2020), on business expectations in (Meyer et al., 2022), on waste management in (Sarkodie et al., 2021) and on education system in (Tarkar, 2020).

2. Short epidemic data description

The data come from Raport zakażeń koronawirusem (SARS-CoV-2), Archiwalne dane dla powiatów (eng. Coronavirus infection report (SARS-CoV-2), Archival data for powiats) in Poland's Data Portal (https://dane.gov.pl/), available in the Internet: https://dane.gov.pl/pl/dataset/2477/resource/33194/table, date of access: 11.04.2022. Data was written in csv files, which contain among others the following information about Polish powiats: name of voivodeship, the name of powiat, TERYT number, number of new COVID-19 cases per 10,000 inhabitants and the date of record state (but not in every csv file - in case of lack of this column, the date was deducted from the name of file).

Details about data and methodology are available in file "readme.txt" placed with csv files in a zip file downloaded from the mentioned source. It contains among others, the definition of the variable considered in our research, i.e. (translated from Polish) "Number per 10,000 inhabitants - Number of people for whom the day before the EWP system received a positive result for the first time, per 10,000 inhabitants", as well as definitions of other terms and general information about possible inaccuracies (e.g. corrections of previous data, delays in reporting,

cases of missing data on people being tested). However, in the studies described in this article, the data uncertainties indicated in mentioned file were found to be acceptably small. In the analysis data from a period 26.01.2021 - 9.06.2021 was considered. Number of COVID-19 cases per 10,000 inhabitants showed two kinds of variability:

- natural and random – that is characteristic in the case of such a phenomenon - that randomness is an integral part of many epidemic models/studies (e.g. (Bittihn et al., 2020; Britton, 2020); Chen-Charpentier et al., 2010; Fraser et al., 2004);
- unnatural and periodic (weekly) – number of cases often drops in Sundays and Mondays and later increases, that is the effect of specificity of testing/reporting system of COVID-19 cases in Poland. For week average = 1, mean level of cases on subsequent days of the week for all powiats for full weeks in February and March (month without additional work free days in considered period) was for example 0.69, 1.19, 1.27, 1.18, 1.19, 0.98, 0.5.

In the plot below (Fig. 1) the example of the mentioned data can be seen in the case of bolesławiecki powiat.

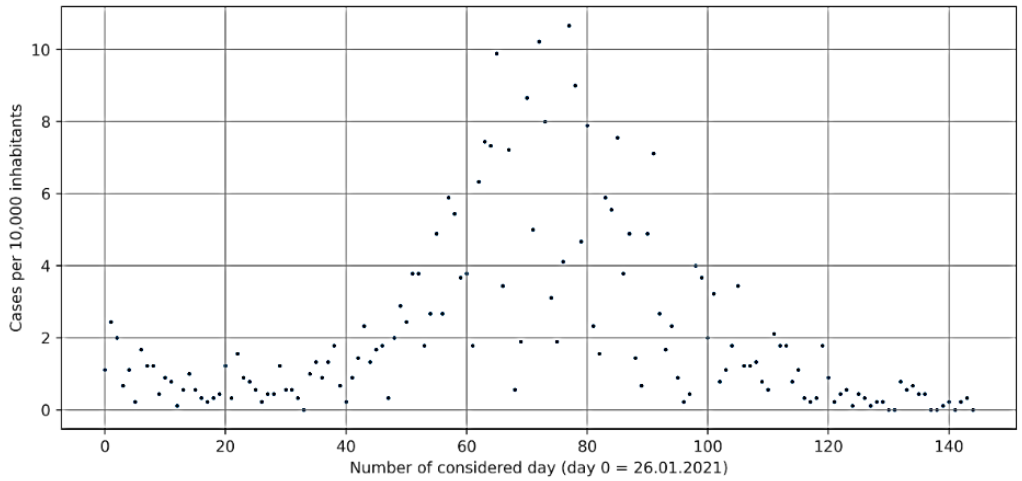

Figure 1. Original data in bolesławiecki powiat. Plot made with Matplotlib.pyplot. Version of Matplotlib: 3.5.0.

3. Operations on the data

In order to reduce the influence of the aforementioned factors on the shape of disease curves, the data from each day was converted into weekly averages, with using a moving average:

$$(new)X_i = \frac{\sum_{j=i-3}^{i+3}(old)\,X_j}{7}, \tag{1}$$

where X_i = number of cases per 10,000 inhabitants in i-th day of the considered period of time before conversion (and weekly average in i-th day after conversion). In the plot below (Fig. 2) the data from bolesławiecki powiat after mentioned transformation can be seen.

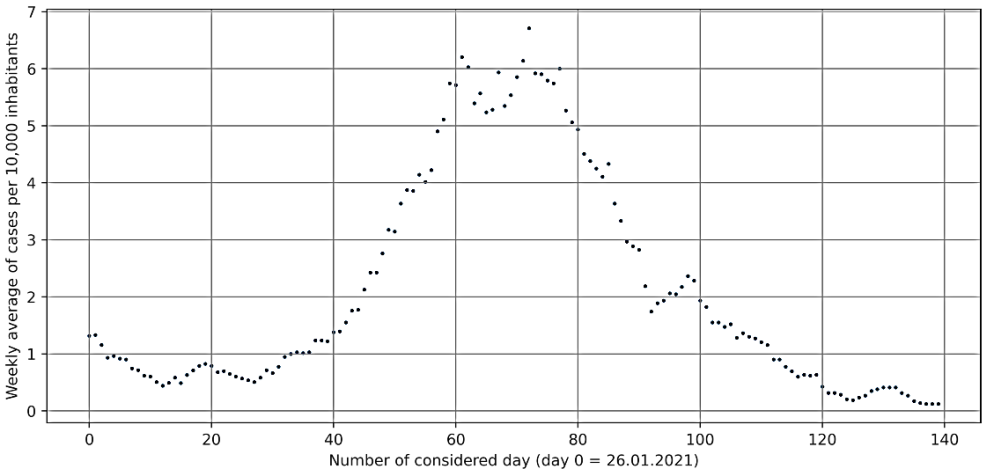

Figure 2. Data from bolesławiecki powiat after applying moving average. Plot made with Matplotlib.pyplot. Version of Matplotlib: 3.5.0.

The converted data was used to determine the approximated polynomial functions of degree 8, which return a value of weekly average of number of cases per 10,000 inhabitants in i-th day. For this purpose function ”polyfit” from the package ”NumPy” of Python programming language was used (version of Python: 3.8.12, version of NumPy: 1.21.2). The degree of polynomial function was chosen by trial and error method based on observation of the plot with function and data. In the plot below integral values of polynomial function created in mentioned way for case of bolesławiecki powiat can be seen (Fig. 3).

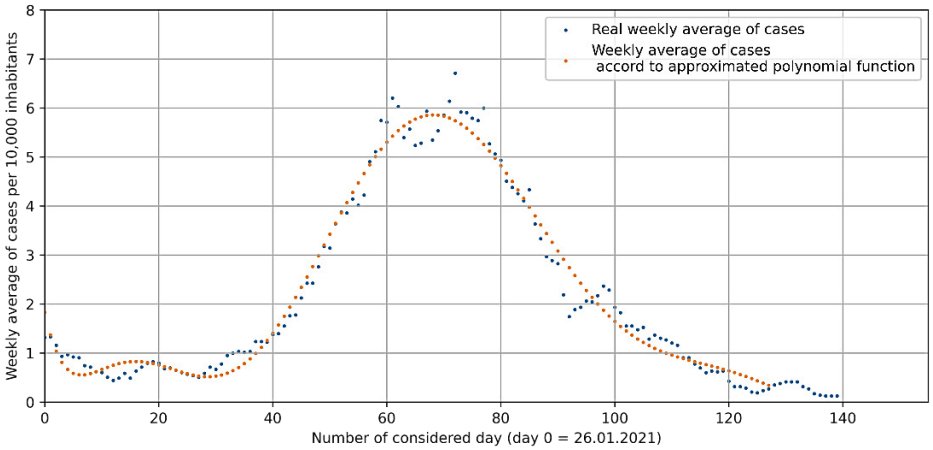

Figure 3. Data from bolesławiecki powiat after applying moving average with created polynomial function. Plot made with Matplotlib.pyplot. Version of Matplotlib: 3.5.0.

In order to describe the functions/epidemic curves obtained in previous step, 5 characteristic points (hereinafter referred to as ch.p.) were determined for each of them:

- first point: maximum value of the function – which indicates moment of highest number of new cases per 10.000 inhabitants;
- second point: local minimum of first derivative of the function – which indicates moment of the fastest decreasing of the number of new cases;
- third point: local maximum of first derivative of the function – which indicates moment of the fastest increasing of the number of new cases;
- fourth point: first local maximum of second derivative of the function - which indicates the beginning of the increase in the number of new cases;
- fifth point: second local maximum of second derivative of the function - which indicates the stop of the decrease in the number of new cases.

For points 2-5, maxima/minima closest to the maximum from point 1 were selected. Because in other places there can occur other local minima/maxima only integer X coordinates of the points were considered (to indicate the day of minima/maxima), so in practice many obtained points are only close to considered maxima/minima. This approach was chosen to not consider exact moments of epidemic (as 16:00, for example). The mentioned points and derivatives for data from bolesławiecki powiat can be seen in the plot below (Fig. 4).

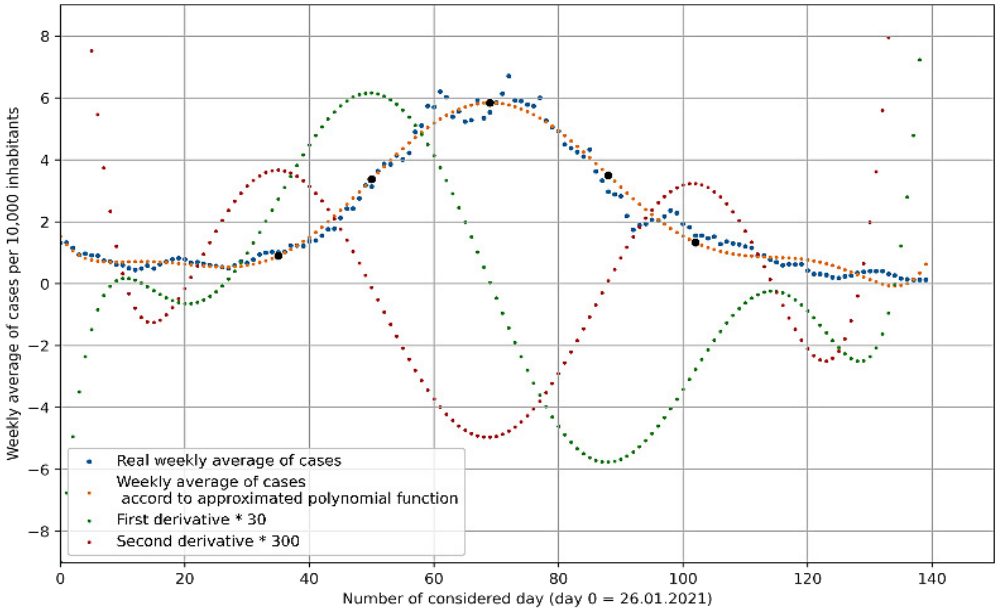

Figure 4. Data from bolesławiecki powiat after applying moving average with created polynomial function, derivatives and characteristic points. Plot made with Matplotlib.pyplot. Version of Matplotlib: 3.5.0.

Of course some of the analyzed curves were not shaped like a single bell curve (”classic wave”), what caused some difficulties in the analysis made in the way mentioned before. For example, it was difficult or even impossible to choose locations of the mentioned 5 characteristic points in the case similar to a monotonic declining function. For this reason,

powiats with an unusual epidemic curve shape were excluded from the further analysis. Their number, however, was acceptably small (only 21 powiats in total 380).

4. Cluster analysis of epidemic curves

Shortly about the used clustering method. In cluster analysis coordinates of 5 characteristic points on every curve were used as variables which described curves. Analysis was performed in program Statistica (TIBCO Software Inc. (2017). Statistica (data analysis software system), version 13. http://statistica.io).

The K-means method was used for the cluster analysis. In this approach firstly K clusters are chosen. Later analyzed objects are moved between them to minimize the variance inside them and maximize the variance between them. In the considered analysis data had been standardized, the cross-validation test (number of tries = 10, generator kernel = 1, number of clusters form 2 to 25, minimal decline=5%) was used to determine the number of clusters (result = 5), Euclidean distance was chosen as a measure of distance and maximum number of iteration of algorithm was 50. Initial cluster centers were chosen in the way to maximize the distance between them.

Numbers of powiats in subsequent clusters were (respectively): 88, 85, 86, 44, 56. To verify the hypothesis that these clusters do not differ, the Kruskal-Wallis test was used. The classic ANOVA analysis was abandoned due to fact that the condition of homogeneity of variance (in majority of cases) on the level of confidence 0.05 was not satisfied. To check this condition Levene's and Brown-Forsythe's tests were used.

Table 1.
Results of checking homogeneity of variance

Variable	P-value of Levene's test	P-value of Brown-Forsythe's test
X coordinate (day) of 1. ch.p.	0,001843	0,007093
Y coordinate (number of new cases per 10.000 inhabitants) of 1. ch.p.	0,000000	0,000000
X coordinate of 3. ch.p.	0,062809	0,135159
Y coordinate of 3. ch.p.	0,000000	0,000002
X coordinate of 2. ch.p.	0,000001	0,000005
Y coordinate of 2. ch.p.	0,000000	0,000000
X coordinate of 4. ch.p.	0,000001	0,000008
Y coordinate of 4. ch.p.	0,000006	0,000018
X coordinate of 5. ch.p.	0,000000	0,000000
Y coordinate of 5. ch.p.	0,034301	0,043779

Source: Authors' own.

P-values of the Kruskal-Wallis test for the clusters were 0 for each considered variable (coordinate). It allows us to reject the hypothesis that there are no differences between clusters. Meanwhile, post-hoc tests showed that pairs of clusters differed (at the significance level of 0.05) in most cases. In the analysis post-hoc comparisons for the average ranks of all pairs of groups was used (see e.g. Sigel et al., 1998; TIBCO, 2017) and p-values for the two-tailed test with Bonferroni's correction for each compared pair were taken.

Table 2.
P-values of post-hoc tests (columns from 2 to 11, titled "a:b", show p-values of the test between a and b clusters)

Variable\ Clusters	**1:2**	**1:3**	**1:4**	**1:5**	**2:3**	**2:4**	**2:5**	**3:4**	**3:5**	**4:5**
X coordinate of 1. ch.p.	1	0	0	0	0	0	0	0,001080	0,127108	0
Y coordinate of 1. ch.p.	0	0,000278	0,466919	0	0,000001	0	0	0,000001	0	0,002889
X coordinate of 3. ch.p.	1	0	0	0	0	0	0	0,005044	0,062469	0
Y coordinate of 3. ch.p.	0	0,000029	0,009989	0	0,000191	0	0	0	0	0,250558
X coordinate of 2. ch.p.	0,347494	0	0	0	0	0	0	0,000384	0,849416	0,000001
Y coordinate of 2. ch.p.	0	0,001664	0,016016	0	0	0	0	0	0	0,084254
X coordinate of 4. ch.p.	1	0	0	0	0	0	0	0,034809	0,022110	0,000001
Y coordinate of 4. ch.p.	0,889435	1	0	0,725732	1	0	0,010150	0	0,024790	0,000273
X coordinate of 5. ch.p.	0,729320	0	0	0	0	0	0	0,000195	1	0,000002
Y coordinate of 5. ch.p.	0,000744	1	0	0,007986	0,039138	0	0	0	0,000189	0,071558

Source: Authors' own.

The plot below (Fig. 5), made with Matplotlib.pyplot. Version of Matplotlib: 3.5.0, shows means and standard deviations of the considered coordinates of characteristic points of the epidemic curves in every cluster.

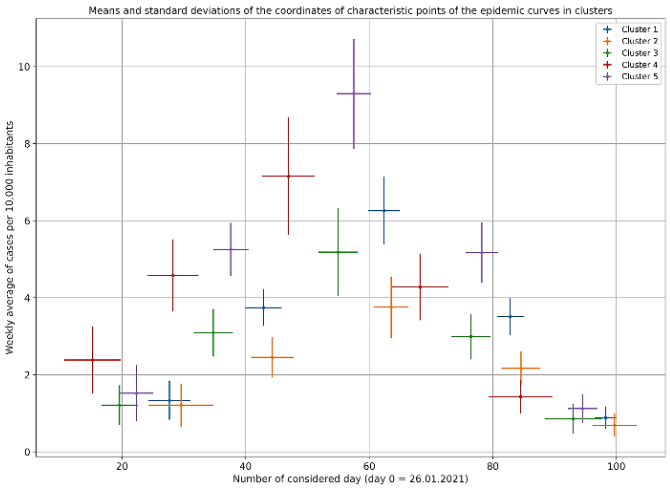

Figure 5. Means and standard deviations of the considered coordinates of characteristic points of the epidemic curves.

On this basis, it is possible to compare the course of the epidemic in every cluster. For example, statistically speaking, powiats from the fifth cluster suffered the most in 3rd wave of COVID-19, and powiats from the second cluster suffered the least (in terms of number of cases per 10,000 inhabitants).

5. Analysis of the relationship with other factors and an attempt to determine predictive models

In this stage of the analysis the following data was considered:

- population density per 1 km sq. in 2020 (in powiats);
- population by age groups in 2020 (in powiats);
- population in cities in% of the total population (in powiats);
- vaccinated population (in powiats).

First three data mentioned above come from Local Data Bank of Statistics Poland, available in the Internet (https://bdl.stat.gov.pl/bdl/start, 13.04.2022). Symbols of the category and the group (in Local Data Bank) from that data comes are respectively K3 and G7, and symbols of subgroups (respectively): P2425, P2463, P2137. URLs of concrete data were unavailable.

The information about the vaccinated population comes from Raport szczepień przeciwko COVID-19, Dane historyczne (eng. COVID-19 vaccination report, historical data), available in the Internet (https://dane.gov.pl/pl/dataset/2538,raport-szczepien-przeciwko-covid-19/resource/34430/table, 13.04.2022).

6. Operations on data and short analysis of their values in clusters

Based on the data about the population in specific age groups, the percentage share of these groups in the total population of a given powiat was determined. Later based on the mentioned population and vaccination data, the approximate percentage of the population vaccinated on August 1, 2021, in given powiats has been calculated (as indicator of society approach to epidemic). These steps were done in Python programming language.

To compare levels of considered factors in clusters, boxplots were made in Statistica environment.

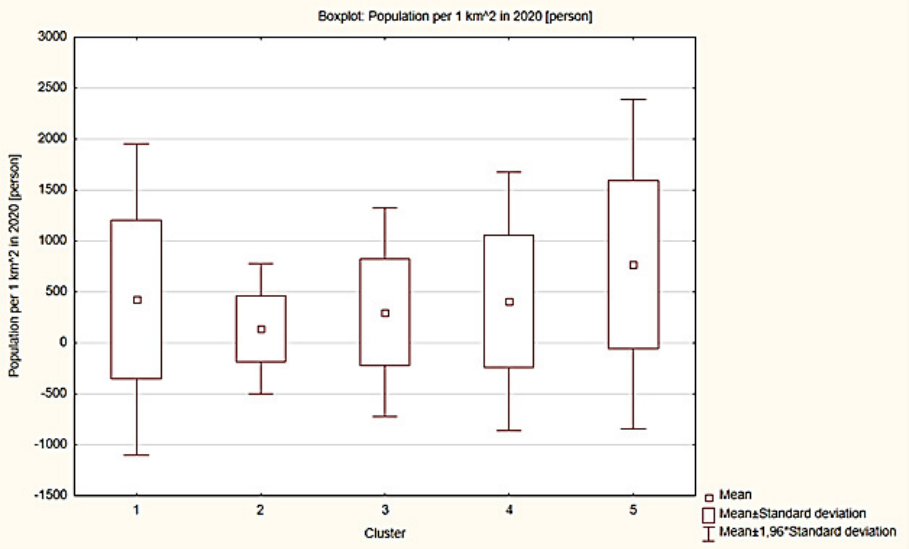

Figure 6. Boxplot 1.

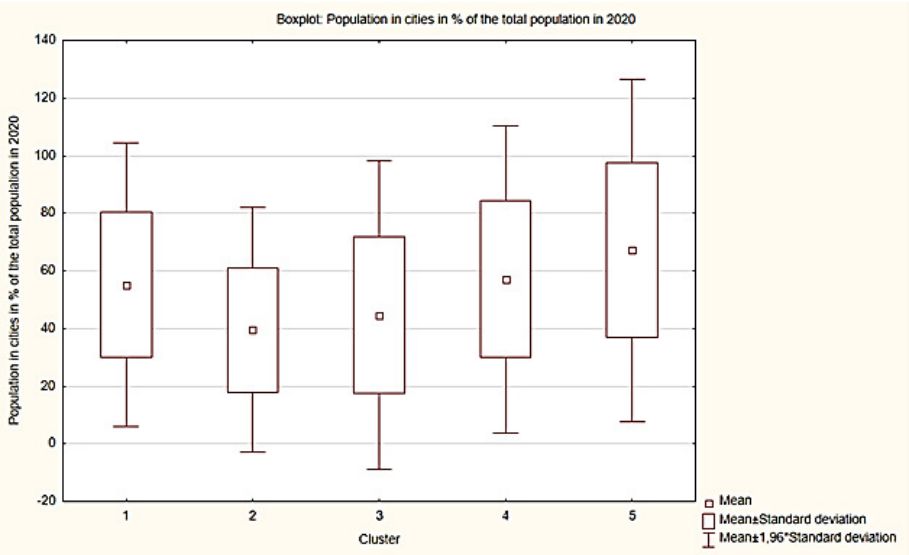

Figure 7. Boxplot 2.

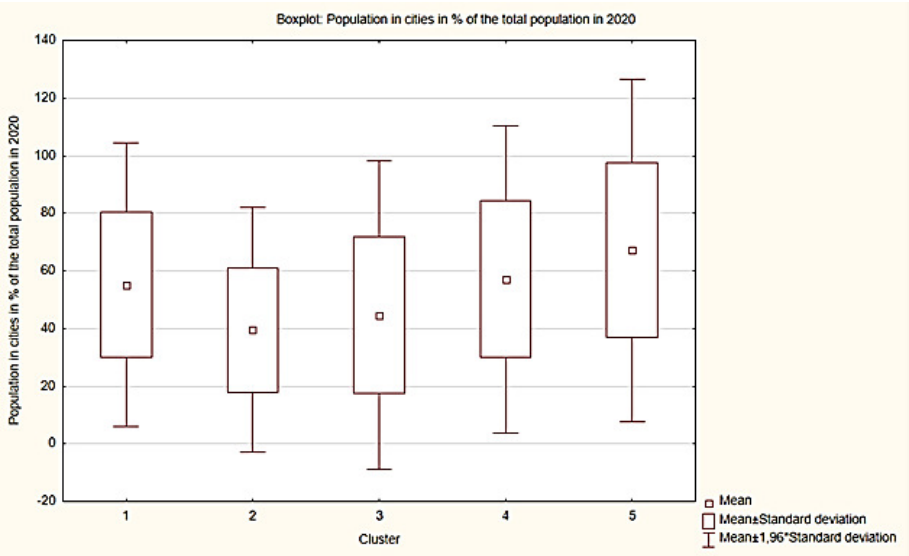

Figure 8. Boxplot 3.

Boxplots shows that the difference between clusters occurs in ranges of standard deviations. To analyze the difference between clusters in considered factors more deeply, Kruskal-Wallis test and post-hoc tests were applied. The classic ANOVA analysis was abandoned because the condition of homogeneity of variance in most cases was not satisfied. To check this condition Levene's and Brown-Forsythe's tests were used.

Table 3.
Results of checking homogeneity of variance, and Kruskal-Wallis test

Variable	P-value of Levene's test	P-value of Brown-Forsythe's test	P-value of Kruskal-Wallis' test
Population per 1km^2	0,000000	0,000058	0
population in cities in% of the total population	0,001332	0,002457	0
% of population in age 0-4	0,055125	0,111768	0,0036
% of population in age 5-9	0,023932	0,025041	0,0129
% of population in age 10-14	0,000130	0,000156	0,2534
% of population in age 15-19	0,001194	0,002659	0
% of population in age 20-24	0,050216	0,103416	0
% of population in age 25-29	0,017470	0,047625	0
% of population in age 30-34	0,006452	0,006751	0,3739
% of population in age 35-39	0,017776	0,164973	0
% of population in age 40-44	0,000002	0,000039	0
% of population in age 45-49	0,000000	0,000076	0,0017
% of population in age 50-54	0,003891	0,009110	0,0098
% of population in age 55-59	0,000005	0,000011	0
% of population in age 60-64	0,006249	0,008411	0,156
% of population in age 65-69	0,050905	0,089036	0,0003
% of population in age 70 and more	0,018269	0,023300	0,1121
% of population in age 70-74	0,003754	0,010453	0
% of population in age 75-79	0,022411	0,043057	0,0421
% of population in age 80-84	0,031218	0,035508	0,6014
% of population in age 85 and more	0,145800	0,160838	0,0597
% of population in age 0-14	0,057461	0,058451	0,0276
Approximated % of population vaccinated against COVID-19 1 August 2021	0,000061	0,000627	0,0002

Source: Authors' own.

Table 4.
P-values of post-hoc tests (columns from 2 to 11, titled "a:b", show p-value of test between a and b clusters)

Variable\ Clusters	1:2	1:3	1:4	1:5	2:3	2:4	2:5	3:4	3:5	4:5
Population per 1km^2	0,000026	0,630083	1,000000	0,000036	0,046110	0,073292	0,000000	1,000000	0,000000	0,000006
population in cities in% of the total population	0,000385	0,011873	1,000000	0,931024	1,000000	0,004056	0,000001	0,049730	0,000058	1,000000
% of population in age 0-4	1	1	1	0,003205	1	1	0,006447	1	0,073277	0,631074
% of population in age 5-9	1	1	1	0,006392	1	1	0,067322	1	0,357379	1
% of population in age 10-14	1	0,417706	0,917887	1	1	1	1	1	1	1
% of population in age 15-19	0,022917	0,000074	0,223467	1	1	1	0,009780	1	0,000051	0,091039
% of population in age 20-24	0	0,000017	0,379794	0,001531	1	0,055360	0	0,638719	0	0,000003
% of population in age 25-29	0	0,002171	1	0,000112	0,066111	0,001179	0	1	0	0,000005
% of population in age 30-34	1	1	0,558777	1	1	1	1	1	1	1
% of population in age 35-39	0,000115	1	1	0,000008	0,047961	0,001868	0	1	0	0,000494
% of population in age 40-44	0	0,018630	1	0,002990	0,080604	0,000180	0	0,348241	0	0,005234
% of population in age 45-49	0,004611	0,045670	0,932833	1	1	1	0,047556	1	0,256082	1
% of population in age 50-54	0,437357	1	1	0,884674	1	0,447016	0,005130	1	0,174725	1
% of population in age 55-59	0,018794	1	1	0,206077	0,385064	0,994277	0,000005	1	0,013059	0,052346
% of population in age 60-64	0,588289	0,274966	1	0,462634	1	1	1	1	1	1
% of population in age 65-69	0,000270	0,004486	0,170404	1	1	1	0,270742	1	1	1
% of population in age 70 and more	1	0,331649	0,269208	1	1	1	1	1	1	1
% of population in age 70-74	0,000014	0,000386	0,012623	0,315325	1	1	0,335752	1	1	1
% of population in age 75-79	1	1	1	0,810500	1	1	0,702522	1	0,119145	0,038024
% of population in age 80-84	1	1	1	1	1	1	1	1	1	1
% of population in age 85 and more	0,481963	1	1	1	0,937631	0,127609	0,156057	1	1	1
% of population in age 0-14	1	1	0,998236	0,017905	1	1	0,166293	1	0,921977	1
Approximated % of population vaccinated against COVID-19 1 August 2021	0,000994	0,154063	1	1	1	0,251513	0,002202	1	0,166014	1

Source: Authors' own.

While searching for the relationship between the type of the epidemic curve (previously determined) and other factors, the following models were tested:

- naive Bayes classifier;
- the method of k-nearest neighbors;
- decision tree(s) in various forms.

The analysis included 356 powiats (in the case of the remaining 3, there was no data on the % of population in cities). Every model was created (and analyzed) in Statistica environment.

7. Results of naive Bayes classifier

Assuming that the predictors have a normal distribution and without divided data into training and test sets - the accuracy of the classification was approximately 40.45% in total. And as below regarding clusters: 1st: 41.75%, 2nd: 39.72%, 3rd: 41.18%, 4th: 8%, 5th: 54.72%. Accuracy should be understand here as a percentage of correctly classified powiats. It is easy to notice, that the accuracy for cluster no. 4 is significantly lower than for other cluster. A similar situation can be observed in the case of trees and random forest model (described later). Probably this is due to a fact, that the cluster no. 4 is the smallest one. Total accuracy equal to circa 40% is not big in the case of the consideration of the prediction model effectiveness but it is enough to conclude that the mentioned factors are connected in some way with the shape of the epidemic curve that was the main goal of analysis.

8. Results of the method of k-nearest neighbors

To determine the k-nearest neighbors model Euclidean distance, data standardization, random test sample size of 25% and distance weighting were used. Number of neighbors (5) was chosen with cross-validation test. Accuracy in classification in test sample was approximately 40.23% And as below regarding clusters: 1st: 32%, 2nd: 37.93%, 3rd: 45%, 4th: 50%, 5th: 55.56. The total accuracy is similar as in the naive Bayes model, however noticeable differences in accuracies in case of clusters can be observed. Especially in the case of the cluster no. 4, that probably follows from the fact that in the case of the k-nearest neighbors model the size of a cluster is not as important/influential as in the naive Bayes model.

9. Results for single decision trees

The accuracy of this model is strongly depended on the parameters adopted when creating the tree (regarding its size, etc.). Trees were made in the module General Classification and Regression Trees (C&RT) in the program Statistica. The following tree creation settings/parameters/conditions were applied:

- equal cost of incorrect classification;
- the Gini measure as an indicator of goodness/suitability of fit;
- estimated a priori probability;
- FACT direct stopping as a stop rule.

The remaining parameters differed between trees: minimal capacity of the leaf, object fraction (parameter of FACT method) and maximal number of nodes. More details about creating process can be found in (TIBCO, 2017) and in sources indicated there.

In the table below (Table 5) there are accuracies of chosen trees in total and in context of concrete clusters, compiled with some parameters and number of nodes. Results regards to the training set (test set was not created in this case).

Table 5.
Accuracies of chosen decision trees

Min. capacity of the leaf	Object fraction	Max. number of nodes	1 acc.	2 acc.	3 acc.	4 acc.	5 acc.	Total acc.	Number of decision nodes	Number of end nodes/ leaves
40	0.1	15	40.91	82.93	17.44	13.64	75	46.91	7	8
30	0.1	20	62.50	43.9	55.81	29.55	75	54.49	10	11
20	0.1	50	56.82	67.07	53.49	29.55	75	57.87	13	14
30	0.05	50	64.77	67.07	56.98	45.45	80.36	63.48	20	21
20	0.05	50	64.77	59.76	68.6	45.45	80.36	64.61	22	23
20	0.01	70	72.73	62.2	69.77	47.73	80.36	67.7	35	36
10	0.01	100	79.55	84.15	79.07	52.27	80.36	77.25	50	51

Source: Authors' own.

Observation indicates that, generally speaking, the bigger tree, the better accuracy. Of course, in the same time the risk of overfitting model is increasing. The results obtained here, as in the previous models, indicate the presence of connections between the type of the epidemic curve (determined before) and other considered factors, but in this case not necessarily every factor (because some factors can be not present in a given tree).

10.Results for random forest

As in the case of a single decision tree, also in that method results were strongly dependent on the parameters adopted during creating the model. Random forests were made in the program Statistica. The following random forest creation settings/parameters/conditions were applied:

- equal costs of incorrect classification;
- number of predictors = 23 (max);
- proportion of test sample = 0.3;
- proportion for subsamples = 0.5;
- the initial value of the random number generator = 1.

The remaining parameters differed between forests: the form of determining a priori probability (equal or estimated) number of trees in forest, minimal capacity of the leaf, minimal capacity of the descendant, maximal number of levels and maximal number of nodes. More details about creating process can be found in (TIBCO, 2017) and in sources indicated there.

In the table below (Table 6) there are accuracies of chosen random forests in total and in context of concrete clusters, compiled with some parameters.

Table 6.
Accuracies of chosen random forests

Number of trees	Min. capacity of the leaf	Min. capacity of descendant	Max. number of levels	Max. number of nodes	1 acc.	2 acc.	3 acc.	4 acc.	5 acc.	Total acc.	Prob. a priori
100	8	5	10	100	56.76	43.48	40.91	0	62.5	43.86	estim.
50	10	5	6	50	56.76	65.22	27.27	0	56.25	44.74	estim.
200	5	3	15	500	43.24	52.17	45.45	0	62.5	42.11	estim.
100	8	5	10	100	48.65	56.52	31.82	6.25	68.75	43.86	equal
50	10	5	6	50	48.65	39.13	40.91	25	68.75	44.74	equal
200	5	3	15	500	51.35	52.17	40.91	6.25	62.5	44.74	equal

acc. - accuracy, min – minimum, max – maximum, estim. - estimated, prob. - probability

Source: Authors' own.

This time accuracies were checked in test set of powiats. The total accuracy was similar in every case, but accuracies in context of clusters changed significantly for other parameters of forests. It is easy to notice that for the cluster no. 4 the accuracy was always low, and not zero only when a priori probability was assumed to be equal, so it indicates that small number of powiats in this cluster can cause such situation.

11.Conclusions

1. The shape of the COVID-19 epidemic curves in most Polish powiats (during the third wave of the epidemic) corresponded to the bell curve (after the mentioned modifications). Only 21 powiats did not have such epidemic curve shape.
2. The curves can be divided into 5 types indicating the course of the epidemic in time.
3. The performed analysis allows to assume that the mentioned curve types depend in significant way on factors such as the age structure of the population, population density, % of population in cities and the approach of the population to vaccination/epidemic; if this were not the case, the accuracy of the models would not be significantly higher than circa 20% what is approximated accuracy of random selection.
4. The determined predictive models may be a tool supporting the prediction of epidemic development, but their effectiveness is moderate.
5. The performed analysis may be the basis for further, more-depth research.

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WAR IN UKRAINE AND NEW MANAGEMENT PARADIGM

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Purpose: The main aim of the article was to present an innovative management approach involving the implementation of selected features of a turquoise organization into a militarized organization (the Armed Forces of Ukraine).
Design/methodology/approach: The subject matter addressed in the article is so new and original that, in principle, there is a powerful research gap in the subject area of the author's interest. In view of the above, the content of the publication and the considerations carried out were based primarily on the author's own work, on available reports and expert opinions and on available scientific publications.
Findings: The publication makes several important findings: first, it was pointed out that there are a number of common features between command and management. Second, the basic features of a turquoise organization are presented, and an implementation of these features to an inherently authoritarian organization (the armed forces) is made. Thirdly, it was found that in view of the Russian army's multiple superiority, there must be other factors that build Ukraine's superiority, i.e. precisely, for example, management, self-motivation, responsibility, i.e. precisely the characteristics of a turquoise organization.
Research limitations/implications: The main research limitation is that the issue addressed is a new topic that has not yet been widely discussed in the literature. Moreover, the concept of implementing the features of a turquoise organization into an organization with an authoritarian character is the author's proposal on this issue - the validity of this approach is evidenced by the analysis of the armed conflict between Russia and Ukraine.
Practical implications: The concept of implementing the features of a turquoise organization into a more autocratic organization is a proposal for managers and commanders to make changes to operate more efficiently.
Originality/value: The topic addressed is new and original, not previously addressed. The article presents an original concept of using the characteristics of a turquoise organization in the process of managing organizations, even those of an authoritarian nature. The added value, after the implementation of the features and assumptions of the turquoise organization, will be, among other things, an increase in the efficiency of the organization, the asset of which will be primarily modern management of it focused on creativity and involvement of staff.

Keywords: new globalization XXI century, globalization, turquoise organizations, war, Armed Forces, management, command.

Category of the paper: Research paper.

1. Introduction

The war in Ukraine is an event unprecedented in its enormity and ruthlessness, which the civilized world could not have predicted. Unfortunately, whatever it may sound like, an armed conflict, let alone a fully-fledged war, is where military equipment, strategies, procedures and their quality are verified along with methods of command, which are highly autocratic in nature and require absolute subordination and execution of orders from superiors.

Therefore, to address the question posed in the title of this paper, first the following questions must be answered:

1. What is the relationship between command and management?
2. Can command and management be treated equally?

To answer these questions, it is necessary to define command and then attempt to find potential similarities between command and management. Commanding means planning, organizing, and controlling tasks to be performed, and motivating soldiers to perform them in line with applicable procedures, regulations, and code of conduct. Command is a basic form of managing people (the army) that is based on the authority to comprehensively shape all elements of combat readiness and capability (Maśloch, 2018). A commander is appointed to control the activities of subordinates. Such authority, derived from military law and regulation, is inextricably linked to the assumption of full responsibility for the decisions made, which cannot be transferred or delegated to others. A commander prepares and implements commanding-related tasks with the help of his subordinates or through subordinate command bodies – military staff (Grzywna, 2014).

In order to conduct considerations on the indicated topic, two working hypotheses were formulated:

Hypothesis 1: In the conditions of the new globalization of the 21st century, the directions of contemporary management will change in an evolutionary way.

Hypothesis 2: In the new global conditions of the 21st century, the autocratic style of managing organizations (e.g. in the armed forces) will change and adopt features previously reserved for turquoise organizations.

Verification of the hypotheses and answers to the previously indicated questions will be carried out based on the analysis of the situation in highly centralized organizations, i.e. in the Armed Forces of Ukraine and Russia, based on available documents, reports and other sources of information. Additionally, the main features of the turquoise organization will be indicated along with an assessment of their implementation to both sides of the armed conflict.

2. Discussion – from autocracy to turquoise

2.1. Comparison between management and command. The military potential of Russia and Ukraine

Striving for the most complete analysis of the exact topic at the beginning, we analyzed the levels of command thoroughly, from the point of view of conducting an armament campaign. It is required to connect command to management and identify the function connected to the main signal in order to answer the fundamental question: is command (could be) the same as management?

There are two important levels of command – operating level (planning and organisation of operations and definition of methods/ways to achieve a strategic goal) and tactical (planning, organising and conducting combat missions by designated units to achieve the assumed operational goal) (Maśloch, 2023). Command and management are compared in Table 1.

Table 1.
Comparison between management and command

Criterion/ Feature	Management	Command
I	**II**	**III**
Definition	Management as a whole is the process of planning, organising, directing, and controlling directed at human, financial, tangible and information resources used to accomplish organisation's goals.	Command is a basic form of managing people (the army) that is based on the authority to comprehensively shape all elements of combat readiness and capability with reference to subordinate soldiers, to prepare them in times of peace for all kinds of missions and tasks, and to guide them during the completion of tasks in times of peace, crisis and war. An order is a typical and most common instrument and measure in commanding. Commanding is a system empowering designated personnel to exercise lawful authority and direction over assigned forces for the accomplishment of missions and tasks. Such power, derived from military law and regulation, is inextricably linked to the assumption of full responsibility for the decisions made. A commander exercises authority directly (e.g., team, crew commander) and with the help of subordinate commanders (e.g., platoon commander, tank commander) or through subordinate commanding units (military staff).
Management functions	Planning, motivating, organising, controlling.	Planning, organising, controlling (the motivational function is highly restricted – a soldier must follow orders without receiving any additional incentives).
Way of giving orders	Official instruction.	Order.
Consequences of not following the instruction/ Order	Disciplinary.	Criminal – Article 343 of the Polish Criminal Code: *"Soldier who fails or refuses to execute an order or executes an order contrary to its wording shall be put in military prison or imprisoned for up to 3 years".*
Governance style	Depends on the type of the organisation, tasks or style preferred by the manager.	Autocratic.

Cont. table 1.

Hierarchy	Depends on the organisation.	Highly hierarchic.
Delegation of authority/ Responsibility	Possibility to delegate authority and responsibility to other (lower) levels of management.	Responsibility cannot be delegated – a given commander is responsible for the decisions taken.
Sources of authority	Appointment, ownership links.	Appointment.
Principles of management – transformation of classical principles of management for the purpose of command	1. Concerns people in particular. 2. Deeply rooted in culture. 3. Requires simple and clear values and goals to be shared by the whole organisation. 4. Should allow the organisation to learn. 5. Requires communication. 6. Requires an extensive system of indicators. 7. Must be clearly oriented towards the primary and ultimate goal (customer satisfaction).	1. Concerns people in particular. 2. Requires simple and clear values and goals to be shared by the whole organisation. 3. Should allow the organisation to learn. 4. Requires communication. 5. Must be clearly oriented towards the primary and ultimate goal (task completion). **In the case of command, a relevant modification should be made by eliminating principles 2 and 6 and altering principle 7.**
Behavioural approach	**Individual attitudes and behaviours of employees**	
	yes	no In commanding, there is no place for personal interpretation of tasks.
Quantitative approach	**Application of quantitative methods (e.g., operational research)**	
	yes	yes
Systemic approach	**Organisation is treated as a system of interlinked elements**	
	yes	yes
Situational approach	**Individualism of the organisation and its adaptation to a particular situation are stressed**	
	yes	yes
Management by objectives	**Improving performance by identifying priorities and tasks assigned to individual employees**	
	yes	no Soldiers' tasks and duties stem from and are governed by rules and regulations and other normative documents.
Management by delegation of authority	**Delegation of decision-making powers and related responsibility to lower management levels**	
	yes	no A commander makes decisions individually and is fully responsible/accountable for their consequences.
Management by results	**Main emphasis on results and not on a method of achieving goals and completing tasks**	
	yes	yes In the case of commanding in extreme situations (e.g., combat operations), an order must be executed, and a specific goal must be achieved, regardless of the expenses incurred.
Management by exception	**Transfer of the "management burden" to lower levels in the organisation**	
	yes	no
Fixed hours	yes	to some extent

Source: Maśloch, 2023.

As shown in the table above, management and command share many features, which allows a conclusion that modern management and command are identical. The next step after formulating such a hypothesis is to analyze the potential of the Armed Forces of Ukraine and Russia, as presented in Table 2 and Figures 1-2.

Table 2.
The military spending of Russia and Ukraine (24.02.2022)

	Ukraine	Russia	Proportions
soldiers	196 000	900 000	21,8%
reserves	900 000	2 000 000	45%
armored vehicles	3309	15 857	20,9%
combat aircrafts	132	1391	9,5%
helicopters	55	948	5,8%
submarines	0	49	-
expenses	4,79 mld USD	45,8 mld USD	10,3%

Source: Own elaboration based on: www. Businessinsider.com.pl

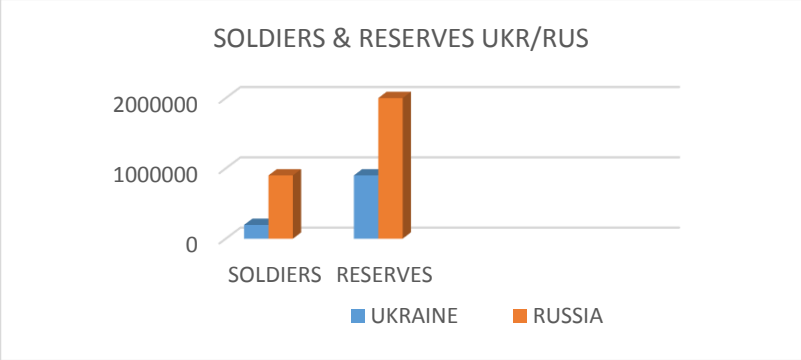

Figure 1. Soldiers & reserves – Ukraine and Russian Army Forces.

Source: Own elaboration based on: www. Businessinsider.com.pl

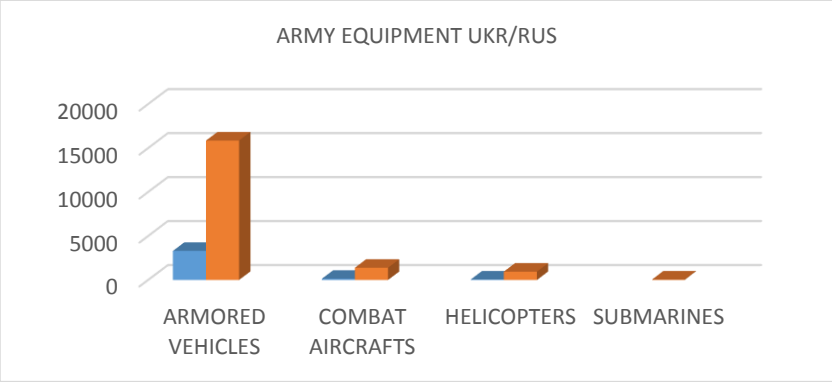

Figure 2. Equipment – Ukraine and Russian Army Forces.

Source: Own elaboration based on: www. Businessinsider.com.pl

As the data presented in Table 2 and Figure 1-2 shows, Russia has a much larger number of soldiers and equipment, and the amounts spent on average annually on the army in Ukraine are only one tenth of the Russian budget for the same purpose. As the data presented show, the difference in military potential between the parties to the conflict is huge, theoretically Ukraine had no chance in a direct military confrontation. An important aspect of the ongoing considerations is the fact that the potential of the countries is taken into account at the time of the outbreak of the conflict, when the Ukrainian side did not have the help of Western countries in terms of supplies of modern equipment and army training. Given the above, important questions arise regarding what really determined Ukraine's success, despite the overwhelming military advantage of the aggressor state? When trying to answer this question, we should return to the implementation of management processes into the structures of the Armed Forces presented in Table 1 (correlation between command and management processes).

2.2. The concept of the turquoise organization and the Armed Forces of Ukraine

Based on the analysis carried out, it should be concluded that the modern Armed Forces are an organization that needs to be managed, which takes over some features of the turquoise organization. However, in order to indicate the evolutionary nature of organization management, it is worth mentioning the most important features of individual colors assigned to the organization management style (the so-called concept of color organizations). A summary of the most important features of colored organizations is presented in Table 3.

Table 3.
Characteristics of management paradigms by metaphor, description, "glue", key breakthroughs, hierarchy, authority and perspective

	RED	AMBER	ORANGE	GREEN	TURQUOISE
Metaphor	Pack of wolves	Army	Machine	Family	Living organism
Description	Permanent coercion as a management tool; high reactivity; surviving in a chaotic and dangerous environment as the main goal.	Rigid hierarchy and strict procedures; stability; highly formalised and hierarchical structure; beating the competition as the primary goal.	Company is a goal-oriented machine; competition; profit orientation; innovation; top down command and control; beating the competition as the ultimate goal.	Challenging the formalised and hierarchical structure – the leader is no longer a dictator and becomes a mentor; focus on work culture and empowerment to motivate employees; stakeholder orientation.	Self-management instead of hierarchy; no positions or supervisors (line managers); the organisation is a living organism with its own creative potential and evolutionary purpose; flexibility as a response to the complexity and variability of the environment.

Cont. table 3.

"Glue"	Fear and aggression.	Hierarchy, procedures and roles in the organisation.	Top down command and control (goals, strategy).	Organisational culture, shared values.	Employees free to use their potential.
Key breakthroughs	Survival is key – use of power, fear, submission, division of labour, command authority.	The world as a circle of events; norms; authority; rigour; fixed processes and formal roles; clear hierarchies and structures.	Management by objectives; competition; profit orientation; freedom; pursuit of own goals; innovation and innovativeness; accountability; meritocracy.	Empowerment; integrity; equality; customer satisfaction; relationships above profits; decentralisation; values; inspiring goals; stakeholder model.	Taming the fear of ego; trust; accountability; intuition; good life as a source of success; self-management; wholeness; evolutionary goal.
Hierarchy	Formal authority of the leader; organised groups.	Rigid rules laid down by the leader.	Leader is not the most important, what matters are employees' competencies.	Retained pyramidal structure, but employees also matter.	No hierarchy – people matter the most.
Authority	In the hands of one person; direct.	Linked to a role.	Partly linked to a role; competencies as an alternative source of authority.	Distributed – the main goal is to pursue the interests of different groups.	No authority – self-decision and self-management.
Perspective	short-term	long-term	long-term	long-term	long-term
Examples	Crime syndicates, Mafia, street gangs, and tribal militias.	Catholic church, military, government agencies, public schools.	Multinational companies, banks.	NGOs, new corporations.	New, pioneer teal organisations.

Source: Author based on: Laloux, 2015.

C.W. Graves speaks in a similar tone – he proposes a few levels of consciousness (evolution of organisation paradigms based on levels of consciousness by C. W. Graves - Figure 3).

The previously indicated disproportions in the number of people and equipment of the Ukrainian and Russian armies indicate that - at least theoretically - Ukraine has no chance in this conflict. This is not happening - Ukraine, despite Russia's multiple advantage, Ukraine undertakes an effective confrontation. Therefore, the success of the Ukrainian Army is determined by other factors, such as motivation, patriotism and the way of managing the armed forces. Management, not traditional, autocratic command. Based on the analysis of the data in Table 1, it should be concluded that the indicated management features are identical to the features of the turquoise organization, which means that some of these features are implemented into the hierarchically organized armed forces of Ukraine.

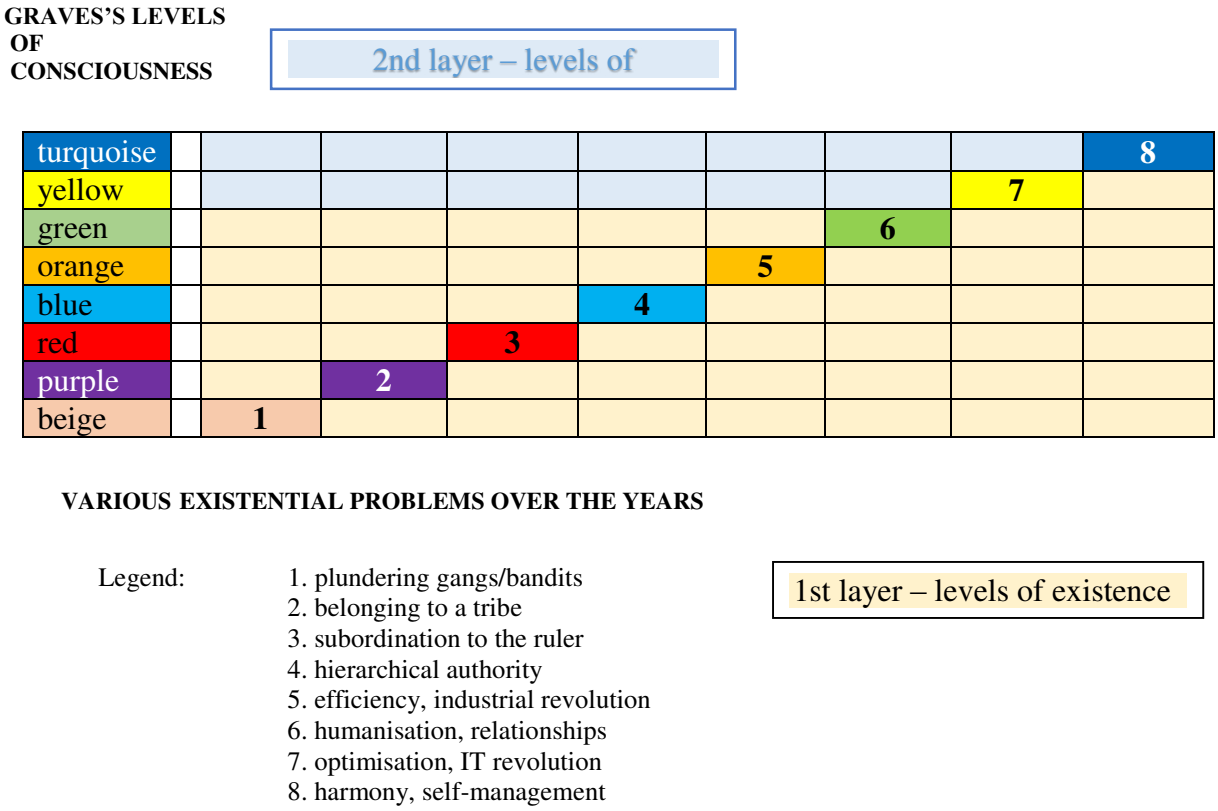

Figure 3. Evolution of organisation paradigms based on levels of consciousness by C.W. Graves. Source: Author based on: Graves, 2005; Grzywna, 2014.

3. Summary

The contemporary global world of the 21st century, a world characterized by an unprecedented pace of technological development, a world in which numerous phenomena, which were previously impossible to predict, have necessitated the redefinition of many previously assumed unchangeable paradigms. Such phenomena include trends related to the implementation of the principles and features of turquoise organizations in favor of organizations managed in an authoritarian manner. Such implementation is clearly noticed when analyzing military activities on the Ukrainian-Russian front. In view of the above, it should be emphasized that the hypotheses put forward at the beginning have been fully confirmed, which is further evidenced by the situation on the front mentioned above, where we have a modernly managed, motivated Ukrainian army versus an autocratically and harshly commanded, demotivated Russian army.

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GREENWASHING AND CORPORATE ENVIRONMENTAL IRRESPONSIBILITY – IMPROPER PRACTICES OF COMPANIES

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Purpose: To identificate factors prompting companies to undertake activities bearing the hallmarks of greenwashing, and to indicate the link between these activities and the concept of corporate environmental irresponsibility.
Design/methodology/approach: The purpose of the article was achieved through a critical analysis of the literature on greenwashing and corporate environmental irresponsibility. In addition, data provided by Eurostat on gross value added for total environmental goods and services sector for the 27 countries of the European Union from the years 2000-2019 were analysed.
Findings: The concept of corporate social irresponsibility is common in the context of immoral and dishonest corporate behaviour. By acting in a socially irresponsible manner companies want to make quick profit, and they do not see the role of socially responsible actions as crucial. In this context corporate social irresponsibility is similar to the concept of greenwashing. Socially irresponsible companies, however, do not intend to "deceive" consumers and "artificially" create an image of socially responsible companies, which is very characteristic of greenwashing practices. The article identifies the most important reasons for greenwashing activities, relating to companies' internal and external motives. The article also presents ways to prevent greenwashing activities, undertaken both at the company level and at the level of superior institutions.
Originality/value: The article systematizes knowledge about the greenwashing practices of companies. Also, links between these practices and the concept of corporate environmental irresponsibility are indicated.

Keywords: Corporate social responsibility, corporate environmental irresponsibility, greenwashing.

Category of the paper: General review.

1. Introduction

Pro-environmental business practices have become an important competitive advantage in the 21st century. They help build a positive company image as the key element of a business strategy. The increased interest in pro-environmental activities (or activities that are safe to the environment) is a direct result of the implementation of sustainable development principles and the development of the concept of corporate social responsibility. Unfortunately, the positive effects of pro-environmental activities are usually immeasurable, unlike the costs of their implementation, which are among the basic indicators of the business effectiveness of a business. Companies therefore often reach for practices aimed at giving the customer the impression that the product they are purchasing was created with environmental principles in mind. Although such practices lead to the development of the company and improve its economic efficiency, they are against the common principles of corporate social responsibility.

The article discusses the factors prompting companies to undertake activities bearing the hallmarks of greenwashing, and points out the link between these activities and the concept of corporate environmental irresponsibility.

2. Theoretical background

2.1. Increasing need among businesses to be seen as "green"

Market effects are primarily reflected in external results. Customers know that by accepting the offer of a company whose activities do not harm the environment they will incur lower costs associated with environmental degradation, which is why they are likely to reject less environmentally friendly products by the competition. Customers are also a significant source of environmental pressure, which forces changes in manufacturing processes. Because of that companies wish to meet consumer expectations connected with product environmental footprint. To do that they increase their green operations by applying environmental criteria in the production of goods and services. Companies implementing environmentally friendly practices make up the environmental goods and services sector. The main goal of these companies is to help protect the environment by offering green products that do not impact the environment. Gross value added describes the increase in the value of goods over a given period. It is the most accurate measure of the economic effect of a sector. The increase in gross value added indicates an increase in the role and importance of the environmental goods and services sector. Table 1 present the gross value added dynamics for total environmental goods and services sector in million euro in the 2000-2019 period.

Table 1.
Gross value added dynamics for total environmental goods and services sector in million euro in the 2000-2019 period

Economic activities	Dynamics measures			
	Dynamics index for the year 2010 (2000 = 100%)	Dynamics index for the year 2019 (2010 = 100%)	Dynamics index for the year 2019 (2000 = 100%)	Average annual rate of change
Total - all NACE activities	179.94%	140.86%	253.47%	5.02%
Agriculture, forestry and fishing	199.63%	195.30%	389.86%	7.42%
Mining and quarrying; manufacturing	214.45%	107.88%	231.35%	4.51%
Electricity, gas, steam and air conditioning supply; water supply; sewerage, waste management and remediation activities	169.99%	148.15%	251.85%	4.98%
Construction	212.13%	154.99%	328.77%	6.46%
Services	153.42%	123.36%	189.27%	3.41%

Source: Eurostat database.

While the average annual rate of change in the years 2000-2019 for all specified economic activities in terms of gross value added for the total environmental goods and services sector is small, ranging from 3.41% to 7.42%, a significant increase in this respect can be observed in 2010 compared to 2000. Gross value added for mining and quarrying, manufacturing increased in 2010 by as much as 114.45% compared to 2000. A similar increase of 112,13% is observed for the construction sector. All economic activities have seen significant growth in gross value added in the consecutive years. The largest increase in gross value added in 2019 compared to 2010 can be observed for agriculture, forestry and fishing (95.30%) and construction (54.99%). Analysing the dynamics of gross value added for the total environmental goods and services sector in 2019 compared to 2000, the largest growth is observed for agriculture, forestry and fishing (289.86%) and construction (228.77%) Progressive greening is therefore visible across all activities, but most clearly in the construction sector.

2.2. Defining greenwashing

Greenwashing is considered a tool for the promotion of business (Huang et al., 2022). It helps establish relationships with stakeholders by creating an environmentally friendly image of the company. Unfortunately, greenwashing is an activity motivated by opportunistic goals, focusing on economic rather than environmental consequences. Greenwashing activities focus public attention not on the environmental damage caused by corporations, but on their minimal efforts to protect the environment (Megura, Gunderson, 2022).

The goal of greenwashing activities is to achieve economic benefits through presenting the offer of a company as environmentally friendly to customers who are increasingly interested in such products. Greenwashing, however, is effective only if consumers are unaware of the fact that they are deceived. This is supported by studies which have shown that while environmentally focused actions do not correlate with a company's financial performance,

revealing the use of "fraud and hypocrisy" strategies impacts them negatively (Walker, Wan, 2012). Customers and other stakeholders lose trust in companies that use dishonest practices in the context of pro-environmental declarations (Lee, Suh, 2022; Remme et al., 2022). It is pointed out that greenwashing does bring benefits, but only short-term, while fines imposed by NGOs and consumer opposition can be long-term (Koseoglu et al., 2021).

Greenwashing is also referred to as „SDG-washing" (Johnsson et al., 2020), which clearly indicates the negative nature of these activities in the context of achieving Sustainable Development Goals (SDGs). Thus, greenwashing emphasizes the gap between a company's market image in terms of corporate social responsibility principles and its actual sustainability efforts (Dixon 2020). Under the guise of implementing socially responsible business principles, companies pursue their business goals aimed at improving their image or making or increasing profits (Toussaint, Cabanelas, González-Alvarado, 2021).

2.3. Corporate social responsibility vs. corporate social irresponsibility in the activities of enterprises

Thinking only in terms of profitability has proven insufficient in evaluating a company due to the fact that it also operates in spaces other than just economic. The increasing importance of environmental protection and the well-being and health of the society has translated into the development of the concept of corporate social responsibility (CSI), which contributes to the realization of sustainable development goals at the corporate level. Unfortunately, companies are more focused on sustainability goals that are aimed at "avoiding harm" rather than those that are aimed at "doing good". The extent of the actual "sustainability goal" in the context of a corporate sustainability assessment depends on the underlying motive for conducting the assessment (Johnsson et al., 2020). It is therefore important to consider striking a balance between "doing good" and "avoiding bad" (Siano et al., 2017). The social effects of the functioning of enterprises should therefore (Salaiz et al., 2020):

1. carry out activities that benefit the society, i.e., act in accordance with the principles of corporate social responsibility, and
2. avoid, prevent, reduce or mitigate inappropriate behavior that harms society, i.e., prevent corporate social irresponsibility.

It can be concluded that social responsibility should go hand in hand with the prevention of social irresponsibility, which requires the involvement of various company resources. Until now, the two concepts of corporate social responsibility and corporate social irresponsibility have been viewed and developed independently of each other. They should, however, be integrated to facilitate the development of a more general normative theory that promotes a wider range of universal criteria translated into global standards of business practice (Windsor, 2013).

Corporate social irresponsibility (CSI) does not bring positive consequences for companies. It can be argued that it actually has a negative impact on corporate performance by causing a decrease in the value of the company resulting from the loss of positive stakeholder relationships. When customers become aware of socially irresponsible behavior, they stop purchasing products offered by the company. Social irresponsibility can therefore lead to a loss of reputation and tarnish the company's image, resulting in lower revenues (Price, Sun, 2017) and poorer corporate financial performance (Chen et al., 2018). The results of empirical studies show that CSI-oriented activities have a longer effect than CSR-oriented initiatives, and that companies with little implementation of CSR and CSI achieve better results than companies heavily involved in CSR or CSI. The results of this research are therefore not very optimistic, and show that it is not worth concentrating all resources in efforts to increase environmental friendliness, but rather settle for activities which are just enough to simply avoid harming the environment.

The nature of business irresponsibility nevertheless determines the behavior of the public, which reacts more negatively to the actions of companies that blatantly violate accepted rules and regulations (Teng, Yang, 2022). The market reaction to punish socially irresponsible businesses is characteristic of liberal markets, whose consumers, through a system of penalties and rewards, want to stimulate companies to act in a socially responsible manner (Jasinenko, Christandl, Meynhardt, 2020). Actions, which can confirm and be part of corporate social irresponsibility, represent a risk connected with the loss of trust, support and positive perception of the company by all its key stakeholders (Harjoto, Hoepner, Li, 2021).

Corporate social irresponsibility occurs when an action taken is unethical from the point of view of the decision-maker's personal values or when it produces results that are worse than other actions in the long run (Armstrong, Green, 2013). Considering long-term profit or long-term viability when planning operations is one of the factors preventing corporate social irresponsibility, which significantly reduces the performance of companies in the long term (Zhong, Chen, Ren, 2022). The planned activities should also promote fair treatment of all stakeholders.

Both socially responsible and socially irresponsible behaviours are influenced by different attitudes and intentions of stakeholders, which are part of open relationships (Pereira et al., 2021). CSI is not the exact opposite of CSR as CSI focuses more on maintaining lasting relationships with stakeholders, while CSR helps build such relationships (Harjoto, Hoepner, Li, 2022). It also remains questionable whether consumers, who prefer socially responsible companies, will tend to punish the ones that are socially irresponsible (Valor, Antonetti, Zasuwa, 2022). The research shows that consumers are more likely to notice socially irresponsible actions, especially in relation to large companies (Jung, Bae, Kim, 2022). Additionally, uniform social and environmental standards implemented across all partners working together in the supply chain translate into positive results. This is because the irresponsible actions of one partner can contribute to undermining the intangible assets of the

entire supply chain, such as corporate trust, corporate image, attitude toward the firm, and word-of-mouth intention (Nunes, Park, Shin, 2021).

The concept of corporate social irresponsibility usually appears in the context of a range of immoral behaviours associated with business. Companies operating in a socially irresponsible manner are primarily profit-driven, and although they operate with legal requirements in mind, they do not see the role of socially responsible activities as crucial (Murphy, Schlegelmilch, 2013). This approach is close to the concept of greenwashing. However, it should be noted that socially irresponsible companies do not try to "deceive" consumers and "artificially" create an image of socially responsible companies.

3. Causes of greenwashing and methods to prevent it

3.1. Determinants of greenwashing

Dishonest behaviour of companies is similar to dishonest behaviour of individuals, but the former is much more criticized (Jauernig, Uhl, Valentinov, 2021). The moral evaluation of deliberate actions which are misleading when it comes to someone's true intentions and of gaining benefit from these actions by both individuals and companies is driven by essentially the same psychological mechanisms. Unfair practices of companies were evaluated much more harshly than those of individuals, which results from the perception that the extent of immorality of companies exceeds that of individuals. The public perception of deception contributes to the condemnation of the violation of material norms. Four motives for deceptive behaviour of companies can be distinguished (Jauernig, Uhl, Valentinov, 2021):

1. adopting a moralizing attitude, invoking moral principles by, among other things, stating principles or ideals explicitly and clearly, or by signalling a willingness to follow the rules of a particular social practice,
2. failing to meet moral principles in at least one case,
3. attempting to hide the inconsistency between accepted moral principles and actual actions, which results in deceiving stakeholders through deliberately failing to adhere to the moral promises made in order to increase profits.

Because the environmental focus of businesses is desired by buyers, thinking only in cost-benefit terms can pave the way for greenwashing activities. If the cost of improving a company's environmental performance outweighs the benefits, and if the company's green image is desired or expected by buyers, greenwashing activities can help the company to maintain economic efficiency (at least in the short term), all the more so because greenwashing activities are not only an actual fraud, but also shallow CSR practices, or the implementation of environmental policies at a minimum level (Gatti, Pizzetti, Seele, 2021). Companies with poorer performance

in terms of socially responsible activities are more likely to be involved in greenwashing (Karaman et al., 2021). What is more, companies often report only those results related to their environmental responsibility that are favourable to them, omitting the ones that indicate their actual negative environmental impact (Arouri, Ghoul, Gomes, 2021; Zhang, 2022b). This is because companies involved in greenwashing publish their CSR reports primarily in order to let their stakeholders perceive the company as addressing social and environmental issues (Mahoney et al., 2013).

Unfortunately, in the period of the green transformation there is a lot of pressure from government institutions to reduce negative environmental impacts. It has been observed that the impact of environmental regulations on product quality motivates companies to resort to greenwashing. This is because companies create their strategic actions to merely meet pressure from the government and competitors, rather than to actually prevent environmental pollution (Zhang, 2022a).

The participation of all kinds of organizations in various certification schemes is also controversial. Helping companies present their products as environmentally friendly contributes to greenwashing (Flagstad, Hauge, Johnsen, 2022). Certification is an attractive prospect not only for international NGOs trying to solve environmental problems in global supply chains (Partzsch, Zander, Robinson, 2019), but also for the companies themselves, for whom certification can confirm their pro-environmental activities. The need to prove one's environmental performance is characteristic especially of companies operating in sectors with the greatest environmental impact (Heras-Saizarbitoria, Arana, Boiral, 2015). Numerous research shows, however, that environmental certification has a positive influence on the market value of businesses (Bernard, Nicolau, 2022; Wen, Lee, 2020), because consumers prefer certified products (Valenciano-Salazar, André, Soliño et al., 2021). Delmas and Gergaud (2021), using wine as an example, tested the impact of eco-labels on the assessment of the product quality by experts. The analysis covered the quality assessments of wines with organic and biodynamic labels issued by third parties, and the quality assessments of wines with organic labels declared by producers but without third-party certification. The results indicated that experts rated the quality of wines with eco-labels without third-party certification lower than the quality of wines with such certification. This means that labelling products with eco-labels without third-party certification may be associated with "greenwashing" and thus reduce the value of certification.

The factors which drive greenwashing are financial pressures and the desire to achieve a rapid profit growth. However, it should be remembered that in order to achieve long-term sustainability a company needs to avoid profit growth in the short term in favour of a long-term development involving systematic and slow growth, make financially prudent choices of business practices, and reorganize key strategic capabilities and resources (Liedong et al., 2022).

Greenwashing is also fostered in environments characterized by lower levels of economic development. Greenwashing in emerging markets is significantly different from that in developed countries due to differences between the functioning of these two spaces (Huang et al., 2020). In developing countries, brown enterprises have a cost advantage over pro-environmental enterprises. In addition, consumers in emerging markets are far less environmentally aware than customers in developed markets. Studies have shown that consumers with poorer knowledge about environmentally friendly products are more vulnerable to greenwashing (Guyader, Ottosson, Witell, 2017). Also, the lack of government regulation to prevent greenwashing activities in developing countries makes them easier to conduct, often without criminal consequences.

Vulnerability to greenwashing also depends on the society's personality traits. Societies placing more emphasis on their image than on implementing real pro-environmental policies are more susceptible to greenwashing (Cislak et al., 2021).

The search for ways to prevent greenwashing is a difficult task, requiring a multifaceted view of the problem. This is because different approaches to solving the problem of greenwashing are needed depending on the type of economy, the organizational culture of companies, legal and administrative solutions in a given country, and the awareness of buyers. Solutions should also be sought at the levels of the management of a business and the economy as a whole.

3.2. Methods to prevent greenwashing activities of enterprises

Due to the negative meaning of greenwashing, it is difficult to analyse its level and the way it is used by enterprises, which makes it harder to find effective methods to solve the problem of greenwashing. However, the subject literature presents some attempts to develop indicators that measure the scale of greenwashing behaviour in enterprises in order to determine the methods to prevent it. It was found that the prevention of greenwashing can be strengthened through the following four mechanisms (Yu et al., 2021):

1. increasing the number of independent managers,
2. increasing the number of institutional investors,
3. reducing the level of state corruption,
4. cross stock exchange.

Companies which come under greater scrutiny are less likely to engage in greenwashing. The four mechanisms that can support enterprises in not engaging in greenwashing activities given by Yu et al. (2021) can be implemented in large enterprises with high market capitalization.

Enterprises can improve their environmental performance through the implementation of environmental management control systems and proactive policies (Nishitani et al., 2021). Unfortunately, assessing a company's environmental performance solely on the basis of the

cost-benefit ratio leads to the discontinuation of the environmental management control system, which results in the deterioration of the environmental performance.

Ways to reduce greenwashing are sought continually, not only at the microeconomic level, but also at the macroeconomic level. It was proposed, for example, that greenwashing could be prevented by the introduction of stricter criteria for issuing all kinds of certifications and ecolabels (Popescu, Hitaj, Benetto, 2021). Studies have shown that only "dishonesty list disclosure" and "unified green certification" can effectively prevent greenwashing activities, and that they must be supported by government regulations (He et al., 2020). Therefore, the phenomenon of greenwashing is more often observed in the manufacturing sector than in the services sector (Baldi, Pandimiglio, 2022), which means that the activities of manufacturing companies are more often monitored by government organizations.

Another way to combat greenwashing is subsidizing consumers who purchase environmentally friendly products. Unfortunately, it is not easy to ascertain that a product is environmentally friendly, which is why factors indicating proper pro-environmental practices of manufacturers are, for example, product price or company profit (Ki, Kim, 2022).

Measures leading to the reduction of greenwashing are also taken within the framework of European Union regulations. It was noted as early as at the beginning of the 21st century that in order to avoid greenwashing the European Union needed to operationalize its commitment to sustainability and move beyond rhetoric (Lightfoot, Burchell, 2004). On 18 June 2020 the European Parliament and the Council adopted a regulation to create the world's first classification system - a "green list" for sustainable economic activities, or a taxonomy. The regulation outlines a general framework for the gradual development of an EU-wide classification system for environmentally sustainable economic activities in relation to six environmental goals:

1. mitigating climate change,
2. adopting to climate change,
3. sustainable use and protection of water and marine resources,
4. transition to a closed loop economy,
5. pollution prevention and control,
6. protection and restoration of biodiversity and ecosystems.

One of the goals of the regulation is to protect private investors and consumers by preventing "green pseudo-marketing", i.e., greenwashing. Support for the European Commission in developing a social taxonomy is to be provided by the draft report on an expanded taxonomy to support economic transformation. The project includes recommendations including, among others (Regulation (EU) 2020/852):

- encouraging increased funding to urgently move away from activities that are significantly harmful to the environment;
- identification of economic activities that significantly harm environmental sustainability goals and defining economic activities that do not significantly affect them;
- identification of future economic activities for which there is no technological way to improve their environmental performance in order to avoid significant environmental damage;
- economic activities that cause significant environmental damage, which cannot be technologically improved, should be considered as activities that significantly harm environmental objectives from a technical point of view;
- developing technical criteria for the potential "decommissioning" of electricity generation activities using solid fossil fuels and other activities for which it is not technically possibile to improve their environmental performance;
- making it mandatory for companies to participate in a labeling/certification process (e.g., the EU environmental certification system, EMAS) to ensure minimum environmental performance as a prerequisite for reporting activities that do not have a significant impact on environmental sustainability goals;
- working out ways in which activities that do not cause significant environmental damage can access green financing;
- developing a taxonomy of economic activities most at risk of needing transformation due to their current negative impact on the environment (brown taxonomy).

Developing methods to prevent greenwashing will only be half the battle if effective mechanisms for implementing these methods in companies are not found. Only understanding on the part of business executives that taking measures to foster environmental protection is not a cost but an investment can bring satisfactory results in this regard.

4. Summary

The development of pro-environmental civilization ensures higher quality of life. It can be achieved through taking real action to serve the environment. The proper functioning of enterprises is mainly assessed on the basis of such criteria as revenue, costs, quality and price of the product offered. The tasks related to the reduction of the negative impact of the implementation of basic activities on the natural environment and the creation of social well-being stand in opposition to the economic goals. Given the fact that customers make their purchasing decisions not only on the basis of price and quality, but also the degree of a product's impact on the environment and, indirectly, on the well-being and health of the society, offering

a responsible product, the construction and distribution of which also takes into account environmental standards and requirements, is becoming a fundamental challenge for enterprises. Unfortunately, environmental measures only bring benefits in the long term, prompting companies to implement practices that give the appearance of pro-environmental behaviour in order to gain benefits in the short term as well. Such practices are called greenwashing.

The article points out the causes of greenwashing activities such as: the desire to achieve a rapid increase in profit in the short term, the need to meet the state environmental requirements, targeting buyers' expectations in terms of certificates obtained. The propensity for greenwashing activities is also determined by the level of economic development and social awareness. The methods of preventing greenwashing should also be subordinated to its causes. These methods can be implemented both at the level of an enterprise, for example through the implementation of an environmental management control system and proactive policies. Solutions to the problem of greenwashing can also be macroeconomic and take the form of regulations, such as an EU-wide classification system for environmentally sustainable economic activities in relation to environmental goals.

Businesses know that greenwashing activities can lead buyers to lose trust in the brand. Rather than changing their behaviour to eliminate greenwashing, companies often focus on developing a brand repair strategy, for example through improving brand legitimacy (Guo et al., 2018). This raises the following question: does the possibility to regain the trust of customers by companies using greenwashing hinder the elimination of this type of behaviour? Is the development of a strategy to repair the company's image an obstacle to undertaking true environmental sustainability activities? These questions open further areas for research on the problem of greenwashing and set further directions for finding solutions to it.

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THE VERIFICATION OF THE APPLICATION OF THE TMAI METHOD FOR SELECTING COMPANIES FOR THE INVESTMENT PORTFOLIO DURING THE COVID-19 PANDEMIC

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Purpose: The aim of the conducted research is to examine the effectiveness of portfolios composed of companies classified using the taxonomic measure of investment attractiveness TMAI in the following quarters in the years 2018-2023.
Design/methodology/approach: To achieve the goal, the TMAI measure was used, which allows for the assessment of the examined objects and their comparison in terms of the analyzed phenomenon**.**
Findings: The analysis carried out allowed for the creation of rankings of companies in terms of their financial situation and the construction of portfolios based on these rankings. The TMAI measure allowed for the identification of a group of companies forming portfolio 4, which allows systematically to obtain a higher rate of return than the reference portfolio. The outbreak of the Covid-19 pandemic and the wars in Ukraine significantly influenced the rates of return of investment portfolios. In the case of the strongest restrictions related to the pandemic, portfolio 5 brought positive rates of return. The study showed that during the period under review, the highest-rated companies did not create portfolios with the highest rate of return, but limited to the first 3 quarters of the pandemic, these portfolios achieved the highest rates of return.
Research limitations/implications: The financial condition of a company, estimated using the TMAI measure, is a variable that is not directly measurable. Its value is generated by observations of diagnostic variables that are directly measurable. The choice of diagnostic variables is a subjective choice of the researcher and should be carried out reliably, preceded by a study of the relevant literature.
Practical implications: The proposed method of assessing companies allows you to indicate a portfolio that systematically gives a better result than the reference portfolio containing all the analyzed companies. The existence of such a portfolio allows the use of TMAI for the initial selection of companies for the portfolio.
Social implications: What will be the impact on society of this research? How will it influence public attitudes? How will it influence (corporate) social responsibility or environmental issues? How could it inform public or industry policy? How might it affect quality of life? Not all papers will have social implications.

Originality/value: Showing that the use of the TMAI method to assess the financial condition of companies is possible and allows their classification in terms of building an investment portfolio even in "difficult" times, i.e. the COVID-19 pandemic. The article, the use of the method is useful for entrepreneurs and investors.

Keywords: TMAI measure, linear ordering, investment portfolio.

Category of the paper: research paper.

1. Introduction

The outbreak of the COVID-19 pandemic was a shock for the global economy, and its consequences in the form of restrictions, restrictions and sanitary regimes were and still are felt in various sectors of the economy. Emotional factors accompanying the pandemic also have a significant impact on investors' decisions on financial markets. The taxonomic measure of investment attractiveness TMAI proposed by W. Tarczyński (1994) is a linear ordering method based on a synthetic variable. Its values are estimated on the basis of financial indicators describing the examined companies. The estimated values of the synthetic variable allow for ranking companies in terms of their financial condition. In this article, such rankings of companies will allow them to be assigned to one of five quantile portfolios, the structure of which will not be optimized.

The selection of appropriate financial indicators allows for the assessment of the analyzed companies in terms of portfolio construction. Research conducted by Łuniewska (2003), Tarczyński (2004), Węgrzyn (2013a, 2014), prove that a synthetic development measure such as TMAI allows for the accurate selection of companies for the optimal portfolio. When constructing the TMAI measure, Tarczyński and Łuniewska (2003) take into account four areas of the company's activity, i.e. profitability, debt level, liquidity and management efficiency. In addition to the nominal values of financial indicators, Węgrzyn (2013b, 2015) also considers the dynamics of selected indicators. In 2017, Tarczyński and colleagues proposed measuring the fundamental strength of a company using the scoring method. This approach does not require standardization of diagnostic variables, but depending on the range in which the variable is located, it receives a specific number of points. In turn, Lisek and Luty (2019) propose simplifying the classic TMAI measure by using less data. Their index eliminates the influence of extreme and unusual values on the linear ordering of the examined objects. Moreover, Tarczyński's (1994) research on the stability of the TMAI measure over time shows that company rankings prepared using this measure are stable over time.

The constructed quantile portfolios will enable the achievement of the aim of the work, which is to assess the effectiveness of investment portfolios composed of companies included in the Wig30 and mWIG40 indices listed on the Warsaw Stock Exchange. In this way, an attempt will be made to answer the question whether using the TMAI measure during the

pandemic and immediately after it, it is possible to build an optimal portfolio that gives better results than the reference portfolio composed of all the analyzed companies. To assess the effectiveness of companies, the expected rate of return, realized rate of return, portfolio risk and the Sharpe ratio will be used.

2. TMAI measure

TMAI is a linear ordering method. The linear ordering procedure includes the following stages: determining the nature of variables, determining variable weights, normalizing variables, determining pattern coordinates in the case of pattern aggregation, patternless or pattern aggregation, classification of ranked objects and recognition of development types (Bąk, 2016).

The construction of TMAI is based on estimating the distance of each object from the reference object using the formula (Tarczyński, 2002):

$$d_i = \left[\frac{\sum_{j=1}^{m} \left(y_{ij} - y_{0j} \right)^2}{m} \right]^{1/2}, \quad i = 1, ..., n, \tag{1}$$

where:

d_i - distance of the i-th object from the pattern object,

y_{0j} - pattern object given by following formula.

$$y_{0j} = \max_i \{ y_{ij} \}, \tag{2}$$

where: y_{ij} , m – as above.

The final step is TMAI normalization:

$$TMAI_i = 1 - \frac{d_i}{d_0}, \quad i = 1, ..., n, \tag{3}$$

where:

$TMAI_i$ - a taxonomic measure of the attractiveness of the i-th object,

d_0 - a standard ensuring that $TMAI_i$ accepts values in the range $[0,1]$,

$$d_0 = \bar{d} + 2S_d, \tag{4}$$

where: $\bar{d}, S_d$ - arithmetic mean and standard deviation d_i.

3. Empirical analysis

The study covered companies listed on the Stock Exchange in Warsaw, included in the indices: WIG30 and mWIG40, in the period from October 1, 2018 to March 31, 2023. Companies from the financial sector and companies that were not listed during the entire period under consideration or had missing data were excluded from the study. 51 companies were qualified for the study (Table 1).

Table 1.
List of companies participating in the study

Amica	Ciech	Enea	Kety	PGE
Amrest	CIGames	Energa	KGHM	PKNOrlen
Asbis	Comarc	EuroCash	KrukSA	PKPCargo
Assecopol	Cormay	Forte	LiveChat	Playway
Azoty	CyfPolsat	GPW	Mercator	Polimex
Benefit	Datawalk	Grenevia	Mobruk	Stalprod
Bogdanka	Develia	GTC	Neuca	Tauron
Boryszew	DinoPL	Intercars	OrangePL	Trakcja
Budimex	Domdevel	JSW	Pak	TSGames
Bumech	Echo	Kernel	Pep	VRG
CDProjekt				

The study used financial indicators from the Notoria database: operating profit margin, gross profit margin, net profit margin, return on equity (ROE), return on assets (ROA), current ratio, quick ratio, increased ratio liquidity, receivables turnover, inventory turnover, operating cycle, liabilities turnover, cash conversion cycle, current assets turnover, asset turnover, asset coverage ratio, debt ratio.

For each company, the above-mentioned financial indicators were taken into account for each quarter in the period October 1, 2018 - April 1, 2023 (18 quarters), on the basis of which synthetic measures were determined. Then, for each quarter, companies were sorted in the TMAI ranking, based on which they were classified into one of five portfolios according to the rule:

- Portfolio 1 – 20% of the highest-ranked companies in the TMAI ranking (positions 1-10),
- Portfolio 2, Portfolio 3 and Portfolio 4 – companies that were placed in subsequent positions and were not included in the portfolio with a higher number, i.e. positions 11-20, positions 21-30 and positions 31-40, respectively,
- Portfolio 5 – remaining lowest-ranked companies, positions 41-50.

In each quarter in the period from October 1, 2018 to March 31, 2023, 5 proportional portfolios were built, the portfolio structure was not optimized (90 portfolios in total). Each portfolio was purchased on the 1st day of the quarter and sold on the 1st day of the following quarter at closing prices. A reference portfolio was also built, i.e. a proportional portfolio containing all companies covered by the survey in a given quarter (18 portfolios). To assess the effectiveness of the portfolios, the following factors were used: expected rate of return, portfolio risk, realized rate of return and Sharpe ratio. Since the estimation of the Sharpe ratio requires knowledge of the risk-free interest rate for each period, its value was assumed at the level of the WIBOR 3M rate on the date of construction of subsequent portfolios.

Table 2 presents the expected rates of return for portfolios built on the basis of individual rankings in subsequent quarters of 2018 - 2023. Expected rates of return that were higher than the expected rate of return of the reference portfolio in a given quarter are marked in bold.

Table 2.
Expected rates of return of the constructed portfolios

	Q4.2018	**Q1.2019**	**Q2.2019**	**Q3.2019**	**Q4.2019**	**Q1.2020**	**Q2.2020**	**Q3.2020**	**Q4.2020**
portfolio 1	-0,09%	**0,19%**	**0,12%**	**0,05%**	0,15%	-0,22%	**0,82%**	**0,54%**	0,09%
portfolio2	**0,02%**	0,06%	-0,08%	-0,22%	0,07%	**-0,39%**	0,49%	0,10%	**0,34%**
portfolio 3	-0,08%	0,16%	-0,02%	-0,27%	0,08%	**-0,60%**	0,52%	0,01%	**0,35%**
portfolio 4	**-0,05%**	**0,24%**	-0,11%	**-0,04%**	**0,38%**	-0,23%	**0,75%**	0,01%	**0,42%**
portfolio 5	-0,10%	**0,19%**	**0,02%**	**0,14%**	0,07%	-0,27%	0,52%	0,10%	**0,32%**
reference portfolio	-0,06%	0,17%	-0,01%	-0,07%	0,15%	-0,35%	0,61%	0,15%	0,29%
	Q1.2021	**Q2.2021**	**Q3.2021**	**Q4.2021**	**Q1.2022**	**Q2.2022**	**Q3.2022**	**Q4.2022**	**Q1.2023**
portfolio 1	0,06%	0,03%	-0,04%	**0,04%**	-0,06%	**-0,07%**	**0,03%**	0,20%	0,07%
portfolio2	**0,19%**	0,09%	**0,45%**	-0,07%	**0,21%**	-0,15%	-0,14%	0,21%	-0,02%
portfolio 3	**0,27%**	**0,25%**	0,10%	-0,06%	-0,05%	**-0,01%**	-0,17%	**0,31%**	0,03%
portfolio 4	0,10%	**0,18%**	0,10%	-0,13%	**0,06%**	-0,08%	-0,10%	0,21%	**0,21%**
portfolio 5	0,16%	**0,20%**	0,04%	-0,07%	0,02%	-0,11%	**-0,08%**	0,21%	**0,11%**
reference portfolio	0,16%	0,13%	0,14%	-0,06%	0,03%	-0,08%	-0,10%	0,22%	0,07%

A comparison of the expected rates of return obtained from individual portfolios with the rate of return from the reference portfolio indicates that Portfolio 4 had a higher expected rate of return than the reference portfolio nine times. Portfolio 3 and Portfolio 2 had a higher expected rate of return than the reference portfolio 6 times over the period considered.

Table 3 presents the risk of portfolios built on the basis of individual rankings in the subsequent quarters of 2018-2023. The risk of portfolios that were higher than the risk of the reference portfolio in a given quarter is marked in bold.

Table 3.
Risk of constructed portfolios

	Q4.2018	**Q1.2019**	**Q2.2019**	**Q3.2019**	**Q4.2019**	**Q1.2020**	**Q2.2020**	**Q3.2020**	**Q4.2020**
portfolio 1	**17,18%**	14,43%	15,08%	12,83%	12,88%	19,44%	**19,09%**	**19,11%**	**18,78%**
portfolio2	14,76%	14,11%	14,65%	**14,30%**	**15,00%**	19,78%	17,28%	16,13%	15,26%
portfolio 3	14,44%	13,78%	15,14%	14,13%	**14,34%**	**20,96%**	18,29%	16,56%	16,72%
portfolio 4	**16,09%**	14,23%	**15,92%**	**14,50%**	**14,80%**	**21,15%**	**19,80%**	16,74%	**19,04%**
portfolio 5	**16,49%**	**16,11%**	**17,19%**	**15,35%**	14,00%	**20,94%**	**19,22%**	**20,42%**	**18,29%**
reference portfolio	15,84%	14,59%	15,45%	14,28%	14,18%	20,54%	18,73%	17,98%	17,70%
	Q1.2021	**Q2.2021**	**Q3.2021**	**Q4.2021**	**Q1.2022**	**Q2.2022**	**Q3.2022**	**Q4.2022**	**Q1.2023**
portfolio 1	**15,73%**	**15,71%**	13,85%	**17,91%**	18,06%	**17,95%**	**18,24%**	**16,85%**	**14,82%**
portfolio2	14,97%	14,00%	**17,42%**	15,02%	**20,20%**	16,16%	16,26%	14,94%	14,26%
portfolio 3	**16,67%**	**14,92%**	13,31%	**15,87%**	18,62%	15,34%	16,81%	**17,03%**	13,58%
portfolio 4	15,39%	14,58%	15,25%	14,76%	**19,10%**	16,51%	**17,18%**	15,01%	**14,96%**
portfolio 5	**16,47%**	**15,46%**	**14,73%**	15,63%	17,96%	**17,53%**	16,17%	15,32%	**15,62%**
reference portfolio	15,72%	14,79%	15,14%	15,86%	18,85%	16,83%	16,82%	15,90%	14,71%

Based on the data presented in Table 3, it can be seen that Portfolio 2 and Portfolio 3 were 15 and 13 times lower in risk than the reference portfolio, respectively. Other portfolios - 6 times in the period under review.

Table 4 shows the realized rates of return for portfolios built on the basis of individual rankings in subsequent quarters of 2018-2023. The realized rates of return that were higher than the realized rate of return of the reference portfolio in a given quarter are marked in bold.

Table 4.
Realized rates of return of the constructed portfolios

	Q4.2018	**Q1.2019**	**Q2.2019**	**Q3.2019**	**Q4.2019**	**Q1.2020**	**Q2.2020**	**Q3.2020**	**Q4.2020**
portfolio 1	**16,04%**	**12,72%**	**3,47%**	9,61%	**4,98%**	**57,06%**	**34,29%**	-5,18%	-2,84%
portfolio2	8,15%	-11,72%	-8,12%	5,39%	-22,88%	34,52%	14,90%	**23,67%**	**12,37%**
portfolio 3	10,19%	**-2,04%**	-8,64%	8,39%	-17,63%	28,89%	5,07%	**14,30%**	**8,80%**
portfolio 4	**24,72%**	-24,87%	**7,43%**	**19,76%**	-19,23%	26,16%	-2,11%	**20,97%**	**8,17%**
portfolio 5	6,45%	**13,36%**	**19,06%**	10,37%	**-1,42%**	**42,64%**	5,47%	3,92%	0,79%
reference portfolio	11,56%	-7,07%	2,28%	11,58%	-11,33%	39,41%	14,19%	8,54%	3,37%
	Q1.2021	**Q2.2021**	**Q3.2021**	**Q4.2021**	**Q1.2022**	**Q2.2022**	**Q3.2022**	**Q4.2022**	**Q1.2023**
portfolio 1	-5,29%	**1,90%**	-9,89%	-9,35%	-19,10%	**0,85%**	**13,60%**	9,20%	4,04%
portfolio2	**13,31%**	-4,91%	-7,68%	-5,37%	**-9,70%**	-17,09%	13,42%	10,19%	3,72%
portfolio 3	**8,80%**	**5,22%**	-8,87%	**-1,83%**	**-8,60%**	-9,75%	**19,42%**	5,06%	6,28%
portfolio 4	**11,10%**	**5,96%**	**1,01%**	**-1,63%**	**-5,51%**	-7,02%	**24,10%**	**30,98%**	**26,45%**
portfolio 5	**13,48%**	-3,66%	-8,61%	**-2,42%**	**-7,87%**	**-6,22%**	4,20%	-6,02%	**17,57%**
reference portfolio	6,33%	0,16%	-7,61%	-4,92%	-10,97%	-7,66%	13,49%	12,70%	12,69%

The analysis of realized rates of return showed that Portfolio 4 achieved a higher rate of return than the reference portfolio by 14 times, and portfolio 2 - by 4 times. The remaining portfolios generated a higher rate of return than the reference portfolio by 8-9 times over the 18 quarters considered.

Table 5 shows the cumulative rate of return, the geometric mean of realized rates of return and the average risk for portfolios built on the basis of individual rankings in subsequent quarters of 2018 - 2023. Values that were higher than the values obtained for the reference portfolio in a given quarter are marked in bold.

Table 5.
Cumulative rate of return, average geometric rate of return and average risk for the constructed portfolios

	Cumulative rate of return	**Average geometric rate of return**	**Average risk**
portfolio 1	**146,65%**	**5,14%**	**16,55%**
portfolio2	39,88%	1,88%	15,81%
portfolio 3	67,05%	2,89%	15,92%
portfolio 4	**232,37%**	**6,90%**	16,39%
portfolio 5	**138,89%**	**4,96%**	**16,83%**
reference portfolio	107,70%	4,14%	16,33%

The analysis of cumulative rates of return (Table 5) showed that portfolios 1, 4 and 5 were characterized by a higher cumulative rate of return than the reference portfolio, in particular for portfolio 4 the difference was nearly 125 percentage points. Portfolios 2 and 3 achieved the lowest cumulative rates of return, which were significantly lower than the cumulative rate for the reference portfolio. Based on the geometric mean rates of return (Table 5), it can be seen that Portfolio 1, Portfolio 4 and Portfolio 5 produced higher geometric mean rates of return than the reference portfolio. The lowest geometric mean was obtained for portfolio 2, which was also characterized by the lowest average risk. It should be noted, however, that the average risks obtained for the constructed portfolios are similar to each other and have values in the range (15.81%, 16.83%). Portfolios 2 and 3 had an average risk level lower than the reference portfolio. Portfolio 4, which achieved the highest cumulative and geometric mean rate of return, had an average portfolio risk higher by only 0.06 percentage points.

Table 6 presents the Sharpe ratios for portfolios built on the basis of individual rankings in the subsequent quarters of 2018-2023. The Sharpe ratios that were higher than the Sharpe ratios of the reference portfolio in a given quarter are marked in bold.

Table 6.
Sharpe ratios of the constructed portfolios

	Q4.2018	**Q1.2019**	**Q2.2019**	**Q3.2019**	**Q4.2019**	**Q1.2020**	**Q2.2020**	**Q3.2020**	**Q4.2020**
portfolio 1	**0,83**	**0,76**	**0,12**	0,61	**0,25**	**2,88**	**1,78**	-0,28	-0,16
portfolio2	0,44	-0,95	-0,67	0,26	-1,64	1,69	**0,85**	**1,45**	**0,80**
portfolio 3	0,59	**-0,27**	-0,68	0,47	-1,35	1,32	0,26	**0,85**	**0,51**
portfolio 4	**1,43**	-1,87	**0,36**	**1,24**	-1,41	1,18	-0,12	**1,24**	**0,42**
portfolio 5	0,29	**0,72**	**1,01**	0,56	**-0,22**	1,98	0,27	0,18	0,03
reference portfolio	0,62	-0,60	0,04	0,69	-0,92	1,86	0,74	0,46	0,18
	Q1.2021	**Q2.2021**	**Q3.2021**	**Q4.2021**	**Q1.2022**	**Q2.2022**	**Q3.2022**	**Q4.2022**	**Q1.2023**
portfolio 1	-0,35	**0,11**	-0,73	-0,66	-1,32	**-0,35**	0,35	0,13	-0,19
portfolio2	**0,88**	-0,37	**-0,45**	-0,53	**-0,72**	-1,49	**0,38**	0,21	-0,22
portfolio 3	**0,52**	**0,34**	-0,68	**-0,28**	**-0,72**	-1,10	**0,73**	-0,12	-0,04
portfolio 4	**0,71**	**0,39**	**0,05**	**-0,28**	**-0,54**	**-0,85**	**0,98**	**1,60**	**1,31**
portfolio 5	**0,81**	-0,25	-0,60	**-0,32**	**-0,70**	**-0,76**	-0,19	-0,85	**0,68**
reference portfolio	0,39	0,00	-0,52	-0,47	-0,84	-0,87	0,37	0,36	0,39

Based on the data in Table 6, it can be seen that the reference portfolio had a positive Sharpe ratio value in 12 of the 18 quarters analyzed, which means that only in these quarters did it bring a rate of return higher than the risk-free rate. The constructed portfolios had a positive Sharpe ratio of 9-12 times. Portfolio 4 had a higher Sharpe ratio than the reference portfolio 14 times, including 11 times when the ratio was positive. At the same time, the reference portfolio was characterized by a twice higher positive value of the indicator than portfolio 4.

Conclusion

The study analyzes the financial condition of selected companies listed on the Warsaw Stock Exchange using the TMAI measure. Based on the research conducted, companies were assigned to one of five portfolios in the analyzed quarters. Then, an attempt was made to assess whether the proposed method of assessing companies allows for identifying a portfolio that systematically gives a better result than the reference portfolio containing all the analyzed companies. The existence of such a portfolio would allow the use of the TMAI measure for the initial selection of companies for the portfolio.

The conducted research allows for the following conclusions to be drawn: The obtained values of the Sharpe ratios allow us to conclude that the "best" portfolio is portfolio 4 in the analyzed period. The analysis of geometric mean rates of return of the constructed portfolios indicates that portfolios 1, 4 and 5 brought higher geometric means than the reference portfolio. Based on the research conducted, it can be seen that the outbreak of the Covid-19 pandemic and the war in Ukraine significantly influenced the rates of return of investment portfolios. In the case of the strongest restrictions related to the pandemic, portfolio 5 generated positive

rates of return. The study showed that during the period under review, the highest-rated companies did not create portfolios with the highest rates of return, but in the first 3 quarters of the pandemic, these portfolios achieved the highest rates of return. It should be noted that the stage of selecting companies for the portfolio is an initial stage, and the next stage is the optimization of the portfolio structure - e.g. the classic Markowitz approach.

To sum up, it can be said that the TMAI measure allowed to identify a group of companies forming portfolio 4, which allowed to obtain a higher rate of return than the reference portfolio. It should be emphasized that the portfolios constructed are not optimal portfolios. It can be expected that optimizing the portfolio structure would improve the results. However, the aim of the research was to analyze the suitability of the proposed method as a tool for selecting companies for the portfolio, and not to build optimal portfolios.

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DIRECTIONS OF DEVELOPMENT OF CONTEMPORARY EDUCATION. CONSTRUCTIVIST APPROACH

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Purpose: The purpose of the article was to show directions for necessary changes in the organization process, education, favorable development of society information.
Design/methodology/approach: In the content done, review contemporaries' theory, scientific research results, and social expectations, pointing to the need for changes in educational implementation tasks. Indicated main directions activities influencing evolution approach to organization process didactic to ensure people teaching myself education expected competences.
Findings: As a result, the accomplished analysis presented recommendations for the organizer's educational activities.
Originality/value: The article has a character review.

Keywords: digital civilization, key competencies, education, constructivism.

Category of the paper: Literature review.

1. Introduction

For several dozen years, we have witnessed the next breakthrough technology, which is difficult to predict the development direction. Application increasingly newer ones and more advanced digital technology systematically change or replace previous ones forms activities man in various zones life. These changes may have a global character, introduce new activity models, social and business, and challenge education.

Reality created by technologies requires possession of a broad scope of competencies. This problem has been addressed many times and has returned to attention within the last dozen years, presenting it in many studies through recommendations reports. One of the most critical documents containing arrangements regarding needs in terms of changes in education is the *Council Recommendation of 18 December 2006 on competencies key in the process of lifelong self-learning* (2006/962/EC) and also the *Council Recommendation of 22 May 2018 on competencies key in the process learning of lifelong self-learning* (Text having meaning for the

EEA, 2018/C 189/01). A relevant step towards developing society information in Poland happened through self-development according to recommendations in 2019 and conclusions contained in *the Strategy OECD Poland skills* and elaboration *Integrated Strategy Skills 2030*. These works indicated main areas and directions changes necessary in Polish system education to ensure the young generation an excellent start to the future.

Competencies are instructions covering knowledge, skills, and attitude, allowing one to realize tasks appropriately (Filipowicz, 2014). The recommendations (Recommendations, 2018, p. 13) have a similar competencies definition. The document defines these competencies "as a connection of knowledge, skills, and positions. Knowledge is based on facts and numbers, concepts, ideas, and theories that are already well-established and help understand a specified field; skills are defined as capacity and possibility of implementation processes and using the existing knowledge to achieve results; attitude describes the readiness and tendency to act or react on ideas, people or situation." The mentioned document defined eight competencies necessary for smooth operation functioning in the developing world of computerized reality (Recommendation, 2018). They have familiar characters and are addressed to people functioning in society. Assumes that having them should constitute the basis for further personal development. Among the mentioned competencies, special attention is given to the return competencies, emotional, social, and in-scope self-learning skills, and digital competencies.

Education's new competencies require changes in how we understand education because the contemporary young generation is people born in the Internet era. "Most probably, the majority of students starting the learning process in schools will work in new types of professions that do not exist" (WhitePaper, 2017). That means that the current education system, especially teachers employed in it, must adjust to new civilization requirements and constant changes related to them in the social and economic environment.

2. Expectations to model education in digital civilization

Dynamic civilization transformations require permanent human activities and creative adaptation to the changing reality. For this reason, fundamental perfecting cognitive processes are related to reasoning and solving problems, thinking abstractly and deductively. Thanks to these abilities, humans may self-teach and build knowledge all life. It helps cope with everyday challenges and make appropriate decisions (White Paper, 2017). This is to underline the meaning of self-learning skills, acknowledging competence, and critical, influencing well-being units and her future. In contemporary education, there are duty assurances teaching conditions to develop this one skill. Teachers have a unique role in this area as they are directly responsible for the effects of education.

Being a teacher requires understanding the direction of civilization development in the variable world and their responsibility for future generations. Today, a teacher's role is comparable to that of a director and manager in organizations other than school. Like the principal, the teacher has to provide leadership, establish procedures influencing motivation, and coordinate and control activities teams engage in work above achieving educational goals. We say here about leadership by the teacher's process of teaching and learning (Arends, 1994, p. 41). On the other hand, referring to the role of the teacher as a manager of the process of achieving educational goals at a specific time by students, we can talk about the management of the self-learning process for students. Like in the educational process, "one of the essential management skills is purpose creation because brightly marked out purpose is necessary to know where is heading or goes along the trail and to power achievements evaluation" (Arends, 1994, p. 42). For this reason, to be able to direct self-teaching to students efficiently, especially attention returns on need possession by teachers, except current knowledge substantive also preparations including newest knowledge of the area psychology education and modern didactics, especially knowledge processes cognitive human and their conditions. This knowledge is necessary to be effective in designing and realizing classes didactic, consciously starting mechanisms necessary for learning students, taking into account their cognitive styles (Franken, 2005, p. 216), consisting of getting to know on your way (Mietzel, 2003, p. 206).

To effectively organize situations, educational knowledge is essential, like a human being teaching how to build your understanding. Explains the mechanism this process delivers through contemporary education constructivist theory learning (Klus-Stańska, 2010, pp. 263-275), which treats teaching as a specific process of research that relies on active getting to know reality, processing information, and broadcasting meanings (source). The key here scope stately tests conducted by Jean Piaget (constructivism individual), Leo Vygotsky (constructivism socio-cultural) (Mietzel, 2003, pp. 91-133; Klus-Stańska, 2010, pp. 263-285). The priority assumption adopted by researchers was that empowered people and arrangement conditions are decisive for the effective learning process. Belong to them:

- arousing motivation to learn in learners by stimulating cognitive curiosity, causing specific cognitive dissonance affecting attention processes and causing focus on particular learning content - in the learner's opinion, what is learned should be meaningful, i.e., interesting, important, and valuable,
- creating conditions for students to take up educational challenges, organizing space for learners to act and participate in academic situations that enable them to use their learning style while actively searching for answers to troubling questions and thus discovering new knowledge and giving meaning to new concepts,
- focusing on success and achieving students' satisfaction with learning outcomes,
- their use of teachers' feedback and support during problem-solving activities,
- organization work, teamwork, creation possibilities, teamwork, and sharing what they know as they process learning.

In a constructivist environment, they play a crucial role in relations between participants and process education based on mutual respect. This is necessary for building feeling and full commitment to the teaching process. The positive atmosphere and interpersonal relations depend on the teacher's attitude and adopted style management team (Mietzel, 2003, pp. 369-370). He's waiting to be a person:

- formulating challenges and motivating action, knowing her subject well, teaching it with enthusiasm, serving as a model for students to strive for internal rewards and the satisfaction that learning brings,
- organizing the educational environment and supporting learners, ensuring a balance between the preparation of students and what is required of them,
- encouraging thinking and creative problem-solving while providing academic and emotional support,
- person managing process learning myself students enabling modern methods and digital resources teaching (Mietzel, 353-419).

Justification parties above assumptions will be found in research conducted on ground psychology positive (Czapiński, 2008; Trzebińska, 2008).

Positive psychology is a science dealing with optimal human functioning and well-being. It focuses on the conditions related to building and developing a person's potential, a sense of satisfaction, and contentment with the undertaken activities. (Seligman, Csikszentmihalyi, 2000, pp. 5-14) During the research, it was noticed that feeling positive emotions during learning activities provides many benefits. They influence the feeling of pleasure, contentment, and satisfaction, ultimately increasing the sense of well-being and commitment to action. The effect expands the scope of attention, causing greater openness to new challenges and flexibility. There is an increase in creativity. These factors significantly influence the development of personal knowledge and competencies. They allow for a more objective assessment of the situation from different perspectives, which in turn promotes the development of empathy and cooperation. It also increases the level of self-control. Researchers have proven that feeling positive emotions triggers physiological reactions in the body that positively impact well-being and readiness to act.

It's worth noticing that psychology positively described factors influencing the commitment to action, defined as the phenomenon of self-determination and the state of flow (state of elation) (Csikszentmihalyi, 1993). This condition consists of a complete commitment to execution activities. It is a state of undisturbed joy and deep satisfaction with the decisions and actions taken. Accompanies ago lost feeling time and lack worries before failure. Psychologists are positive when they talk about "inferno" in a given action when he stops control time intended on his implementation.

Entering the flow state requires fulfillment of the following conditions:

- sense of purpose - action and his objective are For learner myself important . This affects satisfaction, favors building positive self-esteem, allows on crossing restrictions and achieving more and more ambitious goals, opens on following challenges,
- good relationships with other people and building a support network - creates a sense of security and inclusion, is a source of positive reinforcement, makes a good atmosphere for engaging in activities,
- positive, subjective feelings learner myself related to the possibility of obtaining support and information feedback originating from the teacher.

We will also find justification for the role of teachers as persons organizing and managing process learning students and responsible for their effects in theory communication (Dobek-Ostrowska, 1999). In progress communication in a relationship between sender-message-recipient, for the reaction and actions recipients in a significant way degree replies sender who to get the result in the form expected reaction recipient, must take into account:

- own predispositions and level of substantive and methodological knowledge,
- precise characteristics of the recipient (his predispositions and personal characteristics, foreknowledge, experience, operating environment),
- content of the message, its structure, language,
- conditions and method of transmitting the message,
- how to get feedback.

It's worth it here quote Jere Brophy, who stated that "more realistic it would strive to shape and maintain at your students motivation to teach thanks to work above material - the tendency to perceive this one work as sensible and valuable and as middle, thanks which achieves intentional benefits cognitive" (Brophy, 2004, p. 25).

3. Digital educational environment

I cannot forget that, within methodical preparations, teachers expect efficiency and openness to new technological solutions.

The popularization of digital technology can change how life and exercise tasks are performed in contemporary societies. This expansion of technology into space human induced the transformation of the digital economy, causing building society information to be considered one of the most critical tasks. In 1994, the report Europe and Global Society Information: recommendations to the European Council (Europe and the Global Information Society: recommendations to the European Council, 1994) was published. Another step was party in 2000 By Countries EU member states of the project *eEurope – Society Information For*

All (Europe – An information society for all – Communication on a Commission Initiative for the special European Council of Lisbon, 2000). Including alone year in our country left developed *Poland* program - *Action Plan on thing development society information in Poland on years 2001-2006*, in which, referring to the recommendations European, specified main directions development economic and social country.

In parallel, we specified new challenges For education. A groundbreaking document defining new requirements for competencies citizens' society information was published before *Recommendations of the European Parliament and of the Council of 18 December 2006 regarding competencies key in learning by myself all life. It* returned attention to the need for education competencies in IT.

In the following years, many studies regarding new competencies key issues, including the *Council Recommendation of 22 May 2018 on competencies key in the process of self-learning all life, Beyond the Horizon, Course on Education, future system development competences in Poland***,** Foundation Economy and Administration Public 2020, *Shaping Digital Future Europe* opinion released By European Committee Economic and Social in 2020 (European Committee Economic and Social 2020), *New Vision of Education. Future Learning (Learning)* Microsoft Education, *New Pedagogies for Deep Learning*, Civic Education Center Foundation, 2021, *Marekt, Work, Education, Competencies* appeared. *Current Trends and Results Research* (May 2022) PARP, *AI as a shaping megatrend education. How do I prepare for chances and challenges socio-economically related to artificial intelligence*? IBE, Warsaw 2022, *The Future of Education and Skills: Education 2030. The Future We Want. OECD report.* Documents indicate the need for activities in the development of a digital education society. Europe covers two main areas: developing digital competencies for people teaching and educational use of technology for digital purposes, digital transformation, and teaching improvement.

A unique role in the implementation priority purpose strategy included in *the Plan activities in digital education for years 2021-2027* assigns teachers. The document underlines make them a special place in digital creation ecosystem education (EC, 2020). Teachers are a particular group of professionals from which the success process changes civilization. Vital are, therefore, competent teachers, including scope. The report *Digital Education in Schools in Europe* (Euridice, 2019) presented data from which it follows that in approx two-thirds of European systems of education (including Poland), digital competencies are treated as essential competencies included in the framework qualifications related to the professional teacher, at what level description areas and skills are varied. The common feature is the requirement possession teachers :

1) knowledge about how to be inclusive of technologies in your practices, teaching and learning,
2) skills in the area of effective use of technology in the educational process.

With assessment in mind competences digital people employed in the sector education systematically on level internationally take different initiatives. They developed many competence frameworks and self-assessment tools and programs training. These activities were prepared by the Joint Research Center (JRC) and published in the 2017 Digital Competence of Educators (DigCompEdu) report to introduce European frame competencies digitally for educators. A comprehensive model is intended to be a general reference source for model creators of digital competencies in EU member states. Structure DigCompEdu has defined digital competencies specific to the teacher's profession employed in every level of education (from kindergarten up to teaching higher education), particular institutions, and non-formal education (DigCompEdu).

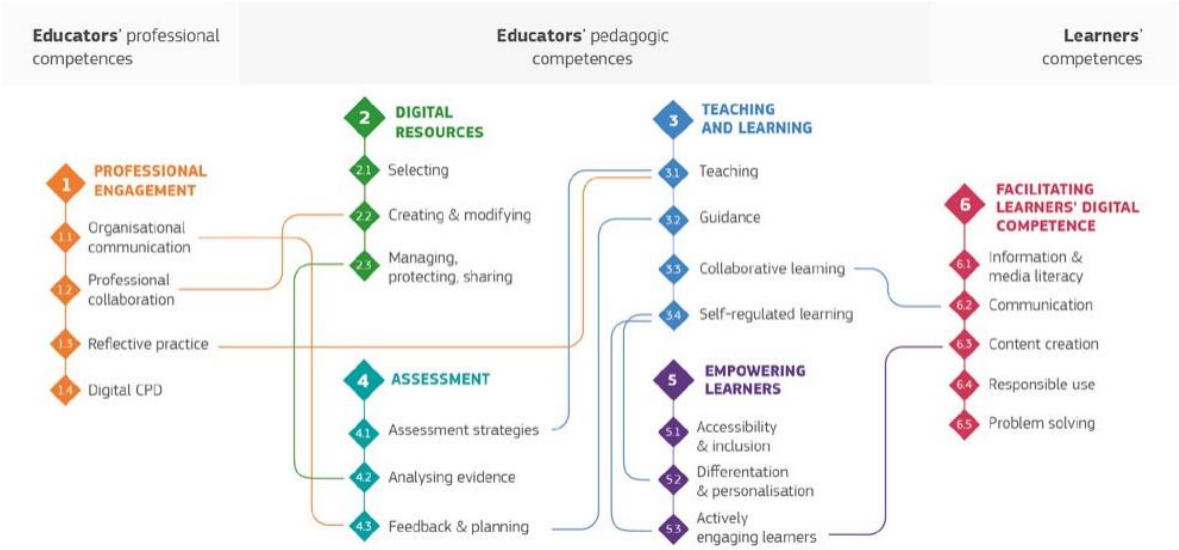

Figure 1 . DigCompEdu.

Source: Redecker, 2017.

DigCompEdu defines 22 digital competencies grouped into six areas:

1. Development - includes developing professional teachers and using various channels of digital communication, technology usage, digital collaboration, developing digital teaching skills, and supporting development by using digital technology (e.g., via participation in online courses, MOOCs, webinars, virtual conferences).
2. Creation and exchange of digital resources - includes competencies needed to be effective and responsible in using, creating, and sharing digital resources.
3. Managing the use of digital technologies in the process of teaching–learning (English: Teaching and Learning) – consists of the use of digital technology in the organization process of teaching and learning embraces, design, planning, and implementation of digital technology on various stages of educational and tends to improve efficiency learning to develop engaged, reflective and based on teamwork self-learning.

4. Assessment – considers skills using tools and digital supporting practices, such as formative and summative assessment. Dedicated use of technology in grades and assessment shaping of students' work progress targeted information feedback and individualized support by digital technology.
5. Learners - includes skills necessary to support the personal development of each student with attention to inclusion and strengthening individual talents. It focuses on using potential technology in reality strategy teaching and learning. I concentrated on the student, his possibilities, needs, pace of work, and interests, increasing students' commitment to the learning process and making learning in and out of school.
6. Supporting competencies of digital students (Facilitating Learners' Digital Competence) - applies activities teacher which indirectly develops students' digital competencies (design tasks demanding the use of digital tools to communicate myself and teamwork requiring the creation of digital, creative exploitation technology to solve specific problems).

4. Specific teachers' digital competencies

According to the Framework Catalogue Competence Digital developed in 2018 on job Ministries Digitization, competencies digital are defined as "harmonious composition knowledge, skills enabling life, self-learning, and work in digital society exploiting technologies. They fold on no:

- IT competencies,
- Information competencies,
- Functional competencies – are described as "based on IT and information competencies and constitute a ground for implementation-specific activities and achieving specific benefits thanks to the application of digital technology" (Framework Catalogue Competence Digital (Jasiewicz et al., 2018). Near competencies commonly contain competencies related to a specific social role.

In 2021, trial identification and the definition of specific teachers' digital competencies in social and academic roles were described. The research subject was based on experts' opinions – university employees, topic contemporary's expectations of specific digital competencies teachers, and teachers' academic. The researcher conducted qualitative tests using focused group interviews (FGI – Focus Group Interview) to meet the material.

During the research, we wanted answers to the following question: What are the specific digital competencies in teachers' social roles that have a relevant influence on the efficiency of their actions while fulfilling specified functions in society and being able to influence the functioning of the whole society?

Investigated trials, they constituted community experts, scientific and academic. Interviews was carried out using the MS Teams platform. Tests were conducted from 22 October to 5 November 2021. Based on carried out interviews, prepared models specific digital competencies for social "teacher" and "academic teacher" roles. Both models are presented below:

A. IT competences

- *The use of digital tools in the teaching process* **includes the knowledge and skills necessary to navigate the ICT environment efficiently, which is** diverse in hardware and software. It involves selecting solutions that meet the standards of teaching effectiveness and are adapted to students' age and cognitive abilities. Thanks to this, students' relationships with ICT tools are moderated by shaping their awareness of the digital environment's impact (including AI) on the learning space, which shapes preferences for searching and selecting information.

B. Information competences

- *The use of digital resources in the student learning process* **-** knowledge about digital resources necessary to implement the student learning process. It consists of using digital resources necessary to implement the student learning process and designing educational situations requiring active information processing, searching, selecting, evaluating, etc. It includes knowledge of the applications of AI and the ability to use AI correctly in a didactic manner.
- *Designing student experiences in a digital environment* – takes into account knowledge of how students function in the digital environment and includes the ability to plan and implement teaching tasks using design methods in educational processes using ICT.
- *Identifying and counteracting cyber threats in education*

C. Functional competencies

- *Shaping students' digital culture in learning processes* concerns knowing the digital culture, including knowledge and compliance with digital hygiene, and designing and conducting an educational process requiring students to process information from various sources while actively constructing personal knowledge. It includes shaping students' attitudes open to taking up challenges using ICT tools and promoting socially approved behaviors in the digital environment.
- *Developing students' digital competencies* - includes current knowledge about common digital competencies of citizens of the information society and development trends.

Specific model digital competencies for the social role of"academic teachers" contain the following competencies:

A. IT competences

- Using information and communication technology devices **-** includes knowledge and skills related to the operation and assessment of the possibility of using various digital devices to carry out teaching tasks in educating students and doctoral students.

B. Information competences

- *Use of information and communication technology devices* – considers using existing and creating scientific information resources in academic education, using scientific knowledge bases, constructing digital messages and disseminating them using available digital information channels, shaping students' information culture, and compliance with digital accessibility standards (WCAG).
- *Promoting the digitization of academic education* **-** includes activities aimed at disseminating solutions conducive to the effective use of ICT tools in education and promoting effective organizational and methodological solutions in the social environment.
- *They are identifying and counteracting cyber threats in academic education*.

C. Functional competencies

- *Profiling the interaction of an academic teacher* - a student/doctoral student through digital tools **-** includes designing the learning process of students/postgraduate students following the principles of modern didactics, enabling them to efficiently construct knowledge in the digital environment and awareness of new ICT solutions (e.g., methods, applications) and their inclusion in academic education.
- *Designing materials and effective management of remote education* **-** involves planning educational tasks and processes using digital platforms, knowledge of tools for implementing remote education and the methodology of designing educational materials and remote classes and conducting them, organizing the work of a dispersed team participating in the remote education process, coordinating processes digital and analog academic.
- *Engaging in the digitization of academic education* **is related to the attitude of a visionary teacher, which consists of identifying with the idea of the** digitalization of education, believing in the rightness of implementing this action, and treating it as a moral obligation. An academic teacher manifests this attitude through a permanent analysis of the development of information technology and its impact on educational processes. This knowledge allows for the conscious implementation of new digital solutions in everyday academic practice and their evaluation and improvement.

5. Summary

In the contemporary world a long time ago, he noticed the multifaceted influence of digital technology on changes in business, education, and administration. The second digital revolution, consisting of integrating man-technologies, was initiated in the middle of the first decade of the 21st century, and it remained named digital transformation. It doesn't rely only on exchanging analog solutions for digital solutions but on entering new, more effective, and more friendly to the user innovative services, models organizational (business), and responding to the information architecture.

Unusually helpful in raising awareness yourself. By the teacher's digital competencies development stage, incredibly functional areas may be a SAMR model developed by Ruben Puentedura. This model defines four horizontal inclusion technologies into the education process, characterizing the degree of use of technology at work by teachers.

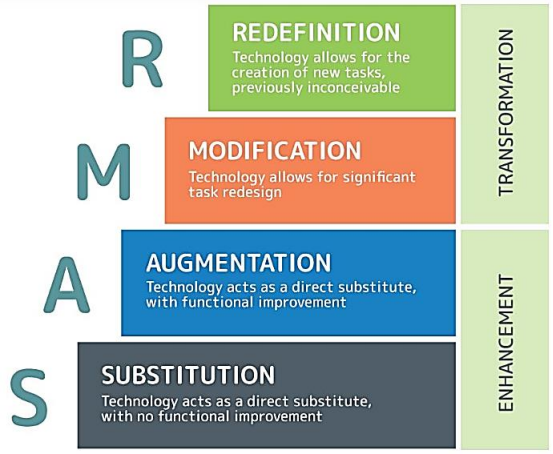

Figure 2. The SAMR Model Explained (With 15 Practical Examples).

Source: https://www.3plearning.com/blog/connectingsamrmodel/

You can suppose that the period of education implemented during the pandemic influenced the level of digital competencies of teachers and students. Obtained experience in the field organization remote education allowed proficiency in self-use of ICT tools. It also provides new knowledge not present earlier in school learning methods. Today's implementation model of modern education locks new organizational forms, educational models, teaching methodologies, models using digital and content tools, open and commercial training resources, support platforms education , open and commercial courses, and training, standardization programs, and educational content, and use social media in education.

Belong notices that everyone who wants to teach has many educational possibilities on the Internet. Resources develop dynamically and are increasingly popular because of personalized plans to create individual people. By all means, power takes advantage of getting richer digital offers. Education is necessary to develop among the teachers in progress. Education formal competence is required for self-realization.

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PROPOSAL FOR AN EXPERT SYSTEM TO AID DECISION-MAKING IN THE DESIGN AND MANAGEMENT OF FLEXIBLE MANUFACTURING SYSTEMS

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Purpose: The objective of this article is to introduce a concept for facilitating decision-making processes in the design and management of flexible manufacturing systems. This concept aims to minimize the risk of either overestimating or underestimating the flexibility and efficiency of production potential.
Design/methodology/approach: The proposal involves the utilization of a hybrid expert system, incorporating a combination of rules, scenarios, and semantic schemes to construct a comprehensive knowledge base. This system also integrates fuzzy logic, artificial neural networks, and agent systems with expert systems.
Findings: The proposed concept of a hybrid expert system allows for the management of flexible manufacturing systems across various levels, including strategic, operational, and technological aspects of production organization and management.
Practical implications: The article has broad applications as it is specifically tailored to address the intricacies of flexible manufacturing systems and expert systems for facilitating decision-making processes within the production context.
Originality/value: Each management level possesses its distinct characteristics, methods, and tools that can be seamlessly integrated through the use of hybrid expert systems.

Category of the paper: Research paper, conceptual paper.

Keywords: Expert systems, flexible manufacturing system, Industry 5.0, production management and engineering.

1. Introduction

The concept of artificial intelligence was first introduced to the scientific community in the mid-1950s by J. McCarthy, who defined it as the endeavor to develop (create) software that enables computers and machines to intelligently process data. Today, artificial intelligence has evolved into an interdisciplinary field. It finds practical application in virtually every area of

human activity. Presently, significant research efforts are directed towards achieving autonomy in systems equipped with artificial intelligence. Consequently, a crucial area of scientific work focuses on advancing knowledge in the automation of control and decision-making processes.

The objective of this article is to introduce a concept for an expert system that facilitates decision-making processes by integrating information flow among various modules in the context of computer-integrated manufacturing (CIM) (including the needs of designing and managing flexible manufacturing systems (FMS)) and the production processes implemented with them. The proposed expert system concept encompasses three key management levels within a flexible manufacturing system: strategic, operational, and support and control of manufacturing processes.

The problem addressed in this context revolves around achieving consistent management and decision-making at both the strategic and operational levels, while also considering the management of manufacturing processes in relation to technological processes. The article discusses the challenge of selecting the appropriate method for information processing and constructing the necessary knowledge bases to facilitate optimal decision-making for this specific issue.

For this purpose, the following research questions were formulated:

Can the implementation of a modular hybrid real-time expert system structure enhance the management and decision-making process at the strategic, operational, and technical levels?

Will the integration of modules within an expert real-time system enhance the information flow within its information system and enable better alignment with the requirements of Industry 5.0?

The first section of the article presents a review of the existing literature concerning the evolution of expert systems, focusing on their role in facilitating decision-making processes and the methods utilized for implementing the reasoning process. The subsequent section examines the operation of computer-integrated manufacturing (CIM) in the context of flexible manufacturing systems (FMS). Following these analyses, the article proceeds to introduce the concept of an expert system in its subsequent part.

The concluding section of the paper provides responses to the defined research and design objectives, specifying the tools and decision algorithms that will be integrated into the expert system during its development. The article concludes with a discussion and a summary, presenting concise bullet-pointed conclusions, and offering recommendations for future research.

2. Development of expert systems in the light of supporting decision-making processes (literature analysis)

The rapid advancement of microprocessor systems, specialized neural processors, and the evolution of multi-core systems is driving the progress of information technologies and introducing new challenges for the development of information systems (Qin, Lu, 2021).

In the initial stages of development, expert systems were primarily constructed using languages such as LISP (Steele, 1990) and later Prolog (Clocksin, Mellish, 2003). However, it quickly became evident that establishing a dedicated framework for expert system operations yielded more favorable outcomes. Presently, specialized programming languages like PROLOG, EXYS, OPS5, and CLIPS, well-known and respected in the IT community, are commonly employed (Wakulicz-Deja et al., 2018). Additionally, some general-purpose programming languages such as C, C++, or Java, offer libraries (e.g., Rete++, Jess) that facilitate the development of expert systems. Moreover, there are software programs designed specifically for expert systems, reducing the need for extensive programming, such as EXPERTRule, NEXPERT (Aiken, Liu Sheng, 1990), or the Polish Sphinx program which includes the PC-Shell framework package (Michalik, Simiński, 1998).

For expert systems to effectively carry out their functions, they require a suitable architecture that typically comprises: a knowledge base, an inference module, an explanation module, a control module, a user interface (including communication with the user), and a knowledge acquisition module (Forsyth, 1986). It is important to note that the knowledge within the system does not need to be comprehensive and can be expanded, and sometimes, the solutions provided may exhibit ambiguity. In such cases, the value of the expert system becomes evident (Mulawka, 1996).

The process of acquiring knowledge in expert systems involves data collection and is often one of the most challenging stages in their development. Knowledge is typically transferred by an expert or groups of experts, which underscores the importance of standardization in practice (Cichosz, 2000). This also applies to the automated acquisition of knowledge based on data generated by sensors or other information systems. The unification of acquired knowledge represents a phase of system learning and can be described as the system's effort to enhance the quality of its operations (Linstone, Turoff, 2002). Acquiring knowledge enables the development of rules that represent knowledge for the expert system (Slatter, Norwood, 1987). The rules employed in expert systems are derived from classical methods of logic, and propositional calculus, which is a fundamental branch of formal logic, is utilized to describe the surrounding world (using propositions) that can be either true or false (Ben-Ari, 2006).

Expert systems, equipped with a knowledge base, are capable of performing the reasoning process. Inference is typically accomplished through three primary operations: matching, selection, and activation. Most often, inference is made progressively or regressively,

depending on the context of the task being performed (Ligęza, 2005). The utilization of mixed reasoning appears to strike a favorable balance between backward and forward reasoning, mitigating the drawbacks associated with each approach. However, it is important to note that constructing meta-rules can introduce complexities, particularly in terms of comprehensive verification of the inference process and their subsequent updates (Mulawka, 1996). Furthermore, it is worth highlighting the concept of percepts and percept calculus, which arises from building knowledge based on natural language formulations (Sobolewski, 1991). These concepts have also contributed to the development of expert systems in the domain of organizing and structuring knowledge in a classified manner. In many cases, applying the crisp set theory to determine whether an element (object) belongs to a set or not is not always feasible (Skowron et al., 2002). Hence, alternative theories such as Zadeh's fuzzy set theory and the Demster-Shafer belief functions theory are employed (Dempster, 2008). The rough set theory, for example, enables the handling of imprecise data (Stefanowski, 1998). It allows the representation of a vague concept using a pair of precise concepts (the lower and upper approximations of the given concept). This theory is predicated on the idea that, by having information represented by attributes and their values on objects, it becomes possible to establish relationships between objects (Bazan et al., 2004).

It is worth mentioning that the induction of decision rules can also be conducted using methods rooted in rough set theory. Another crucial aspect is the development of algorithms for generating decision rules from decision tables, including the automation of this process (Grzymała-Busse, 1993).

For operational management at the tactical level, a table-based architecture should be considered (Stefanowski, 2001), where, in addition to knowledge in a given field, it is possible to take into account not only domain-specific knowledge but also the inclusion of strategic knowledge *(meta-knowledge)*. In this context, the use of multiple tables with hierarchical information structuring can be advantageous, providing a finer level of detail (Skowron et al., 2002). Decision tables form a decision system closely intertwined with the information system, and the theory of rough sets can be applied to them. A visual representation of an information technology system can be created as a table containing objects and attributes that describe a specific process (Pawlak, 2004). Decision tables can be either deterministic or non-deterministic, involving rules that describe objects that may also be deterministic or not. It is important to note that the use of tables may be constrained by the presence of internal inconsistencies within the rule knowledge base. Decision rules are formulated for both descriptive and classification purposes, establishing a close relationship with decision tables (Stefanowski, 2001).

In the context of describing interactions within complex systems composed of numerous modules, semantic networks, well-constructed frameworks, and appropriately developed scenarios serve as viable alternatives to the rules commonly found in expert systems.

A framework is constructed from slot-cages (slots), which, in turn, are built from cages (fasets). This hierarchical arrangement enables them to adopt the structure of a directed acyclic graph, facilitating the construction of a hierarchical decision-making structure (Wakulicz-Deja et al., 2018).

A semantic network is a collection of interconnected (related) objects with diverse implementations and serves as a graphical representation of logic. The foundation for comprehending the functioning of a semantic network is the associative model of human memory, in which terms are explained using other terms, thus giving rise to a structure of associations that can be closed. The last significant element within the analyzed array of methods and tools used in expert systems is scripts. They are employed to record knowledge regarding stereotypical sequences of events or events occurring within a known context (Rojek, 2017).

In the context of incomplete knowledge characterized by contradictions, inconsistencies, and uncertainty, it becomes necessary to employ fuzzy concepts. What experts find relatively straightforward, which is the formulation of approximate opinions, is challenging in computer modeling (Negnevitsky, 2002). In such situations, approximate (fuzzy) reasoning should be applied. For practical realization of these kinds of issues, the Bayesian network is often used, taking into consideration the certainty factor (CF) method (Dempster, 2008).

Flexible manufacturing systems, during both their design and subsequent operation, can effectively leverage a wide array of artificial intelligence methods, starting from neural networks through fuzzy logic often employed in process automation, and genetic systems, which excel at optimizing manufacturing processes (Barbosa et al., 2015). Nevertheless, the most powerful approach involves the adept integration of artificial intelligence methods into a cohesive inference and data processing system, resulting in the creation of hybrid systems (Shen et al., 2006). These hybrid systems may also incorporate agent systems and classic rule-based expert systems (Zhang et al., 2022).

An analysis of the literature reveals that current solutions exhibit a high level of specialization, primarily stemming from the prevailing technical constraints and emerging theories within a specific phase of knowledge development and the practical feasibility of their implementation. Drawing from this literature review, it becomes evident that there exists a noticeable research gap in the advancement of specialized real-time expert systems that encompass the fusion of aspects related to both strategic and operational management while concurrently conducting real-time analysis of the execution of technological processes and digitally mapping them for the purpose of decision-making across various functional levels.

3. Integration of the manufacturing process in flexible manufacturing systems

The primary issue examined in the article pertains to the integration of decision-making processes across technological, operational, and strategic levels concerning the management of flexible manufacturing systems through the utilization of an integrated expert system (Figure 1).

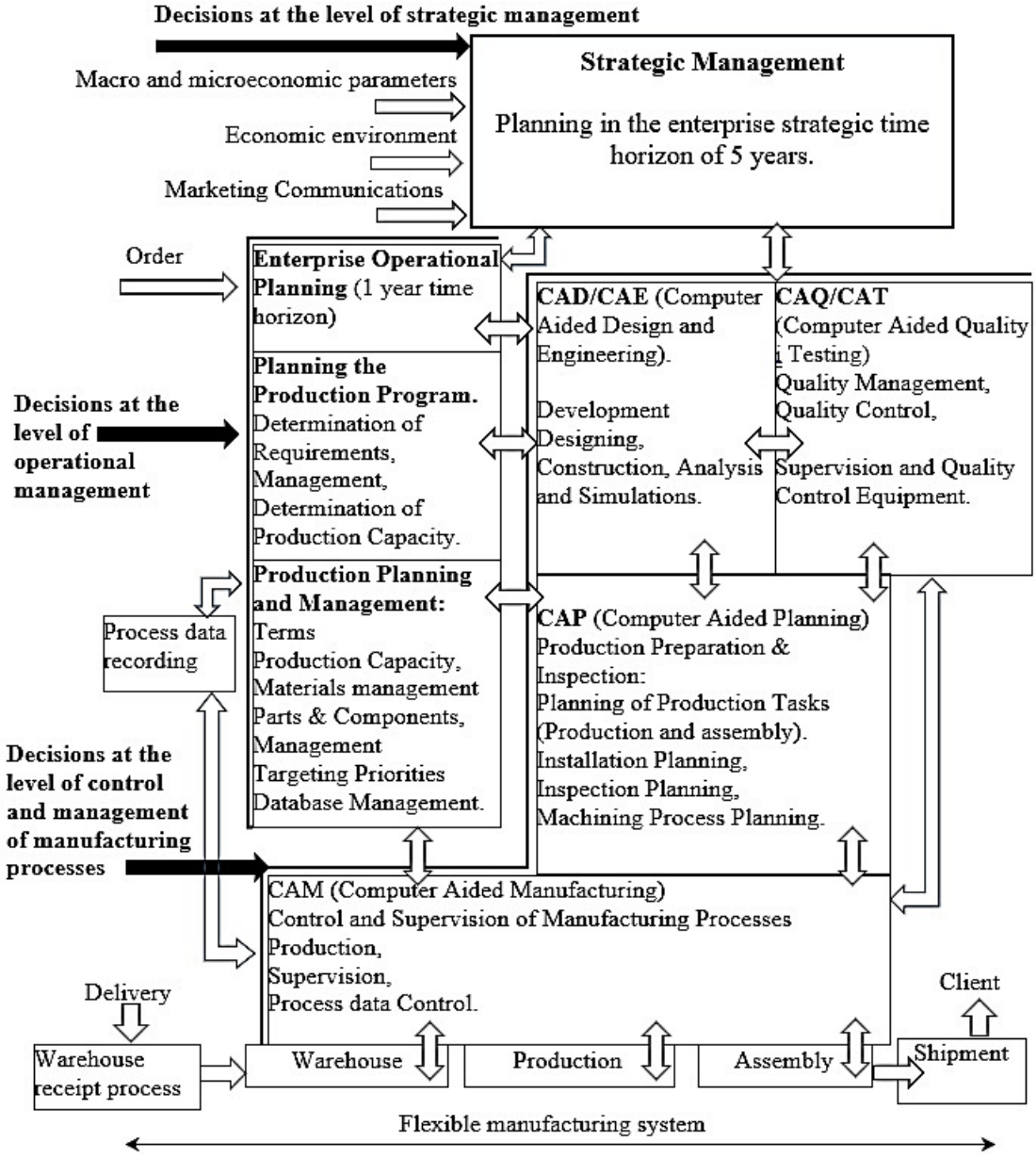

Figure 1. Computer-integrated CIM manufacturing and planning in the enterprise, taking into account three levels of management in a flexible manufacturing system.

Source: Zawadzka, 2007.

Strategic decision-making in the context of a flexible manufacturing system revolves around assessing the declared level of flexibility during its design phase. It is important to note that a flexible manufacturing system is a complex technical system typically comprised of eight functional (infrastructural) subsystems and three flow subsystems. These functional subsystems encompass production, control, transport, manipulation, storage, workshop aids, disposal and delivery, as well as diagnostics and control. The flow subsystems, on the other hand, pertain to the flow of energy, information, and material (Figure 2).

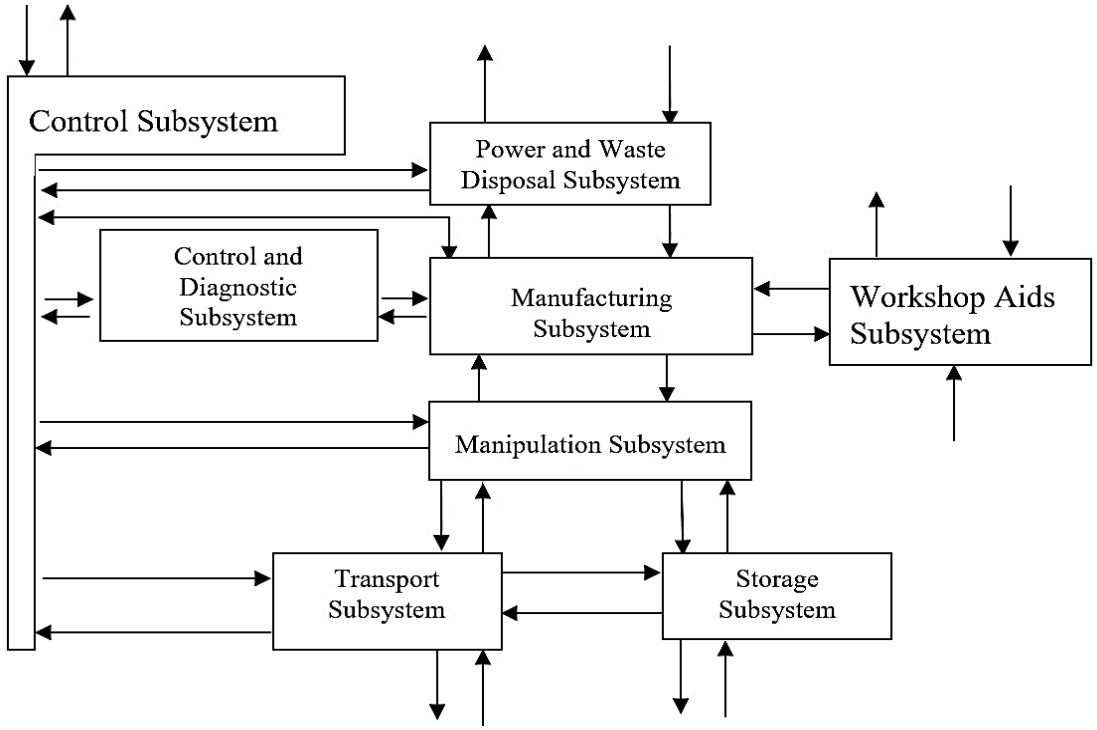

Figure 2. Interaction of subsystems included in the flexible manufacturing system.

Source: Lis et al., 1994.

The costs associated with implementing the system can be substantial, potentially exceeding hundreds of millions of euros. The decisions made regarding the selection of suitable technological and IT infrastructure will play a pivotal role in determining the operational characteristics of the system, as well as the lifespan of its individual subsystems, its adaptability and modernization in relation to both the products being manufactured and the overall production line infrastructure (Figure 3).

To mitigate the risk of overinvestment, the design of a flexible manufacturing system necessitates the incorporation of multiple feedback loops, which are designed to validate the design and detect any errors that may arise during the design phase, encompassing both the product and the required production infrastructure.

The technological efficiency of product construction is significantly influenced by decisions concerning the level of flexibility within the manufacturing system. Consequently, the integration of three key domains (strategic, operational, and technical) has become increasingly pertinent, especially in the context of the ongoing global digital transformation, which facilitates the enhanced integration of these processes.

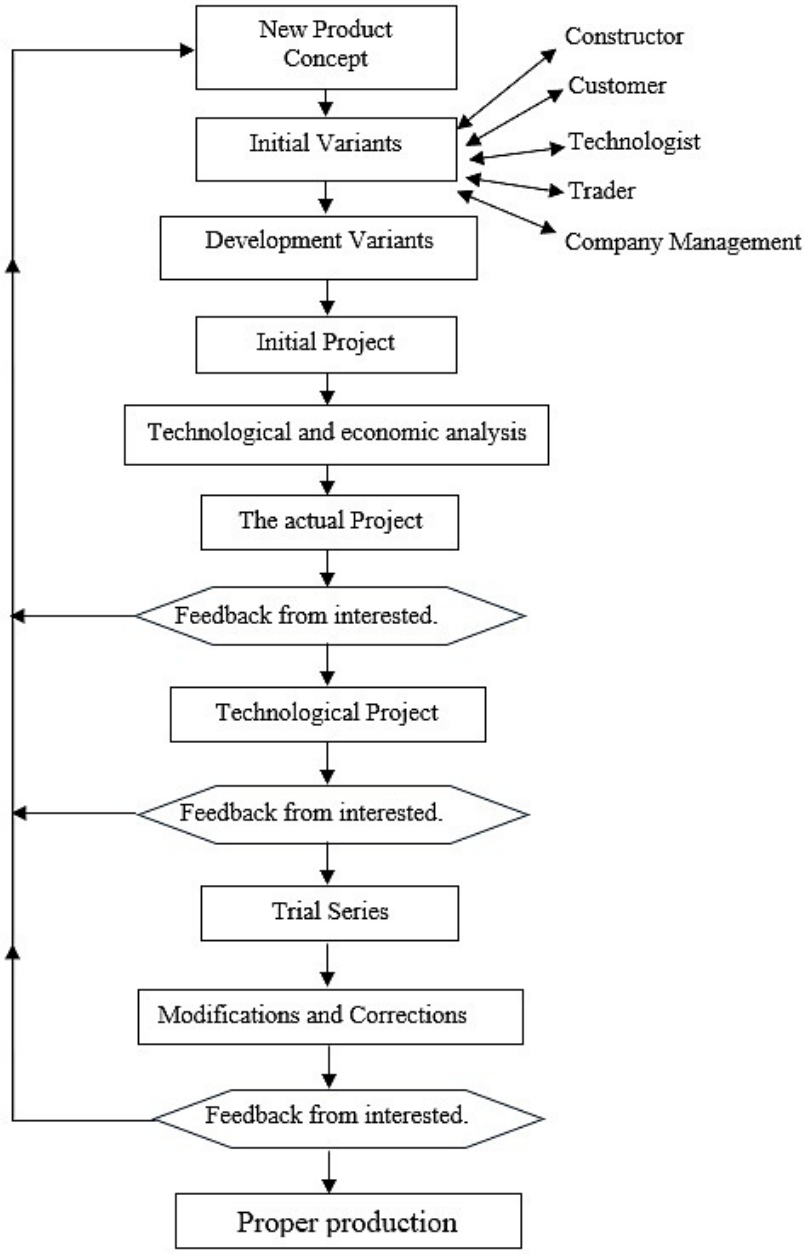

Figure 3. Decision-making algorithm for the degree of automation in the process of preparing the production of a new product using an automated, flexible manufacturing system.

Source: Honczarenko, 2000.

At the strategic level, making decisions necessitates the effective transformation of information into a form that can be characterized as knowledge about the relevant system. This level of knowledge processing represents the highest form of knowledge within the context of flexible manufacturing systems and can be described as wisdom that supports the system's operation. Strategic management frequently focuses on optimizing an enterprise's operation and, in more critical situations, ensuring its survival (Figure 4).

Decisions made at the operational level involve the utilization of knowledge concerning data processing and its application within the production scheduling process in a flexible manufacturing system. This knowledge encompasses the capabilities of the production system,

enabling the optimization of resource utilization and the adjustment of the production system to meet customer requirements. Operational management should be closely intertwined with the computer integration of CIM production, with specific focus on the technical aspects of designing and preparing the production process, due to the adaptability of the production process and the system's potential to modify product design, technology, and instrumentation.

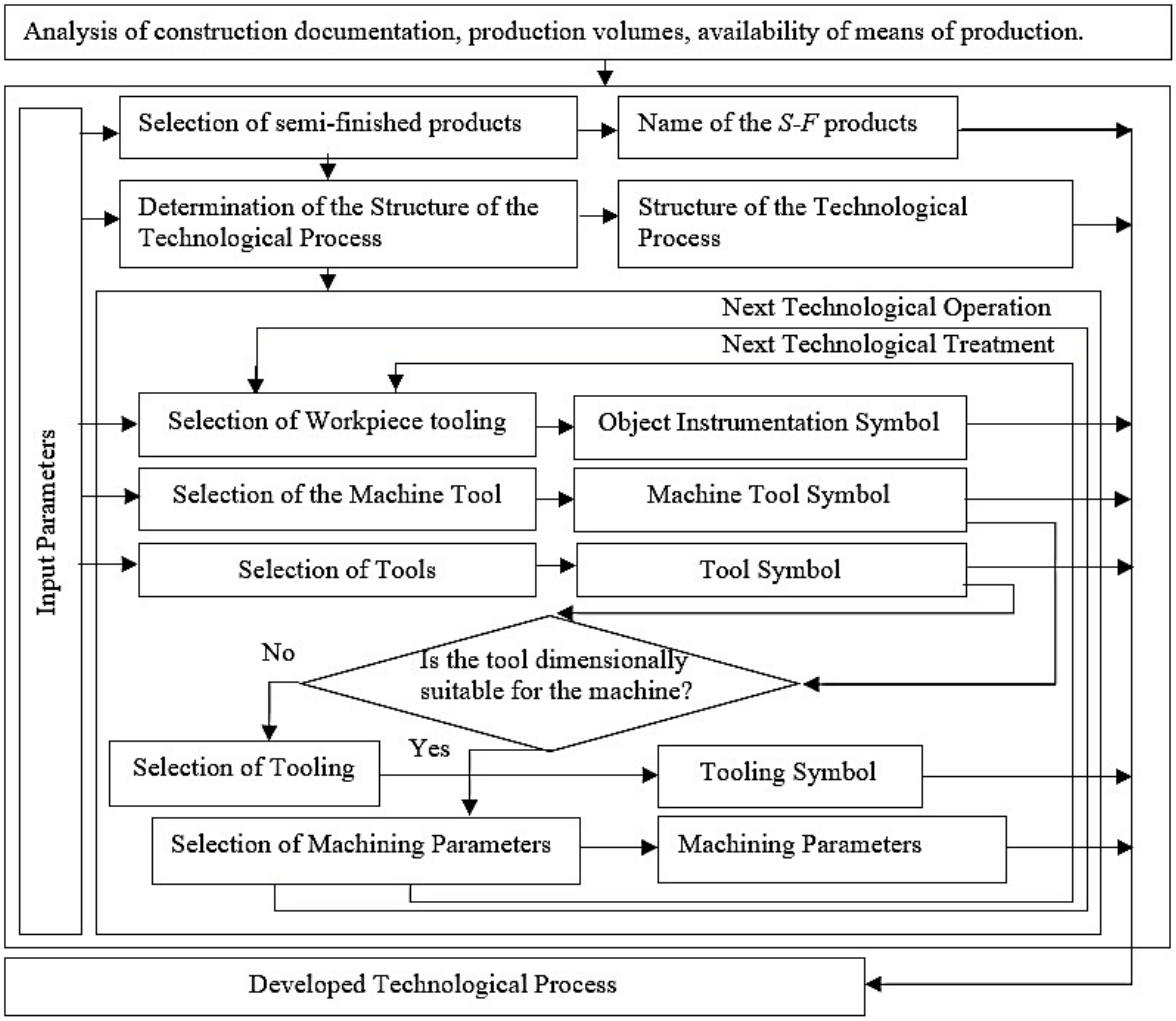

Figure 4. Decisions at the level of implementation of the technological process.
Source: Rojek, 2017.

Information required for decision-making at the technological process level is typically derived from factors such as machining parameters, weight and dimensions of products and components or materials, as well as parameterized to meet the control requirements of CNC devices. The challenge arises from dealing with a considerable number of processes and their high level of flexibility. This can lead to numerous combinations of product types and, consequently, necessitate adaptations in logistics processes for specific groups of technological processes. Moreover, the use of autonomous machining heads and systems supporting the technological process, which intelligently adapt the manufacturing process to dynamically changing conditions within the machining zone in real-time, is becoming increasingly

prevalent. Consequently, the execution of the technological process may evolve over time or even be interrupted by the control and diagnostic system should it surpass a critical threshold defining the minimum acceptable process quality.

The presented concept of the expert system was formulated following an analysis of the operation of a flexible manufacturing system. This system is equipped with CNC technological devices for machining and is complemented by supported manipulation subsystems that encompass manipulators, industrial robots, and mobile autonomous transport systems.

4. Proposal for an expert system to support decision-making in the design and operation of flexible manufacturing systems

The integration of manufacturing systems, as presented in part 3, and the intricate interactions among individual systems and subsystems necessitate the development of methods and tools, including the amalgamation of diverse data and information processing techniques in a manner most suitable for the flow of information and the characteristics of technological processes within flexible manufacturing systems. Therefore, based on a review of the literature related to the construction and operation of expert systems, a proposal was made for a hybrid modular system. This system takes into account a range of tools and information processing techniques employed in expert systems and other artificial intelligence systems. It enables the amalgamation of various decision-making levels within a flexible manufacturing system into a unified system (Figure 5).

During the process of building the core knowledge bases for the suggested expert system, it is anticipated that data for generating rules or decision tables will be sourced not only from expert knowledge but also from specialized systems, e.g., fuzzy logic rough sets, neural networks, genetic algorithms, and agent systems. Following the processing and consolidation of this data, it can then be passed on to subsequent tiers of the integrated management system. This approach allows for the efficient management of information flow by leveraging the strengths of the various information processing methods in use while mitigating their individual shortcomings.

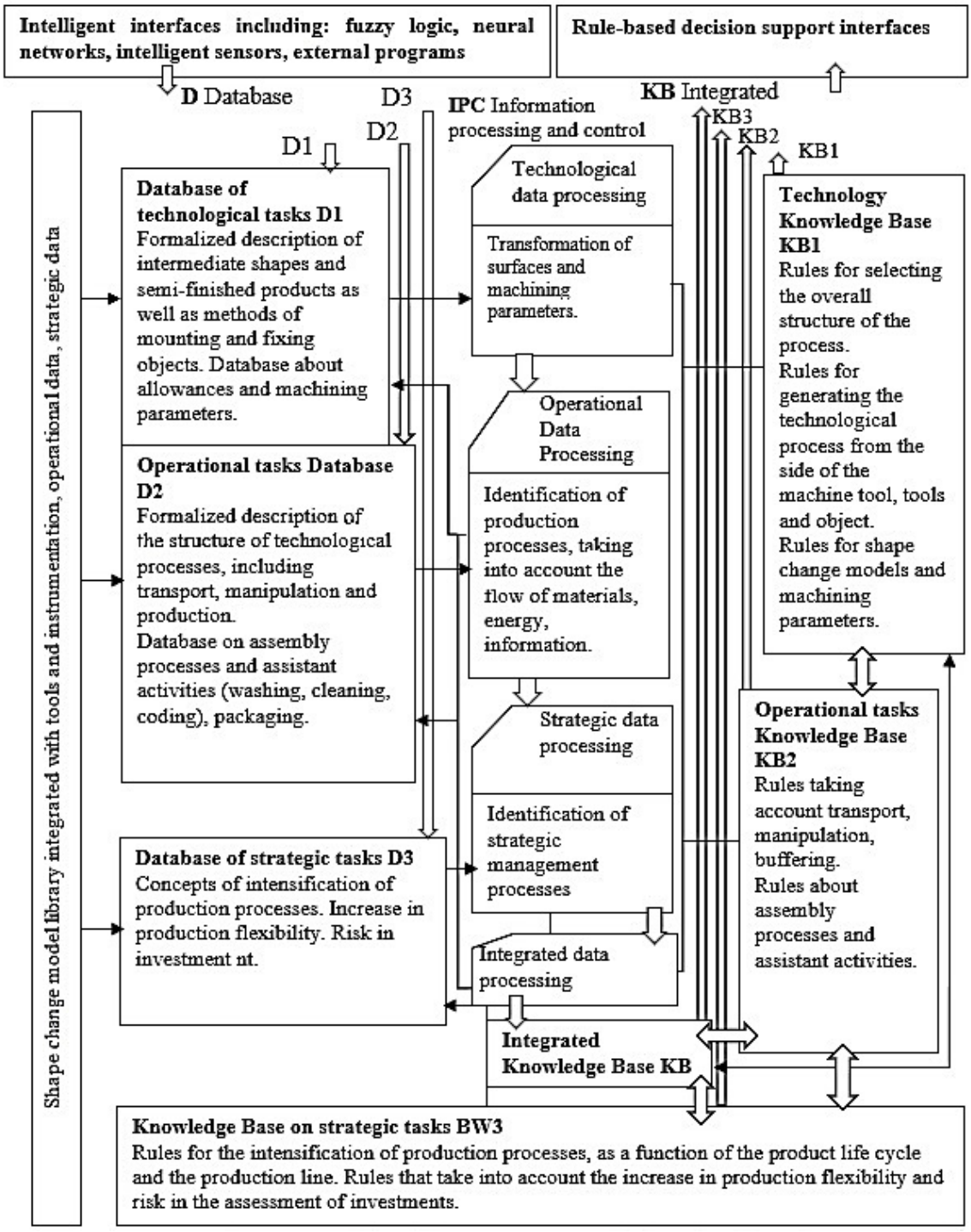

Figure 5. Expert system supporting technological processes based on rules.

The main idea of the proposed expert system is to process information at three levels of its operation (cascade with feedback) (Figure 6).

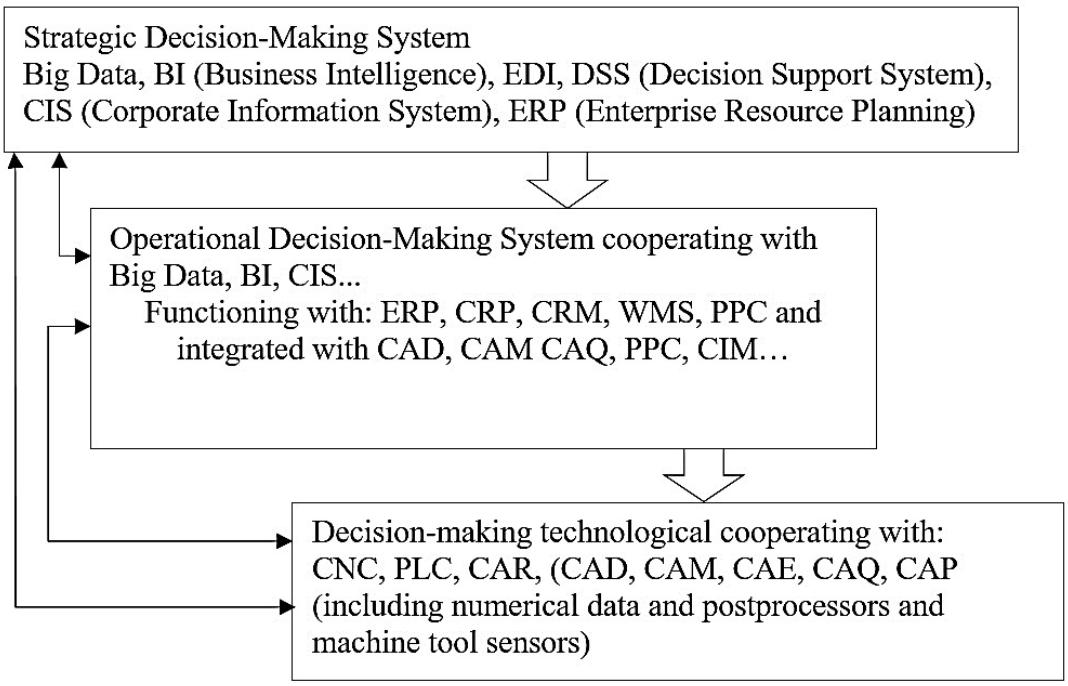

Figure 6. Proposal of an expert system supporting technological processes in accordance with the concept of computer integration of CIM manufacturing.

Consequently, this approach enables the fine-tuning and training of the decision support system's sensitivity at varying stages of information processing, allowing it to be well-suited and adaptable to real-world tasks.

In this scenario, the technical challenge to address involves the integration of information originating from the individual modules within the integrated expert system.

In the context of the technological level for an expert system, it is imperative to identify the critical activities and parameters that the system will execute, as they will define its functional structure. To accomplish this, a framework can be employed, akin to the principles of object-oriented programming in traditional programming (Figure 7).

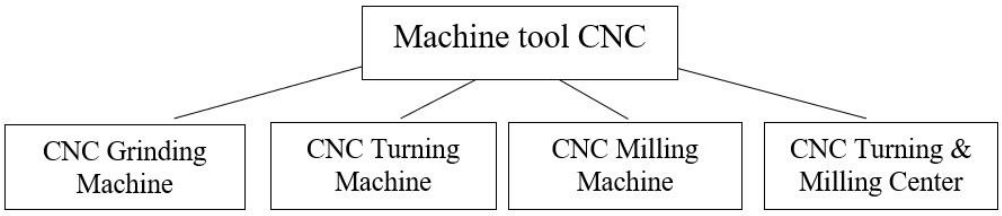

Figure 7. Example of a framework structure in a hierarchical structure for the classification of knowledge in relation to the concept of a CNC machine tool for an expert system.

When delineating the structure of the technological process, it is essential to consider factors such as production volumes, the level of flexibility within production processes, and the structural and technological intricacies of the products, components, and materials that will be incorporated into the production process (Figure 8).

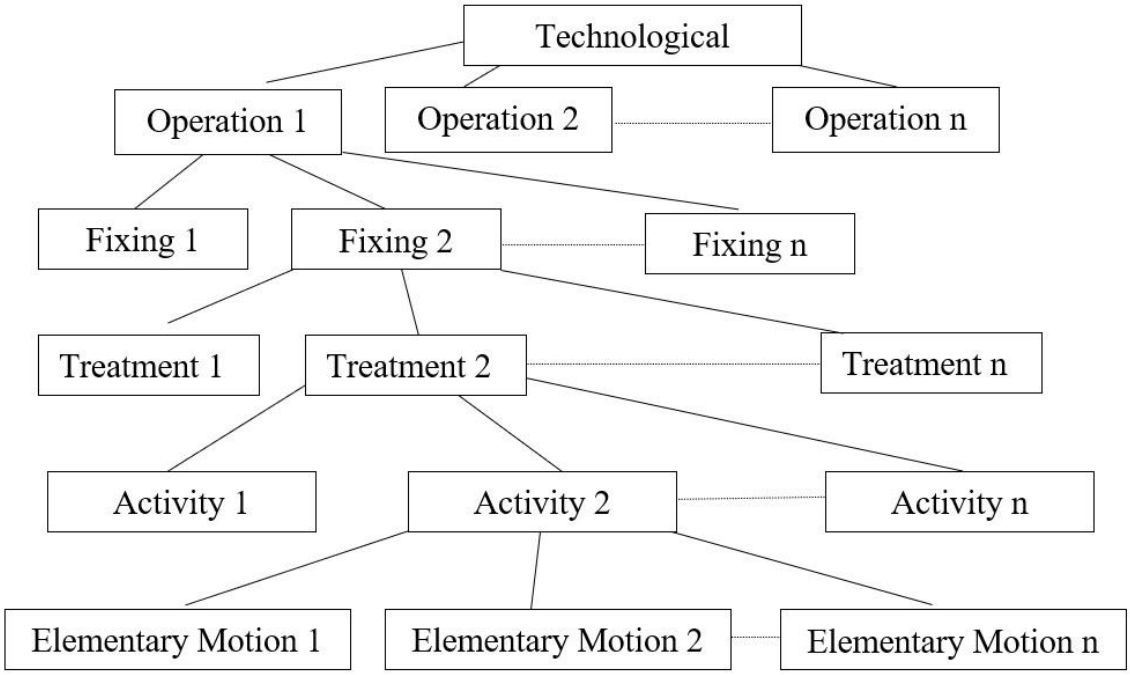

Figure 8. Hierarchical structure of the technological process.

Source: Chlebus et al., 2009.

The management of decision-making processes at the production (technological) level will revolve around the adaptability and interchangeability of technological devices (CNC machine tools) in relation to operational parameters and instrumentation, encompassing components like handles and devices, machining tools, as well as the associated cooling systems and the maintenance of their active surfaces.

At the lowest level of expert system functionality, there should also be a correlation with technological parameters concerning tool allowances, machine tool power, and the physical properties of processed materials, such as hardness and machinability. Technological management level should also consider processing time, which is associated with material characteristics and processing parameters. These aspects need to be linked with the quality of individual operations and treatments. This relationship should account for the requisite surface microstructure parameters (surface topography) and geometric factors like parallelism, perpendicularity, and coaxiality. Decision tables can prove to be valuable in this context, facilitating the establishment of interactions between various components of the technological process (Table 1).

The decision to deploy a CNC machine for a specific process will be influenced not only by the technical specifications of the device but also by factors like its placement and its interaction with other FMS subsystems, such as the kinematic complexity of the manipulation process, transportation distances, methods of buffering and retrieving parts, as well as determining and fixings. For this reason, it is advantageous to employ multiple decision tables that are suitably structured hierarchically. This approach facilitates the acquisition of comprehensive information about the processes and the production system.

Table 1.
Example of the decision board for selecting a CNC machine tool

Number CNC Machine Tool	Characteristics CNC Machine Tool				
	Multi-spindle machine tool over 20 thousand rpm	**More than 20 tools in stock**	**Compatible with a 5-axis robot equipped with <50 mm**	**Mechanical stiffness**	**Decision to use a CNC machine**
1.	Yes	Yes	No	High	**Yes**
2.	No	Yes	No	Low	**No**
3.	Yes	No	Yes	Very high	**Yes**
4.	Yes	No	No	Average	**No**

Note. **Yes** or **No** decision to use a CNC machine.

Source: Own study.

All the mentioned groups of information can be quite easily associated with the costs of implementing the technological process. On this basis, another category of information needed to develop rules describing the implementation of the technological process should be derived from. These include the retooling times of technological devices in relation to both handles and devices, as well as tools defined as cutting blades, and the infrastructure that gives them features that enable them to be used for machining external or internal surfaces.

The formulated rules should also consider the time required for the transportation of materials, components, semi-finished products, and finished products within the storage, manipulation, and transport subsystem. This should encompass the buffering of tools and their transportation within the area of interaction between technological devices and manipulation systems.

In such situations, it is advantageous to employ semantic schemas that facilitate the creation of an information structure capable of forming a suitable knowledge base. This knowledge base will in turn support decision-making tasks in this context (Figure 9).

At the technological and operational levels of the expert system's operation, the primary decision-making activities will revolve around minimizing alterations within the flexible manufacturing system regarding enhancing the rigidity of the tool-machine system, variations in the approach to mounting, diverse methods of executing the transport and manipulation process, and the strategy for cooling the machining zone.

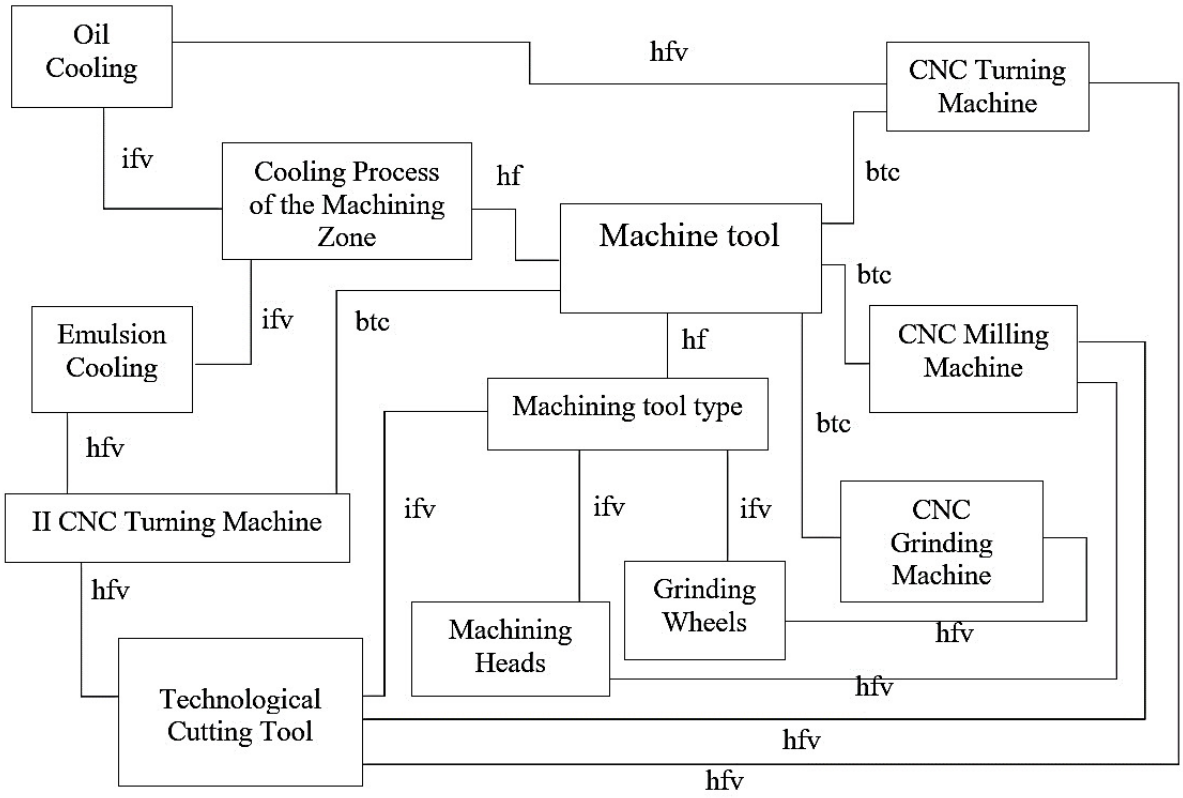

Figure 9. An example of a semantic network of a technological process specifying connections and interactions between individual objects included in it (ifv (is a feature value), btc (belongs to a class), hfv (has a feature value), hf (has a feature).

Any alteration in the system configuration necessitates investing time in retooling and aligning the machining system with the demands of the technological process to uphold the required quality while also considering acceptable process implementation costs. To facilitate the real-time operation of the expert system, it is advisable to incorporate fuzzy sets, which can serve as a tool supporting the operation of rules describing the dependencies of the technological process. Considering the sensors integrated into the equipment of CNC machines, robots, and machining tools for tasks like wear identification, or those employed to automate the operations of machining heads, including the monitoring of force components in the machining zone, it is sensible to introduce agent systems for managing the technical process at this stage. This approach allows for the assessment of the condition of individual devices and the transmission of precise data to the structural framework of the expert system responsible for the real-time technological support of the manufacturing process (Figure 10). In such a scenario, the expert system accurately mirrors the actual flow of information and transforms into a digital representation of the processes transpiring within the flexible production system.

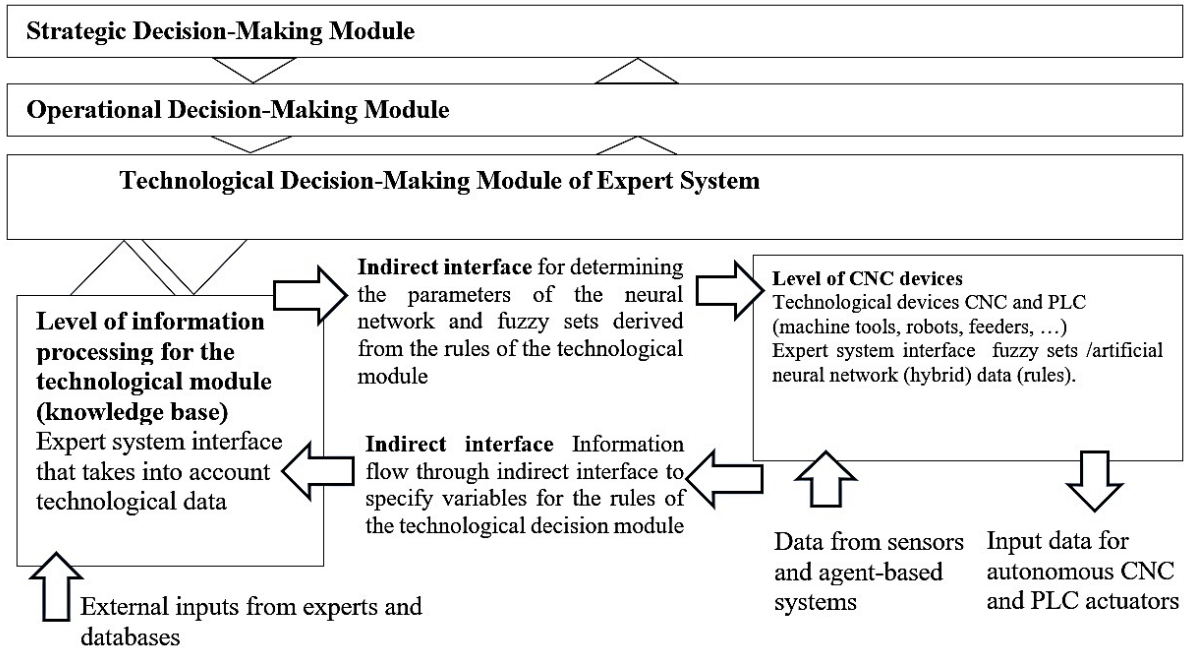

Figure 10. Information flow for the technological level of decision-making and the proposed topography of methods and tools for the decision-making system.

Operational management within a flexible manufacturing system primarily involves the planning of production processes, encompassing production logistics like supply, storage, and transport subsystems. Consequently, in the envisaged hybrid expert system, the adoption of multi-agent systems technology is planned for the operational management level. These agents will be tasked with emulating the self-organization and autonomy of systems in the domain of transport, storage, and supply, with specific focus on internal transportation. The depiction of these processes can also be achieved with the aid of fuzzy sets (including fuzzy logic controllers and neural networks), which are complemented by decision tables and expert system rules. It should be noted that the database for the operational management level and the resulting decisions are derived from the possibility of implementing technological processes, often conditioned by knowledge of mechanics and physical interactions occurring in the interaction with chemical affinity in the tool-workpiece system. Such a knowledge base possesses a distinct nature in contrast to operational management, which is influenced by incoming orders and the flow of information, materials, components, and products, along with the requisite equipment necessary to execute the technological process as a function of time and energy expended (Figure 11).

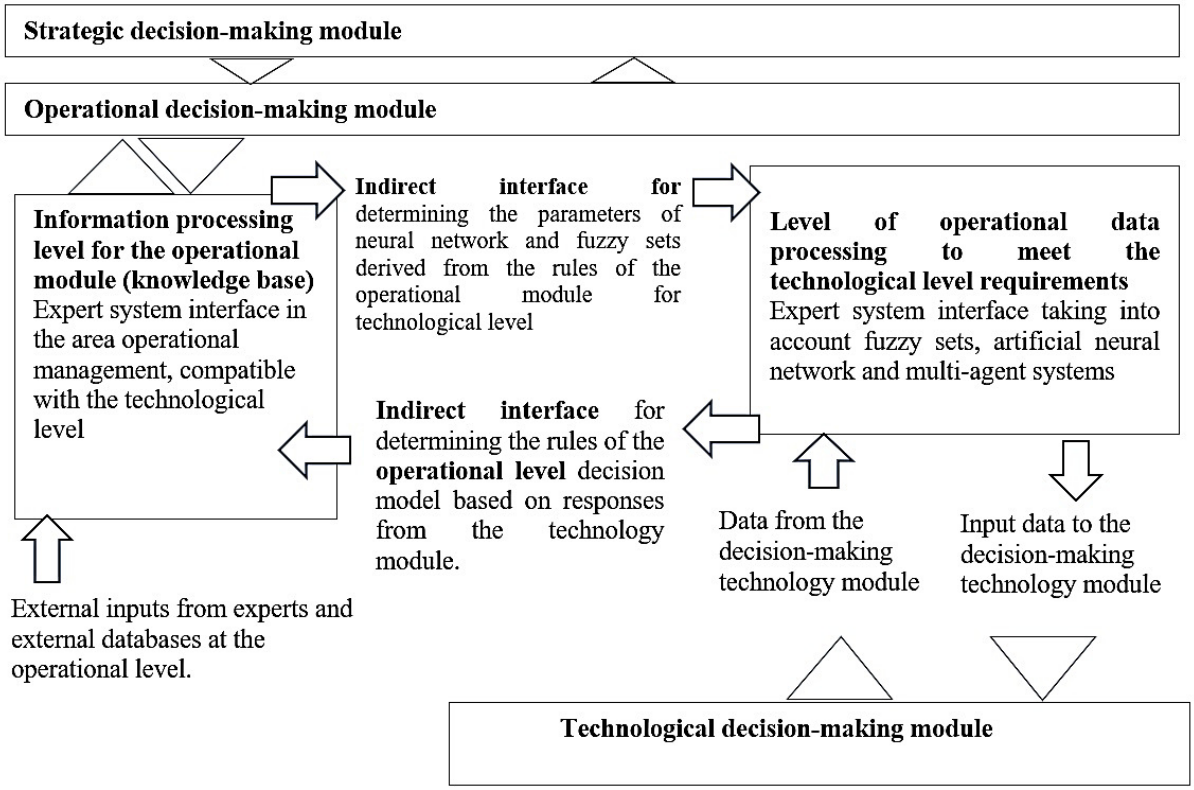

Figure 11. Information flow for the operational level of decision-making and the topography of methods and tools.

The third tier of the hybrid expert system is intended to provide decision support at the strategic level in terms of the design, development, and management of a flexible manufacturing system. It is anticipated that the strategic reasoning subsystem will not only facilitate the external expansion of the knowledge base, which describes the environment of the information system, but will also be closely interrelated with the operational and technological management subsystems.

In the third module of the expert system, economic factors will play a crucial role, with analysis conducted at both regional and global levels. These economic parameters can have an impact on the modification, assessment, and planning of the scale of the production process carried out through a flexible manufacturing system.

Strategic-level decisions can be made through approaches such as backward reasoning, and future scenarios can be constructed based on these decisions. In this context, establishing semantic relationships and employing suitable fuzzy inference in conjunction with neural networks is of significance. However, in this case, their operational model will not focus on the technical aspects of the technological process, as indicated at the technological level of the proposed system. Instead, it will revolve around market observation and economic parameters within a specific economic sector, as well as the analysis of the economic conditions associated with production and investment processes characteristic of a particular type of flexible system (Figure 12).

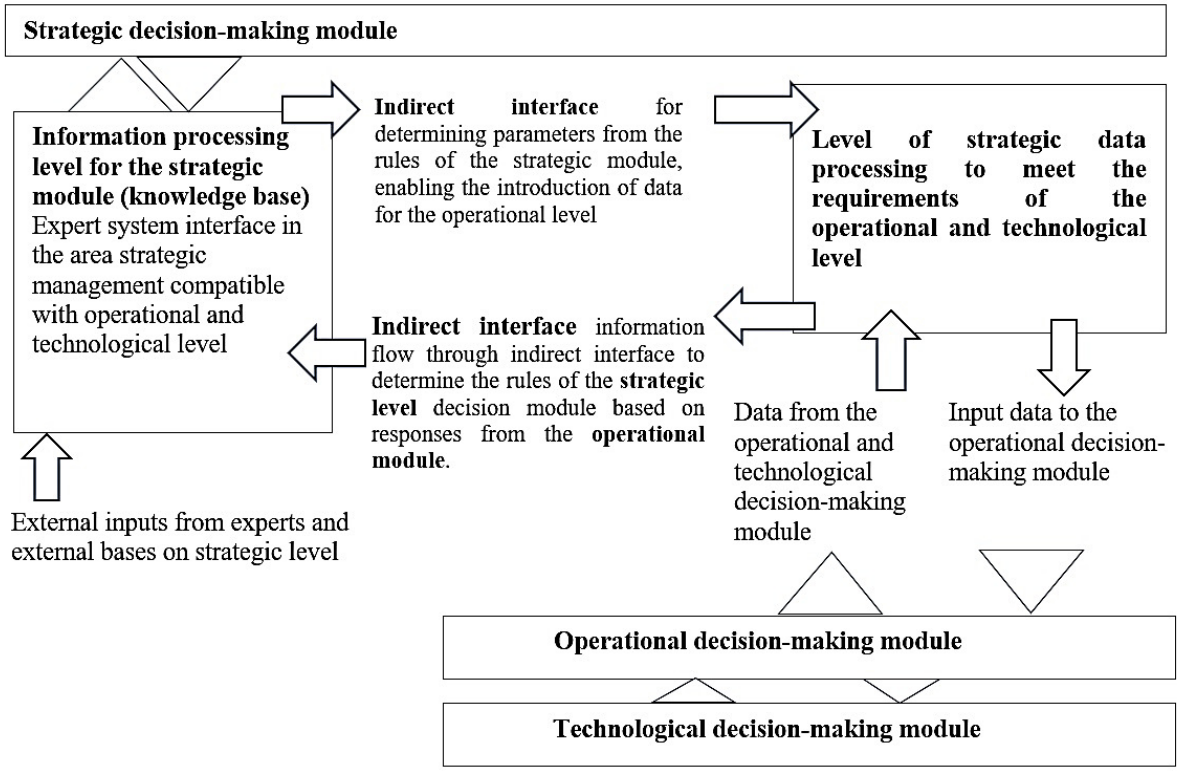

Figure 12. Information flow for the strategic level of decision-making and topography of methods and tools.

Developing a comprehensive decision support system for the design of flexible systems appears advisable, given the substantial business risks associated with managing such systems. The costs associated with designing, implementing, operating, and expanding flexible manufacturing systems underscore the rationale for decision support systems in this domain. Enhancing these systems can be viewed as a purposeful endeavor.

5. Discussion

The proposed configuration of the decision support and management system for a flexible manufacturing system places primary emphasis on the core structure of the rule-based expert system, which should be equipped with specialized modules of the strategic, operational and technological data processing system based on appropriately developed knowledge bases (heterogeneous sources of knowledge) and interfaces enabling integration of individual modules.

In light of the considerations mentioned above, the question raised in the introductory section of the article about whether implementing a modular structure for a hybrid real-time expert system, mapping the structure of a flexible manufacturing system and the interactions within it, can improve the management and decision-making processes at the strategic, operational, and technical levels of a flexible manufacturing system, should be answered

affirmatively. The question can be answered positively, since the analysis conducted suggests that the adoption of multi-stage data processing may enable proper scaling and adequate stabilization.

The second question can also be answered in the affirmative. The analysis has demonstrated that the integration of modules in a real-time expert system can enhance the information flow within its information system and align it more effectively with the requisites of Industry 5.0. It appears that the suggested multi-stage integration of subsystems may play a role in stabilizing information flow. Similar to biological structures responsible for cognitive processes and nerve impulse conduction, where information flow is transformed through electrical and chemical interactions within specialized regions of nerve cells. This allows for the appropriate amplification or attenuation of the signal. These biological structures exhibit a degree of autonomy, each assigned to specialized tasks for carrying out specific levels of information processing (e.g., the medulla oblongata). Interactions between systems occur only in specific situations, most commonly during critical moments for the body, such as when balance thresholds are exceeded, for instance, in dangerous situations. Therefore, the article proposes various approaches to processing information that are well-suited to specific tasks.

The article presents a concept for a system that facilitates the decision-making process with regards to designing flexible manufacturing systems and managing production processes, while taking into consideration the intricacies of constructing a flexible system, its operation, and the effectiveness and quality of implemented technological processes. The structure of flexible manufacturing systems and computer-integrated manufacturing was thoroughly examined, leading to the proposal of an integrated approach to management and decision-making, both at the strategic and operational levels, as well as the management of manufacturing processes in relation to technological processes.

The article highlights the importance of structuring information hierarchies to align with the tasks performed in various subsystems and systems, extending all the way to individual CNC devices, robots, and AVG mobile robots. Moreover, when considering the integration of these devices, the knowledge base should encompass sensors and sensor groups, as well as control and diagnostic systems situated within technological devices and PLC controllers responsible for integrating executive devices across production lines and warehouses. This approach enables the creation of a digital representation of the production line within a flexible manufacturing system, complete with interactions and feedback loops within the expert system, essentially forming a mirror image of the FMS information.

6. Conclusions

The concept is tailored to the unique functioning of flexible manufacturing systems and expert systems that provide decision-making support in the production process. Drawing from the research conducted, the following conclusions were derived:

1. The proposed concept of a hybrid expert system holds the potential to aid decision-making in the context of advanced flexible manufacturing system design. It can play a role in cost reduction during design, implementation, and ongoing operation, while minimizing the risk, overinvestment and reversal of all positive aspects of the functioning of flexible production systems.
2. The development of integrators that connect individual management levels through artificial intelligence methods could facilitate the optimal management of such a complex production system. To achieve this, the proposal involves using a hybrid expert system, which includes rules, semantic schemas, decision tables, and tools for implementing fuzzy logic, as well as artificial neural networks and agent systems integrated with expert systems.
3. The costs associated with implementing the technological process can be estimated by leveraging real-time technological data obtained from CNC machine tool controllers and industrial robots. The expert system at the technological level can utilize this data to construct a knowledge base about individual processes over time. Using this foundation, it becomes possible to estimate costs through the use of fuzzy sets and neural networks, without the necessity of simulating all components of the manufacturing process originating from CAM systems. Such an analysis can be conducted at both the technological and operational management levels.
4. Designing virtual manufacturing systems using CAD/CAM systems does not provide a direct answer as to their efficiency and processing time until all technological paths are analyzed, and technological processes are implemented in order to obtain precise information on the time and costs of the process. However, this approach is time-consuming, and the sheer volume of interactions involved makes it practically impossible to conduct a comprehensive analysis.
5. The use of rules in an expert system is comprehensible to a human (expert), allowing them to construct a knowledge representation in the form of a knowledge base. However, the rules have limitations due to the inability to model incomplete knowledge and they do not allow for modeling the full domain and provide automatic reasoning. They also do not allow for backward rule diagnostics. Rule-based reasoning does not always align with the theory of probabilistic reasoning. As a result, relying solely on rule-based expert systems for a complex system like a flexible manufacturing system does not facilitate the integration of its components and consistent real-time data processing.

6. In the analysis of hybrid expert systems, it has been observed that modifying the information flow between different system levels can enhance its stability. Progressing to higher levels of information processing involves translating data that can be adapted. This enables the complex information flow to ascend to broader areas of strategic management while descending to the level of technological decisions with the assistance of rules complemented by fuzzy sets (including hardware-level Fuzzy Logic controllers and neural networks). These can be responsible for identifying specific processes. Agent systems collaborating with sensors, PLC and CNC control systems of technological devices, as well as mobile systems, can facilitate decisions at the operational management level. Importantly, this proposed concept does not exclude expert knowledge; their wisdom can be incorporated into the system through the rules that form the system's overarching structure.
7. It was observed that the configuration of an expert system can function dispersed as a network of individual methods and tools and then, thanks to modern digital transformation possibilities, information can be processed in the system and appropriately unified and transferred for use at subsequent levels, reaching the stage of strategic management.
8. The article is intended for managers and specialists in the fields of management and production engineering, particularly in mechanical engineering and management and quality sciences. The article falls within the domain of technical concepts and a comprehensive analysis of decision support using artificial intelligence methods.

In the subsequent phases of research, the intention is to validate the presented concept by employing actual objects and specific systems and subsystems within a flexible manufacturing system using computer simulations imitating their functioning. The subsequent stage will involve simulating all the subsystems of the flexible manufacturing system as a digital twin, which will be integrated into the expert system. Consequently, this will facilitate correlation research aiming to understand how the digital model of the flexible manufacturing system generates information regarding its status, and how the corresponding integrated expert system identifies responses and formulates decisions to support management processes in the flexible manufacturing system.

Future research will focus on the concept of facilitating the near real-time flow of information between subsystems. The research will revolve around the creation of intermediate interfaces that can parameterize information, making it suitable for further processing. This will enable the development of an automated mechanism for the seamless transfer of information within a modular expert system that replicates the structure of a flexible manufacturing system.

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THE PROBLEMS AND EFFICIENCY OF INVESTMENT IN SHARES OF COMPANIES WITH A HIGH PRICE-TO-BOOK VELUE RATIO IN THE CONTEXT OF INTELLECTUAL CAPITAL ISSUE

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Purpose: The main aim of the article was to present the problems with application of the investment strategy based on companies with high P/BV ratio and to examine its efficiency, taking also into account the enterprises' intellectual capital issue.
Design/methodology/approach: The study was conducted with respect to companies listed on the main market of the Warsaw Stock Exchange in the period 2010–2022 and was based on data published by WSE, which for individual companies included in particular P/BV ratio, P/E ratio, share price, EPS and ROE. The study was conducted in four approaches: (i) growth companies identified only on the basis of P/BV ratio, (ii) growth companies with an additional result criterion, (iii) companies with an estimated high level of intellectual capital identified only on the basis of P/BV ratio and (iv) companies with an estimated high level of intellectual capital with an additional efficiency criterion.
Findings: The study carried out in the field of analyzing the efficiency of investment strategies based on companies with high P/BV ratio values, including taking into account the issue of intellectual capital in the enterprise, allows to conclude that, at least from the point of view of the considered period of the study, this is an approach that allows "to overcome" market. At the same time, however, the results of the study showed that the use of easily accessible and popular additional criteria identifying companies in the portfolio does not necessarily provide an advantage over the broad market or the usual approach without additional criteria. This applies especially to a longer time horizon.
Research limitations/implications: A certain limitation of the study and its results and final conclusions is the adopted, not very long, time frame (10 years), which was partly due to the availability of data and adaptation to the stock market cycle.
Practical implications: Investment strategies based on companies with high price-to-book value ratios are not on the losing end when compared to the market index.
Originality/value: The article presents an original approach to application of the investment strategy based on companies with high P/BV ratio and to examination its efficiency, taking also into account the enterprises' intellectual capital issue. The article is addressed in particular to researchers dealing with the subject of valuation and measurement of intellectual capital in an enterprise, as well as analysts and stock market investors.

Keywords: price-to-book value ratio, intellectual capital, growth stocks, investment strategy.

Category of the paper: Research paper.

1. Introduction

Among many investment strategies used by investors on the capital market (Damodaran, 2012; Zaremba, 2013), some of the most popular and compared in terms of results are the strategy of investing in shares of growth companies and the strategy of investing in shares of companies with value potential (Miller, Prondzinski, 2020). Regardless of certain differences in the characteristics of growth companies and companies with value potential, the former are most often associated with high values of price multipliers, such as price-to-book value (P/BV) or price-to-earnings (P/E), and the latter with their low values (Zarzecki, Wołoszyn, 2016; Donnelly, 2014; Miller, Prondzinski, 2020; Penman, Reggiani, 2018).

As Chan and Lakonishok (2004) note, considerations regarding investments in growth companies and companies with value potential are also one of the best examples of a fruitful exchange of ideas between academic research and investment practice. On the one hand, the results of academic research created the basis for investment strategies that were implemented on the capital market, and on the other, the investment community developed procedures for identifying growth companies and companies with value potential and created benchmark indices for them, which subsequently allowed for the continuation and deepening of scientific research in this area.

The beginnings of the division of companies into the two groups mentioned above, and the increase in interest in the effectiveness of investment strategies based on them, are associated in particular with the works of Fama and French (1992) as well as Lakonishok, Shieifer, and Vishny (1994), in which attention was paid to higher rate of return on shares of companies with potential value than on shares of growth companies - the so-called "the value premium". This premium is explained, on the one hand, by the higher risk of companies with low market multipliers, identified with their financial problems and poor results (Fama, French, 1992), and, on the other hand, by the market's underestimation of shares of companies in difficult financial and earnings situations (companies with value potential) and the market's revaluation of shares of growth companies characterized by improving financial and earnings conditions (Billings, Morton, 2001; Skinner, Sloan, 2002; Haugen, 1995; Lakonishok et al., 1994; Penman, Reggiani, 2018).

The existence of "the value premium", especially in a longer time horizon, is confirmed by numerous studies from various stock markets (Fama, French, 1992; Bauman et al., 1999; Sun, 2012; Gupta, Arora, 2019). This situation also undermines the efficient market hypothesis formulated by Fama (1970), according to which share prices reflect all information available at a given moment, which means that investors cannot expect above-average profits (Malkiel, 2003).

At the same time, it should be noted that the advantage of companies with value potential over growth companies in terms of the rate of return on investment is not sustainable over time. As long-term statistics for the US market show, periods of advantage of one group over the other alternate, with companies with value potential more often coming out on top and the average rate of return on investment for them is higher (Giannotto, 2023; Hartford Funds, 2023). Nevertheless, recent years have seen the dominance of growth companies, associated mainly with rapidly developing modern technology sectors, which benefited from easy access to low-interest capital resulting from quantitative easing after the financial crisis in 2008 (Lynch, 2021; Bevanda et al., 2021).

At this point, it is also worth paying attention to the above-mentioned considerations, including in particular those relating to growth companies, issues related to the intellectual capital of enterprises, which in a simplified approach is identified with the difference between the market and book value, which is a direct reference to the price-to-book ratio (Edvinsson, Malone, 1997; Sveiby, 2010).

For this reason, the main aim of the article was to present the problems with application of the investment strategy based on companies with high price-to-book value ratio and to examine its efficiency taking also into account the enterprises' intellectual capital issue. The study was conducted in relation to companies listed on the Warsaw Stock Exchange based on their share quotations in the period 2010-2023.

The article consists of a theoretical introduction and its expansion in relation to the perception of the P/BV ratio, methodological part, research results and summary.

2. The price-to-book value ratio as a measure of the investment attractiveness of company and its intellectual capital

2.1. P/BV ratio in general

The price-to-book value ratio is one of the most popular price multipliers used on the capital market as part of the financial analysis of companies (market indicators), their valuation (comparative methods), or generally assessing their investment attractiveness (Nawrocki, 2011). It is calculated according to the formula (Czekaj and Dresler, 2005):

$$\frac{P}{BV}ratio = \frac{Market\ Value}{Book\ Value} = \frac{Share\ Price}{Book\ Value\ per\ Share} \tag{1}$$

where:

$$Book\ Value\ per\ Share = \frac{Shareholders' Equity - Preferred\ Equity}{Number\ of\ Common\ Shares\ Outstanding} \tag{2}$$

Depending on whether the equity in the company, which is the basis for the denominator of the P/BV ratio, is positive or negative, the P/BV ratio values may also be positive or negative, but often in the case of negative equity in the company, the indicator simply does not counts and denotes with an "x" or "-".

In general, the P/BV ratio is the ratio of the company's market value (company's capitalization on the stock exchange) to its book (balance sheet) value, identified with the value of equity, and gives an indication of how investors perceive a given company. The limit value of the indicator can be 1, which means that the capital market values the company's shares at the same level as their book valuation (equity per share). Index values higher than 1 mean a market valuation higher than the book valuation, and values below 1 mean a market valuation lower than the book valuation (Czekaj, Dresler, 2005). At the same time, however, it should be borne in mind that high P/BV ratio values (well above 1) do not necessarily mean that the shares of a given company are overvalued, and low values (well below 1) mean that they are undervalued. The perception of overvaluation or undervaluation of a given company's shares by investors, apart from the P/BV ratio itself is also determined by its financial condition and earning capacity, in particular expectations regarding the improvement of financial results (Sierpińska, Jachna, 2000; Nawrocki, 2011). In this regard, a specific two-dimensional P/BV ratio – financial condition and results matrix can be used (Table 1).

Table 1.
Price-to-book value ratio – financial condition and results matrix

		P/BV ratio	
		low	**high**
financial condition and results	bed	weak company with low valuation	overvalued company
	good	undervalued company	good company with high valuation

Source: own work.

Therefore, the shares of a given company can only be said to be overvalued when its high P/BV ratio is matched by its poor financial condition and lower earnings expectations. Companies in which high P/BV ratio values correspond to good financial condition and systematic improvement of financial results are usually positively assessed by the capital market and highly valued, and are referred to as growth companies. Such companies, apart from high price multipliers such as P/BV or P/E, are particularly distinguished by an upward trend in results in the past, which, according to forecasts, is to be maintained also in the future, high profitability of sales and return on equity (ROE) and the lack of dividend payments (earned profits are invested in further development) (Segal, 2021; Mikołajewicz, 2014). In turn, the shares of a given company can be said to be undervalued in a similar way when the low P/BV ratio corresponds to an improvement in its financial condition and an increase in earnings expectations. Companies for which low P/BV ratio values correspond to poor financial condition and deterioration of financial results are usually negatively assessed by the capital market and lowly valued. Companies of this type are called value due to a certain value potential that can be released if the problem they are facing is removed and they return to the growth path (Mikołajewicz, 2014).

2.2. High price-to-book value ratio as a determinant of intellectual capital in companies

The interest in the P/BV ratio is not limited only to the investment sphere, but has also appeared for many years in the discussion on the measurement or assessment of the intellectual capital of enterprises in the management literature. The key issue in this context is to perceive the intellectual capital (IC) in an enterprise as the difference between its market value (MV) and book value (BV) (Edvinsson and Malone, 1997; Sveiby, 2010):

$$IC = MV - BV \tag{3}$$

Due to the same variables, this approach to intellectual capital can be easily translated into the P/BV ratio (1).

Although the concept of intellectual capital appeared in the literature many years ago (Pirogova et al., 2020), it remains a category that is difficult to clearly define (Buenechea-Elberdin, 2017). Therefore, both in the literature and in economic practice, there are different definitions of this category, and in research on the nature of intellectual capital, a certain terminological heterogeneity can be noticed. Most often, it is identified with intangible assets, hidden assets, invisible assets, non-tangible assets, non-financial assets, intellectual resources, intangible resources, knowledge capital or intellectual matter (Bombiak, 2016; Sledzik, 2011). Generally speaking, it can be said that the definitions of intellectual capital approach this category in two ways, treating it as (Sydler et al., 2014; Bombiak, 2016; Hussinki et al., 2017):

- a factor that creates value for the company and strengthens its competitive advantage,
- the sum of its components, including in particular:
  - human capital – the intellectual potential of employees and the possibilities of using it determined by their motivation;
  - structural capital (internal, organizational) – organizational culture, systems, methods and processes as well as organizational and information infrastructure facilitating the flow of knowledge in the organization and the use of human potential;
  - relational capital (external, network architecture) – all relationships with external stakeholders (investors, suppliers, customers), as well as the reputation resulting from these relationships.

In relation to considerations on intellectual capital, its specificity is well reflected in the "iceberg" model and the "tree" metaphor. In the "iceberg" model, the company's resources are presented divided into tangible (e.g. land, buildings, equipment, inventories, securities) and intangible (e.g. employee competences, management philosophy, organizational culture, reputation, customer loyalty, brand), with which indicates that the latter, unlike the former, are less visible to the environment and more difficult to value, but at the same time have a greater ability to generate added value for the company (Dobiegała-Korona, Herman, 2006). In turn, the "tree" metaphor indicates that what is visible to the surroundings (crown, i.e. trunk and leaves) is the so-called the external image of the company, which is the result of invisible, hidden values inside the company identified with intellectual capital (tree roots). We can draw

the conclusion that when the roots of a tree no longer perform their tasks well, the entire tree will be destroyed (Adamska, 2015).

Returning to the issue of using the P/BV ratio as an identifier of companies with a high level of intellectual capital (P/BV > 1, especially significantly above 1), it should be noted that this is a simple but highly imperfect approach. On the one hand, it is criticized due to its far-reaching generality and combining the monetary value of intellectual capital with the value also generated by other types of capital in the enterprise (Jardon, Martinez-Cobas, 2021). On the other hand, attention should also be paid to the significant burden of this approach, which often occurs in the case of listed companies, with high dynamics of changes in their market quotations (prices), which may lead to distortions in the measurement and assessment of the level of intellectual capital of the analyzed entities (Nawrocki, 2022). In this respect, it is worth bearing in mind that the price of company shares on the stock exchange market is not determined solely by objective, fundamental factors, but is, to a large extent, the result of investors' emotions regarding various information and related expectations (Zaremba-Śmietański, 2013).

Therefore, this method is more suitable for the initial identification of entities with a potentially high level of intellectual capital than for its precise measurement. At the same time, its credibility can be increased based on the quotations, or P/BV ratio, of the analyzed companies in the form of an average or median over a longer period (preferably several years). Thanks to this, single high readings, which are often the result of a temporary increase in emotions among investors, will only have a limited impact on the situation of the analyzed entities. Moreover, indications of the high level of intellectual capital of the surveyed entities based on the P/BV ratio should be verified based on the assessment of changes in their economic and financial situation (Nawrocki, 2022).

3. Research methodology

The main aim of the article was to present the problems with application of the investment strategy based on companies with high P/BV ratios and to examine its efficiency taking also into accounting the enterprises' intellectual capital issue. The study was conducted in relation to companies listed on the main market of the Warsaw Stock Exchange in the period 2010-2022, which was dictated by the availability of data, while verifying the following research hypotheses:

H1: The use of an additional resulting criterion identifying growth companies increases the investment efficiency compared to relying solely on the P/BV ratio.

H2: The use of an additional efficiency criterion identifying companies with a high level of intellectual capital increases the investment efficiency compared to relying solely on the P/BV ratio.

H3: The efficiency of investments in companies with a high level of intellectual capital is higher than the efficiency of investments in "ordinary" growth companies.

H4: Investing in companies with a high P/BV ratio allows you to beat the market, i.e. achieve a higher rate of return than the rate of return from the main market index.

H5: Investing in companies with a high level of intellectual capital allows you to beat the market, i.e. achieve a higher rate of return than the rate of return from the main market index.

H6: The efficiency of investing in companies with a high P/BV ratio increases with the extension of the investment period.

H7: The efficiency of investments in companies with a high level of intellectual capital increases with the extension of the investment period.

The study was based on data published by WSE (WSE, 2010-2022), which for individual companies included: number of issued shares, market value, book value, P/BV ratio, P/E ratio, DY (Dividend Yield). All data is provided on a given day. Moreover, based on the data mentioned above, the following was also calculated for individual companies: share price (market value/number of issued shares), EPS (share price/P/E ratio) and ROE (P/BV ratio/P/Eratio).

Taking into account the main purpose of the article, the formulated research hypotheses and the availability of data, the study was conducted in four approaches:

1. limited to the first decile of companies with the highest P/BV ratio values on a given day (growth companies identified only on the basis of P/BV ratio);
2. limited to the first decile of companies with the highest P/BV ratio values on a given day, while taking into account the y/y increase in EPS (growth companies with an additional result criterion);
3. limited to the first decile of companies with the highest P/BV ratio values on a given day, while taking into account the condition that the minimum P/BV ratio of a given company over a period of 3 years is higher than the P/BV ratio of the company closing the first decile (companies with a high level of intellectual capital identified solely on the basis of P/BV ratio);
4. limited to the first decile of companies with the highest P/BV ratio values on a given day, while taking into account the conditions that the minimum P/BV ratio of a given company over a period of 3 years is higher than the P/BV ratio of the company closing the first decile and that the ROE of a given company for the last 12 months is at least 20% (companies with a high level of intellectual capital with an additional efficiency criterion).

The calculations were assumed to be carried out based on the adopted algorithm (Figure 1).

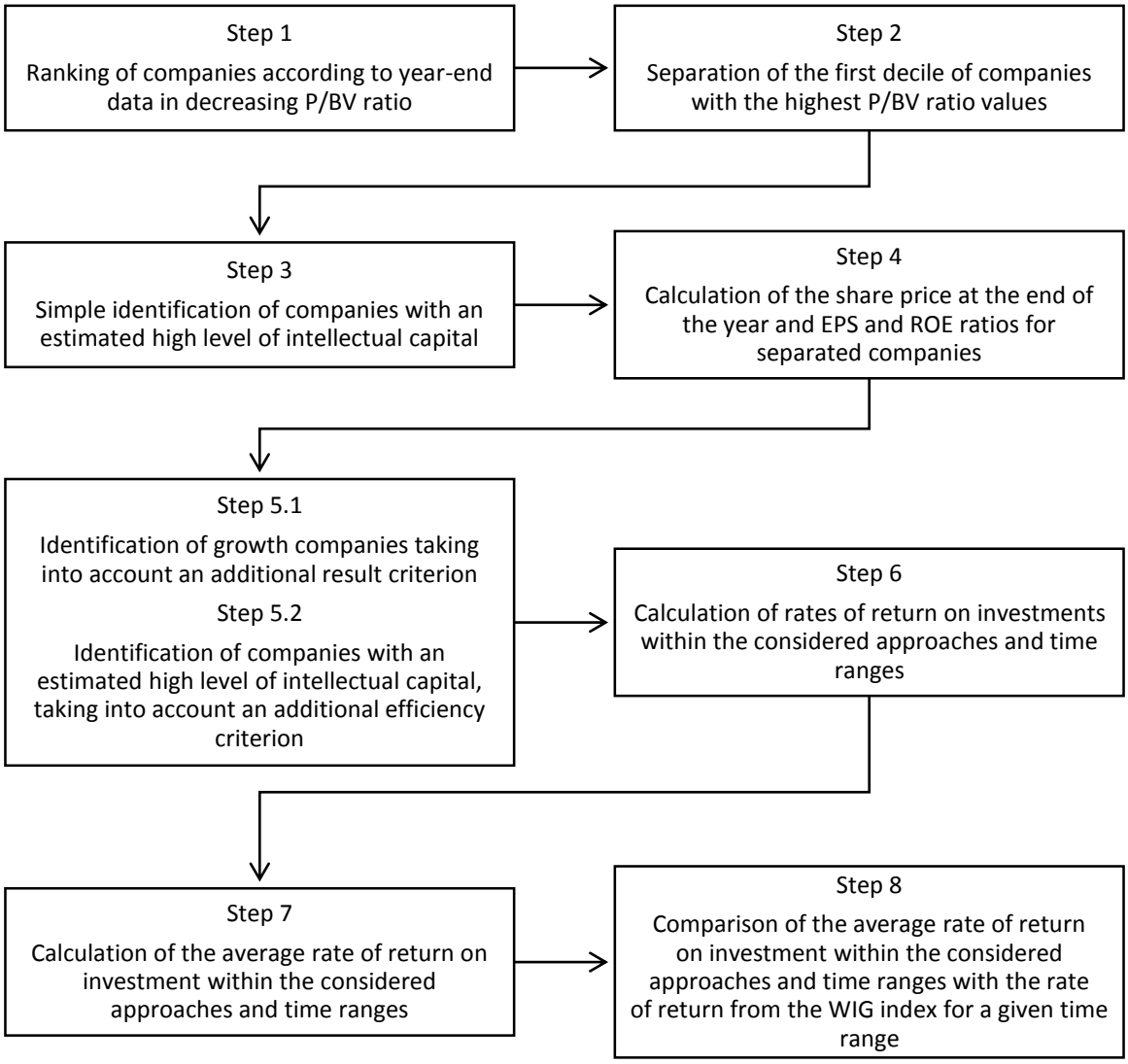

Figure 1. Algorithm for performing calculations.

Source: Own work.

The ordering of companies listed on the WSE main market according to data at the end of the year after decreasing P/BV ratio (step 1) was assumed to start from 2012 and end in 2021. Then (step 2), it was assumed to separate for each year the first decile of companies with the highest P/BV ratio values (simple identification of growth companies) and, in step 3, calculate for previously separated companies in each of the years considered the difference between the minimum P/BV ratio in the last 3 years and the P/BV ratio of the company closing the first decile in a given year (simple identification of companies with a high level of intellectual capital). In step 4, it was assumed to calculate additional data, i.e. EPS and ROE, which will then be the basis for identifying growth companies, taking into account an additional result criterion confirming the improvement of financial results over time, i.e. y/y increase in EPS (step 5.1) and companies with a high level of capital intellectual, taking into account an additional efficiency criterion confirming the high effectiveness of the adopted business

model, i.e. ROE of at least 20% (step 5.2). Step 6 assumed the calculation of investment growth rates within the considered approaches and time ranges (price from the examined period/price from the base period – 1), and then (step 7), on their basis, calculation of average rates of return (arithmetic mean). Taking into account also annual shifts within the time ranges of investments longer than one year, this gave for each of the considered approaches 10 one-year cases, 9 two-year cases, 8 three-year cases, 7 four-year cases, 6 five-year cases, 5 six-year cases, 4 seven-year cases, 3 eight-year cases, 2 nine-year cases and 1 ten-year cases. In the last, eighth step, it was planned to compare the average rates of return calculated in step 7 within individual approaches and time ranges with the rate of return from the WIG index for a given time range, which will allow us to determine whether a given approach allows us to beat the market.

4. Research results

The efficiency analysis of the investment strategy based on companies with high P/BV ratios, taking also into account the enterprises' intellectual capital issue, was carried out in accordance with the methodology outlined in the previous section.

Due to the significant volume of calculations and obtained results, the following sections were limited only to the presentation of final results (investment growth rates) within individual approaches and time ranges (Table 2 - Table 5), including, as a reference point, the results for WIG index (Table 6).

Table 2.
Individual and average rates of return on investments in growth companies identified solely on the basis of the P/BV ratio. Values for particular time ranges

Start year	Investment time range in years									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2012	36%	13%	19%	45%	75%	69%	131%	150%	128%	112%
2013	-15%	-12%	-1%	16%	7%	32%	36%	38%	32%	
2014	12%	25%	41%	23%	47%	51%	64%	51%		
2015	13%	33%	18%	37%	42%	56%	45%			
2016	3%	-12%	9%	54%	47%	34%				
2017	-16%	3%	32%	44%	31%					
2018	8%	51%	54%	23%						
2019	55%	84%	52%							
2020	-2%	30%								
2021	-18%									
Average	**8%**	**24%**	**28%**	**34%**	**41%**	**49%**	**69%**	**80%**	**80%**	**112%**

Source: Own calculations based on WSE data.

Table 3.
Individual and average rates of return on investments in companies with an estimated high level of intellectual capital identified solely on the basis of the P/BV ratio. Values for particular time ranges

Start year	Investment time range in years									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2012	43%	23%	27%	60%	100%	90%	179%	205%	170%	146%
2013	-14%	-19%	0%	35%	39%	84%	69%	55%	24%	
2014	10%	28%	58%	46%	81%	90%	96%	82%		
2015	14%	45%	39%	70%	77%	89%	78%			
2016	10%	-6%	21%	60%	56%	39%				
2017	-14%	15%	63%	69%	55%					
2018	21%	70%	70%	37%						
2019	41%	53%	33%							
2020	-16%	-29%								
2021	-10%									
Average	**8%**	**20%**	**39%**	**54%**	**68%**	**78%**	**106%**	**114%**	**97%**	**146%**

Source: Own calculations based on WSE data.

Table 4.
Individual and average rates of return on investments in growth companies identified taking into account P/BV ratio and EPS growth. Values for particular time ranges

Start year	Investment time range in years									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2012	46%	18%	16%	35%	54%	29%	31%	55%	66%	48%
2013	-7%	-1%	14%	31%	21%	75%	93%	89%	85%	
2014	16%	30%	44%	10%	18%	32%	60%	58%		
2015	15%	35%	32%	60%	65%	80%	71%			
2016	3%	-12%	10%	57%	49%	28%				
2017	-14%	4%	49%	60%	41%					
2018	30%	102%	107%	65%						
2019	37%	57%	39%							
2020	-10%	-17%								
2021	-20%									
Average	**9%**	**24%**	**39%**	**45%**	**42%**	**49%**	**64%**	**67%**	**75%**	**48%**

Source: Own calculations based on WSE data.

Table 5.
Individual and average rates of return on investments in companies with an estimated high level of intellectual capital, identified taking into account the P/BV ratio and ROE. Values for particular time ranges

Start year	Investment time range in years									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2012	58%	44%	51%	75%	102%	47%	68%	70%	103%	127%
2013	-13%	-16%	-5%	16%	-2%	7%	2%	9%	5%	
2014	9%	29%	57%	31%	40%	63%	91%	94%		
2015	19%	59%	62%	114%	125%	130%	119%			
2016	12%	1%	42%	90%	75%	62%				
2017	-18%	14%	43%	55%	60%					
2018	37%	126%	119%	87%						
2019	59%	63%	51%							
2020	-6%	-13%								
2021	-17%									
Average	**14%**	**34%**	**53%**	**67%**	**67%**	**62%**	**70%**	**58%**	**54%**	**127%**

Source: Own calculations based on WSE data.

Table 6.

Individual and average rates of return on the WIG index. Values for particular time ranges

Start year	Investment time range in years									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2012	8%	8%	-8%	9%	34%	22%	23%	20%	46%	21%
2013	0%	-15%	1%	24%	13%	14%	11%	35%	12%	
2014	-15%	1%	24%	12%	14%	11%	35%	12%		
2015	18%	46%	32%	34%	30%	58%	31%			
2016	23%	11%	13%	10%	34%	11%				
2017	-9%	-8%	-11%	9%	-10%					
2018	2%	-1%	20%	0%						
2019	-3%	18%	-2%							
2020	22%	1%								
2021	-17%									
Average	**3%**	**7%**	**9%**	**16%**	**19%**	**23%**	**25%**	**22%**	**29%**	**21%**

Source: Own calculations based on WSE data.

To better illustrate the differences in the obtained research results, Figure 2 presents the average rates of return within the considered approaches and time ranges, including the results for the WIG index as a reference point.

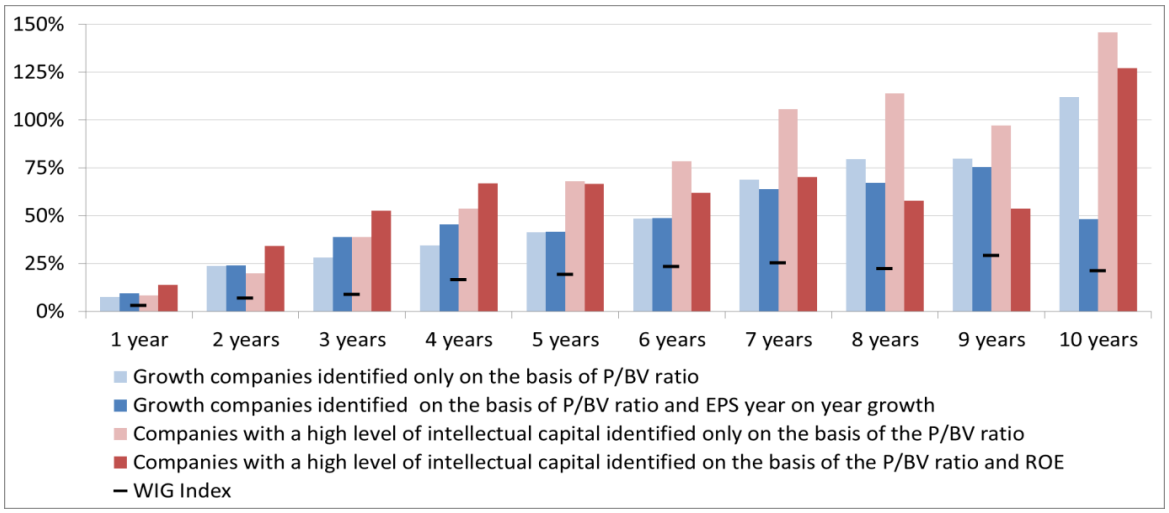

Figure 2. Average rates of return on investments for specific time ranges.

Source: Own calculations based on WSE data.

Taking into account the obtained results, first of all, it should be stated that investments in companies with a high level of P/BV ratio (both growth and with an estimated high level of intellectual capital) from the perspective of average rates of return allowed to beat the market (WIG index) in all considered approaches and time ranges. When it comes to individual comparisons within specific time ranges, the WIG index beat the considered approaches only in the case of one-year investments (2013, 2016, 2017 and 2020) and two-year investments (2016). Therefore, from the perspective of average rates of return on investments, hypotheses H4 and H5 can be considered true, and from a detailed perspective, they can be considered conditionally true, i.e. for the investment time range of over 2 years.

Secondly, the use of additional criteria identifying companies for investment, either growth companies (EPS increase) or those with an estimated high level of intellectual capital (ROE of at least 20%), did not provide a clear decision regarding the improvement of investment efficiency. From the perspective of average rates of return on investments, generally up to a period of 4 years such an improvement can be identified, and in the case of longer investment ranges, the additional criterion either ceases to be important (similar results) or translates into a deterioration of investment effectiveness. The situation is quite similar from a detailed point of view, where approaches with an additional criterion identifying companies for investment prevail even up to the investment time range of 5 years. At the same time, however, it should be noted that this predominance is not complete and even in these shorter investment time ranges, there were cases where the application of an additional criterion did not translate into a higher rate of return on investment. Therefore, from the perspective of average rates of return on investments, it can be concluded that hypotheses H1 and H2 are only partially confirmed, limited to shorter investment time ranges (1, 2, 3 or 4 years), and from a detailed perspective they cannot be considered as true even when limited to shorter investment time frames.

As for hypothesis H3 and the comparison of the effectiveness of investments in "ordinary" growth companies and companies with an estimated high level of intellectual capital, both from the perspective of average rates of return on investment and from a detailed perspective, the advantage of the latter can generally be seen. At the same time, however, this advantage is not complete, i.e. it does not always apply to both approaches (with and without an additional criterion). Therefore, hypothesis H3 cannot be considered fully true.

The last issue to be verified concerns whether the effectiveness of investments within the four approaches considered increases with the extension of the investment time frame (hypotheses H6 and H7). Taking the perspective of average rates of return, the results obtained indicate that in general such a growing tendency can be noticed, although it is not ideal (especially in relation to approaches taking into account additional criteria identifying companies for investment). A similar situation is seen taking into account the individual perspective within individual "starting years". The longest sequence of increasing cumulative rate of return on investment was recorded for approach iv (companies with an estimated high level of intellectual capital identified taking into account P/BV ratio and ROE, Table 5) for the years 2015 (6) and 2017 (5). Moreover, within the considered approaches there were 5 cases with a duration of 4 years and 7 cases with a duration of 3 years. Thus, although a positive cumulative rate of return on investment was recorded over a time horizon of over 2 years for all the approaches considered, it did not systematically increase from year to year as the investment period lengthened, but withdrawals of one year or longer occurred. Therefore, from the perspective of average rates of return on investments, hypotheses H6 and H7 are only partially true, in particular with regard to shorter investment time ranges (up to 4 years), and from a detailed perspective they cannot be considered true even when limited to shorter investment time frames.

5. Summary

The study carried out in the field of analyzing the effectiveness of investment strategies based on companies with high P/BV ratio values, including taking into account the issue of intellectual capital in the enterprise, allows us to conclude that, at least from the point of view of the considered period of the study, this is an approach that allows "to overcome " market. At the same time, however, increasing the effectiveness of this investment approach and consolidating it over time (by eliminating random companies) requires the implementation of more sophisticated additional criteria identifying growth companies or companies with an estimated high level of intellectual capital. As the study results showed, the use of easily accessible and popular additional criteria identifying companies in the portfolio (EPS and ROE) does not necessarily give an advantage over the broad market or a simple approach without additional criteria. This applies especially to a longer time horizon. At the same time, however, it must be borne in mind that using other, more sophisticated additional criteria is, due to their limited direct availability, much more time-consuming and labor-intensive in the application of a given investment strategy.

It is also worth paying attention to the fact that even if the research hypotheses considered showed an advantage of one approach over the other (strategies without additional criteria vs. strategies with additional criteria, growth companies vs. companies with an estimated high level of intellectual capital; growth companies and companies with an estimated high level of intellectual capital vs. the broad market), this advantage was not total, i.e. it did not apply to all the cases considered. In this regard, it should be borne in mind that changes in company share prices on the capital market do not always result from their fundamental or technical situation. Moreover, in the capital market, just like in the economy, we are dealing with a cyclical phenomenon, which means that even fundamentally good entities experience weaker trading periods and their share prices fall. Therefore, the expectation of achieving higher and higher rates of return over time, or beating the market year after year for an extended period of time, has a low probability. These issues are discussed more broadly by the market efficiency theory or the random walk theory (Fama, 1970; Malkiel, 2014).

Undoubtedly, a certain limitation of the conducted research and its results as well as final conclusions is adopted, not very long, time frame (10 years), which was partly due to the availability of data and adaptation to the stock market cycle.

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CIRCULAR SOLUTIONS FOR FOOD PACKAGING. INNOVATIVE COATED PAPER PACKAGING AND ITS CARBON FOOTPRINT

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Purpose: The strive towards circularity within the packaging sector has been an ever-growing challenge. Regular paper seem to be a good solution due to its natural and renewable origins and relative ease in its end-of-life processing. Food products require defined barrier and mechanical properties and seal functions that cannot be provided by regular paper or cardboard. The underlying objective of the paper is to indicate the best scenarios with regard to circularity challenge. Possibly, the implementation of innovative, highly functional, and recyclable coated paper/cardboard materials for food packaging applications would allow to replace traditional multi-layered plastics.

Design/methodology/approach: The objective of the paper is to verify the environmental performance of selected coated paper material over its counterparts from multi-layered plastics with the use of the Carbon Footprint approach (CF). CF is used to compare the environmental impacts of a chocolate tablet life cycle with the use of different packaging materials: coated paper (CPCS) and oriented polypropylene (oPP). A special focus is on the recyclability issue of the packaging materials and their contribution to overall environmental performance.

Findings: The results show that CPCS packaging has a slightly lower CF. Overall, CPCS packaging is contributing half of CF in comparison to oPP packaging. The difference is higher as far as packaging manufacturing is concerned, but due to the higher weight of CPCS packaging for chocolate tablets, its contribution to CF in whole life cycle rises.

Research limitations/implications: Since the assessment is made during the packaging testing process, its results are not yet final and could be due to change if the composition of CPCS will due to some further changes. Secondly, the shelf life tests are not finished yet and do not impact the life cycle so far.

Originality/value: The study is focused on the assessment of innovative coated paper packaging and investigates its CF in comparison to currently used packaging material for chocolate tablets. Its results could contribute to the selection of more sustainable and circular packaging.

Keywords: coated paper materials, food packaging, carbon footprint (CF), circular economy, life cycle management.

Category of the paper: research paper.

Introduction

Food packaging is one of the most important actors in the food supply chain, as it protects and preserves the quality and safety of food products and extends their the shelf life (Coles, 2013; Lenartowicz-Klik, 2020). As a consequence, food packaging has a high share of material and energy consumption within the food life cycle, as well as a significant contribution to its emissions, waste generation, and related environmental impacts (Czarnecka-Komorowska, Wiszumirska, 2020; Meng et al., 2023; Xia et al., 2024). Finally, in contrast to most of the other products, the packaging itself has the highest contribution to the impacts that occur in the end-of-life phase, when product has been consumed. It seems that the challenge of sustainability and circularity is putting the food life cycle under high pressure with regard to the recyclability and biodegradability of their packaging materials (Gutierrez, Meleddu, Piga, 2017; Czarnecka-Komorowska, Wiszumirska, 2020; Kan, Miller, 2022; Adibi, Trinh, Mekonnen, 2023; Ferrara et al., 2023; Meng et al., 2023).

The challenge is strongly mainstreamed by new regulations on extended producers responsibility and recycling targets, which are currently being issued in the EU but also in countries and regions across the globe. It is also highly supported by more and more aware consumers who are changing their preferences towards more sustainable packaging materials. Consumer demand and emerging guidelines of the European Commission are driving packages towards circularity by aiming for 100% reusable and/or recyclable packages in 2030 (European Commission, 2019). It seems that the challenge is being approached from many different perspectives and has evidently many paths to follow (Czarnecka-Komorowska, Wiszumirska, 2020; Adibi, Trinh, Mekonnen, 2023; Liang et al., 2023; Meng et al., 2023; Xia et al., 2024). In current paper, we follow one of them that was settled by the REPAC^2 project consortium and is currently being faced by its research and industrial partners. The paper reflects only midway and partial results of the project. The approach is focused on paper/cardboard materials for food packaging, which are one of the key solutions in the food sector. But to achieve the potential increase in its use, together with the improvement of its sustainability and achievement of circularity in its use, it needs transdisciplinary and strategic approach (Wojnarowska, Ćwiklicki, Ingrao, 2022).

The need for a transdisciplinary and strategic approach could be illustrated by the constraints that set the landscape for food packaging development (Lenartowicz-Klik, 2020). The first constrain that should be considered is the specificity of the product itself and the functional and hygiene requirements of the packaging material and its application. The diversity of food products and enormous number of their market variants require packaging that is appropriate for each one of them (Coles, 2013; Mizielińska et al., 2018b, 2018a; Kaszuba, Frydrych, 2021; Wierzchowski, Bartkowiak, 2022). This food product and packaging nexus is itself an area that needs to join several different fields of knowledge and practice. The second constraint comes from the economic and logistic aspects of food supply chains that dominate

the decision-making nowadays (Nitkiewicz, 2021, pp. 246-260). The accessibility and costs of materials, their weight and shape options, transportation convenience, storage conditions, or marketing potential define the scope of the second constraint (Mizielińska et al., 2018b, 2018a; Lenartowicz-Klik, 2020; Szumicka, 2022; Wierzchowski, Bartkowiak, 2022). The final constraint is related to the current sustainability and circularity objectives of production and supply chain activities and their consumption counterparts. This final constraint is often the objective of advanced innovation processes in order to be consistent with a first constraint and remains unclear and yet not achievable as far as its expected potential is concerned (Adibi, Trinh, Mekonnen, 2023; Ferrara et al., 2023; Liang et al., 2023; Meng et al., 2023; Xia et al., 2024). This constraint is often in opposition to the second constraint and requires decades of practice and searching for its market-accepted embodiment. The final constraint requires strategic approach and medium- and long-time horizon in order to have all the consequences visible and considered within decision-making process.

In the paper, we focus on paper-based packaging material, which is adjusted to the requirements of food packaging through the application of a coating. The idea comes from the need to replace fossil based plastic packaging with some counterpart that could outperform them with regard to sustainability and circularity performance. The selection of coated paper comes with a certain assumption concerning its manufacturing, use, and recyclability phases.

The White Paper of World Economic Forum recommends the use of the following strategies in order to equip paper-based packing with circularity and sustainability advantages (WEF, 2016): 1) eco-design, 2) eco-management and 3) environmental impact reduction.

The REPAC² project will contribute to achieve the abovementioned results by increasing the fraction recyclable paper-based packaging and potentially decreasing of the fraction unrecyclable plastic packaging. This achievement will be achieved through recycling-oriented eco-design, eco-management through optimization of end-of-life processing from the perspective of packaging and food producers, resulting in a decrease in packaging-related emissions.

According to the CEPI recommendations, when designing alternative barriers, the following aspects should be considered and verified (CEPI, 2020):

- Ensure that paper fraction of the packaging breaks down into single fibers when pulped within a specified time frame.
- Give preference to polymers and other sealing agents that can be removed from the fiber in the conventional screening process.
- Give preference to polymers, sealing agents and application processes that can be dealt with efficiently by the paper mill process and effluent water systems and do not compromise the finished product, the production process or the environment whilst being recycled.
- Metallic and other inorganic coatings applied via vacuum deposition shall not hinder the repulping process and shall be capable of being screened out.

Using coated paper has the potential to meet the functional criteria of food producers and, at the same time, foster the achievement of recycling goals. Unlike paper-plastic laminates and plastic multilayers, coated paper has a potential to fit into existing paper recycling system and outmatch the alternative packaging due to its recycling properties and eco-management of its reverse logistic flows.

Methods and materials

In order to illustrate the challenge of circularity and sustainability by developing the coatings and coated paper packings for the purpose of replacing fossil based, unrecyclable plastic packaging on food market a single research case is presented. The case is based on ongoing process of coated paper packaging development and uses it's up to date evidence to assess the environmental impacts and circularity issues within. The research case is based on solid chocolate tablet (without filling) as a food product. The investigated product is packed within 3-sided sealed pouch with horizontal form-fill-sealer (HFFS). For the purpose of achieving shelf life of 2 years for a chocolate tablet it is important to keep OTR[1] and WVTR[2] parameters below certain levels. Not achieving appropriate barrier protection versus oxygen or water might result in chocolate crystallization and "white skin" appearance as a consequence. Besides, such parameters as seal strength, mechanical resistance, barrier properties or printability issues are also important in developing safety and market ready product. In our study we consider actual packaging of chocolate tablet that is oriented polypropylene (oPP) and its potential alternative – paper coated with cold seal adhesives (CPCS). Both types of packaging are printed.

CPCS packaging is considered as recyclable together with paper fraction of waste. The additive of coating is less than 5% of a total weight of a packing and should not influence the paper recycling process.

The environmental assessment is made with Carbon Footprint method – namely Global Warming Potential (GWP) that was developed by International Panel on Climate Change (IPCC) in 2013 and later updated in 2021. This approach to the assessment of food product packaging is quite common, but the preference is to use more advanced variants of life cycle assessment. It is worth to notice that different approaches take into account a food product within a packaging (Gutierrez, Meleddu, Piga, 2017; Adibi, Trinh, Mekonnen, 2023; Meng et al., 2023), or the packaging only (Ingrao, Gigli, Siracusa, 2017; Xia et al., 2024). The method used for the assessment is denoted as IPCC 2021 GWP100 v. 1.01. The method takes the time horizon of 100 years as a point of reference. The method is based on characterization of impacts,

[1] OTR – oxygen transmission rate [$cm^3/(m^2 \cdot 24h)$].
[2] WVTR – water vapor transmission rate [$g/(m^2 \cdot 24h)$].

which are expressed in single unit of emitted kg of CO_2-eq. Impact factors within GWP100 are referring to the source of generated carbon footprint and include such categories as fossil, biogenic and land transformation sources (PRé Sustainability, 2022). The assessment is made in form of CF screening (European Commission DG Environment, 2010; Fields, Simmons, 2014; ISO, 2018; Liang et al., 2023).

Results of Carbon footprint of a chocolate tablet and its packaging

Goal and scope of the assessment

The major goal of the assessment is to verify whether coated paper packaging could outmatch its plastic based counterpart with regard to circularity and sustainability. Since it is a first part of a wide research on coated paper packaging, we focus here on the Carbon Footprint assessment that could bring out very specific conclusions concerning both concepts.

Functional unit for the assessment is a chocolate tablet of 100 g within two variants of packaging: a) oPP of 22 g or b) CPCS of 30 g. Since the CPCS testing is not yet finished the assumption is that the shelf life of a tablet is 1 year. The following life cycle phases are included in the study: supply of resources for manufacturing, manufacturing, transport to distribution and end of life processing. The phases of distribution itself and use are excluded from the assessment. This is due to lack of CPCS testing results and possibility to model chocolate shelf life in accordance to its storing conditions.

Life Cycle Inventory

Since the functional unit is assessed within two variants the inventory data is collected for both of them. Chocolate tablet remains the same for each one of them while the packing inventory is changing within supply and manufacturing process, transport in distribution and end of life processing. Table 1 presents the primary data for functional unit and its life cycle inventory except for end of life processing. Packaging section is divided for CPCS and oPP packaging while primary resources are concerned.

Table 1.
Life cycle inventory for functional unit

CHOCOLATE TABLET			PACKAGING	
Type of material Volume [kg per kg of the product]				
sugar	0,4860		Paper	0,30003
cocoa mass	0,1202		Inks	0,00062
cocoa butter	0,1874		Heat seal additive	0,00337
whole milk powder	0,0661		Oil barrier additive	0,02100
skimmed milk powder	0,0651		Cold Seal	0,04380
whey powder	0,0501		Food contact varnish	0,02280

Cont. table 1.

milk fat	**0,0200**			
emulsifier lecithin (from soy)	0,0058		oPP	0,022
emulsifier E476	0,0010		Cold Seal	0,04380
vanilla extract	0,0002		Inks	0,00062
Transport (supply) Distance*weight [km*kg]				
Truck, EURO5	303,0000		Truck, EURO5	1093,9250
Reagents and chemicals [kg/kg of the product]				
Cleaning agent	0,000255		Solvents	0,000394
Automatic cleaning agent	0,000027			
Rinse aid agent	0,000002			
Type of energy used, energy source [MJ/kg]				
electricity (country mix)	0,48632301		electricity (country mix)	0,864
Type of fuels used [m3/kg]				
natural gas	0,021657		natural gas	0,0011
	[kg/kg]			
propane butane (for internal transport)	0,000235686			
Water use [m3/kg]				
water	0,000612		water	0,336
Internal transport - Distance*weight [km*kg]				
small truck, EURO5	1		electric forklift truck	1
Distribution packaging [kg/kg]				
display 100g x 20 pcs	0,0275		wooden pallets	0,06
pallets (288 cartons/ pallet)	0,039930556		stretch foil	0,02
strech foil	0,000868056			
foil separator	0,000089583			
carton separators	0,00146875			
carton corners	0,000472222			
Transport (distribution) - Distance*weight [km*kg]				
small truck, EURO5	460			

Source: author's own research calculated in SimaPro software

The end of life phase is included in the assessment with the following assumptions:

1. Chocolate tablets are consumed and present no impact within the use phase of its life cycle.
2. A packaging as a whole is considered to be a waste that is collected separately from consumers (CPCS with paper fraction, oPP with plastic fraction of municipal waste).
3. Recycling scenarios are based on specific share of material actually recycled with accordance to current data on European recycling levels separately for paper and plastics.
4. The fraction of the waste that is not recycled is considered to be processed in accordance to standard procedure for specific fraction and includes incineration and landfill processes.

According to the abovementioned assumptions, the recycling rates are set for European average with regard to the processing technologies, as well as the level of recycling (Haupt et al., 2018).

All the inputs are taken directly from chocolate and coated paper manufacturers being raw data or estimates that are based on total use of media, electricity and resources. The transportation is an external process, as far as supply and distribution is concerned, and its

data is estimated on basis of distance, load and averaged type of vehicles used by the third-party logistics operators or suppliers. All the material, energy, transportation and waste flows are modelled with support of Ecoinvent and AgriFootprint databases.

Life cycle carbon footprint assessment

As mentioned before GWP100 method is used to calculate carbon footprint for the functional unit. The assessment is made within SimaPro 9.4 software. Figure 1 shows the total Carbon Footprint for both analyzed variants with regard to contributing manufacturing processes: packaging, chocolate tablet and distribution packaging. The major impacts are related to the manufacturing of a chocolate tablet. The packaging itself contributes to 11,5% of CF in coated paper variant and barely 12% in oPP variant. The impact of distribution packaging is negligible.

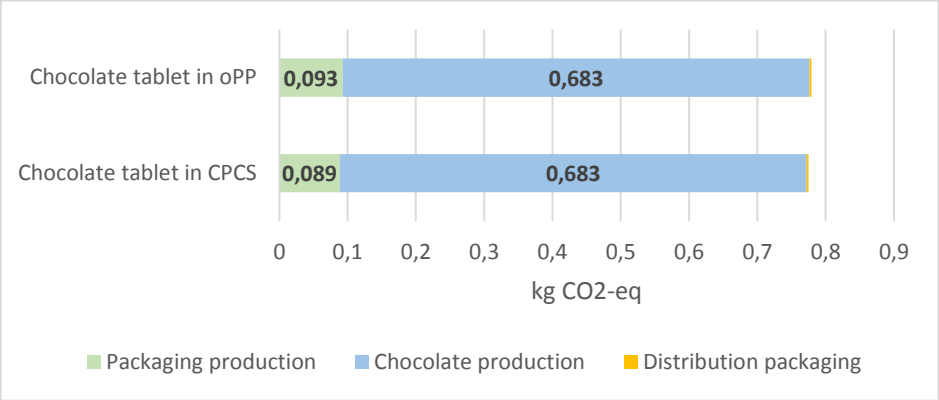

Figure 1. Total CF for both variants of functional unit – contribution of different production processes. Source: author's own research calculated in SimaPro software.

The structure of CF is presented in Figure 2. For both variants the fossil-based sources are the most significant. Land transformation is the second highest source of impact while biogenic sources are responsible for 7% of total impacts.

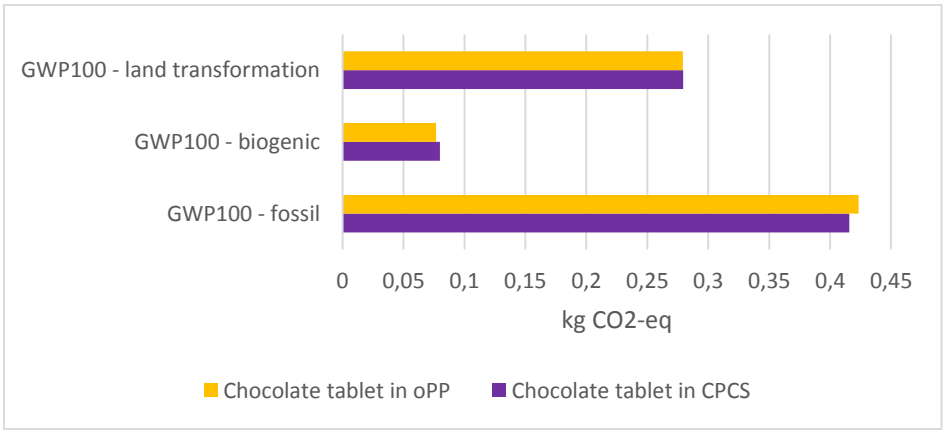

Figure 2. The structure of CF sources for both variant fo functional unit.
Source: author's own research calculated in SimaPro software.

Discussion

In order to investigate the differences between the two variants of packaging, the manufacturing process of packaging production is investigated separately. **Figure 3** presents the contribution of major processes for CF of both investigated packaging. The production process of oPP is more than twice impactful, while CF is concerned. The manufacturing process that includes the supply of resources and its transformation is the most significant contributor to total CF in both cases. The transportation of raw materials, and for some part transportation in distribution is the second highest contributor to CF. Surprisingly, energy use, including electricity and fuels for manufacturing machinery, has only slight contribution to CF. Finally, and surprising again, the recycling processes bring "negative" results for both packaging but with evident dominance of oPP packaging. This is surprising due to the assumed higher recyclability of paper-based packaging.

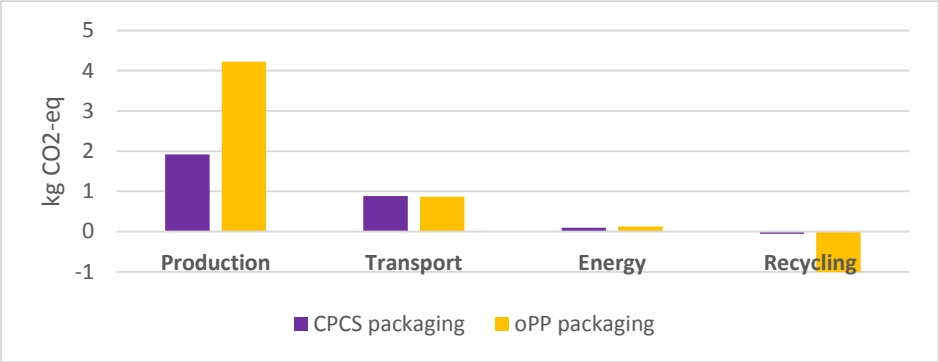

Figure 3. Contribution of selected processes to overall CF for both packaging.
Source: author's own research calculated in SimaPro software.

Closer look at the structure of flows, as shown on **Figure 4** and **Figure 5**, brings out the reasons for that contribution. PP as a secondary material is supplementing more harmful raw PP material, and, therefore, brings much more valued environmental benefit. The assumed recovery of 81,5% of paper for pulp production is contributing in merely 3,8% to decrease of total CF of CSCP packaging, while, recovery of 60% of plastic contributes to 27,5% decrease of total CF for oPP packing.

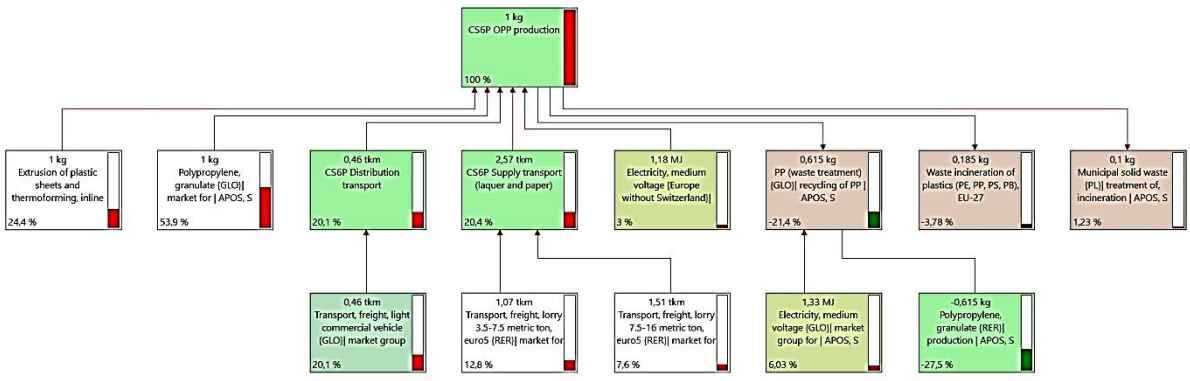

Figure 4. Contribution of processes and material and waste flows to the CF of oPP functional unit.
Source: author's own research calculated in SimaPro software.

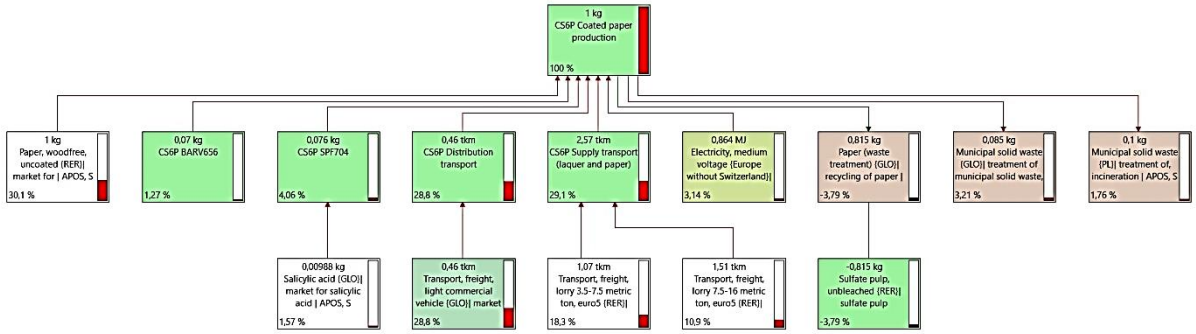

Figure 5. Contribution of processes and material and waste flows to the CF of CPCS functional unit. Source: author's own research calculated in SimaPro software.

Summary

These results do not change the hierarchy of the two packings while total CF is concerned. Overall, CPCS packaging is contributing half of CF in comparison to oPP packaging. But if we consider the holistic view of sustainability and circularity, the conclusions could be a bit more complex. First of all, the life cycle of CPCS packaging has more visible reverse flows, with significantly higher rate of circularity for of major flow of paper. In case of CPCS, the return flow of pulp could be directly used in the same life cycle. The recycling of plastics is more complex process due to the collection of different plastic fraction and common processes of their processing. PP might be partial result of the recycling process, but as the evidence from European data shows, it constitutes relatively smaller share in comparison to PE or PET recovery (Haupt, Kägi, Hellweg, 2018).

As for the sustainability aspects of analyzed packaging, it is important to underline the role of eco-management in its life cycles. Eco-management should take into account the different perspectives of running food product and their packaging life cycles and should support them with valuable decision-making variables. If the waste processing system is well developed, perhaps it is advisable to check the possibilities of oPP packing collection and recycling before the experimental change to CPCS packaging is introduced. On the other hand, less developed recycling systems could handle paper packaging in a more efficient manner and could contribute to sustainable CF performance of its life cycles.

Finally, the eco-design approach is also important for perfecting the match of a food product with sustainable packaging. If the functional requirements are met within innovative CPCS packaging, it is the green light for its implementation. But if the requirements are not yet met or some proofs and experiments are missed, it is better to finalize the development process and avoid a potentially unsatisfied consumer.

Acknowledgements

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ACTIVE AND PASSIVE APPROACH TO OPPORTUNITIES IN CRISES EVENTS

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Purpose: The primary purpose of the paper is to discuss active and passive approaches to opportunities in strategic management. Crisis situations usually have negative consequences for companies but are also an impetus for implementing changes and seeking opportunities. Theoretical considerations focus on the identification of opportunities in strategic management and their impact on strategy reorientations. The theoretical verification of the above issues allowed to pose a research question: how did IT companies seize opportunities in the face of recent crisis events?
Design/methodology/approach: In the article the theoretical concept of R. Krupski in its approach to opportunities was applied. To verify this concept qualitative research - case studies on the example of selected companies in the IT sector was used.
Findings: According to theoretical considerations, a passive-external approach to opportunities should be the natural approach to crisis events. The cases presented indicate that the approach to opportunities depends on the specifics of the business, the experience gained and knowledge possessed, as well as the ability to find oneself in a dynamic environment. Both the passive-internal approach and the active-internal approach to opportunities are feasible in times of crises.
Research limitations/implications: The qualitative research conducted is a prelude to further quantitative research on how companies seize opportunities in times of crisis. This research applies only to the IT sector and is worth extending to other sectors.
Originality/value: The novelty of this article is the consideration of opportunity and how it is perceived under crisis conditions. These issues should be considered particularly relevant in the framework of business operations, especially in view of recent events, i.e. the COVID-19 pandemic and the war in Ukraine.

Keywords: crisis, opportunity, approach to opportunity, IT sector.

Category of the paper: research paper.

1. Introduction

Regardless of the specifics of the business, including those determined by the scope of services provided or the target audience, there are times when any enterprise begins to operate under crisis conditions. Taking into account the fact that the eventuality of such an occurrence, as a rule, is independent of the enterprise, and in practice can paralyze entire economies, it should not be overlooked, but taken for granted. Management staff, on the other hand, should to some extent be prepared for it.

In general, crises generate negative effects, simultaneously affecting all participants in economic life, i.e. from consumers and entrepreneurs to the functioning of entire systems, for example: financial. They can affect single individuals or have a global scope. Although they evoke negative feelings in the vast majority of people, it is impossible to ignore their positive impact as well. It should be noted that in the face of many failures, collapses and bankruptcies, crises ultimately lead to an increase in the rate of economic development. They stimulate innovation and provoke entrepreneurial attitudes. Many companies see them as an opportunity leading to expansion or competitive advantage. However, the approach of viewing a crisis as a development opportunity is not just a one-time decision or a momentary action, but a process based on which a company pursues its goals.

Undoubtedly, the goal of any enterprise should be considered its successive development, which is determined by the adopted strategy and described in the business model. The strategy indicates the courses of action for specific areas, which are consistent with the previously adopted general assumptions. Although it is precluded to indicate a specific moment of crisis, the strategy should assume detailed ways of dealing with a potential emergency. Companies, on the other hand, should analyze the market and be prepared for possible threats by implementing mitigating measures.

Companies in a crisis situation may look for opportunities for their expansion. In practice, this involves spotting a gap and exploiting it.

2. Approaches to crisis in economic practice

In economic practice, crisis is not a common phenomenon, but an unusual event. Although in many cases it is destructive and leads to the collapse of entire organizations, there are situations in which it is a stimulant for development. The occurrence of a crisis can therefore be viewed as the emergence of an opportunity to gain expansion or competitive advantage. Due to the fact that it is impossible to prevent a crisis situation, in the functioning of modern enterprises, it is increasingly common to observe behavior aimed at adequate preparation to

perceive, recognize and respond to such events. The dynamic environment and the unexpected nature of the emergence of crises make it necessary for companies to understand the determinants of this phenomenon (Zakrzewska-Bielawska, 2008).

The issue of crisis has been the subject of scholarly consideration for many decades. Undoubtedly, the approaches identified in the last century should be considered as leading, in which a crisis, including mainly in organizational terms, is defined as:

- a phenomenon of a universal nature, within which governance does not always take place. It occurs at many levels, which means that it should not be viewed solely in national and international terms. A crisis can affect different areas of activity, so it should not be identified only with the financial system (Milburn, 1972),
- circumstance with a significant and direct impact on the organization as a whole and its members. In this regard, the impact on other stakeholders is also observed, including suppliers, customers, competitors and society (Milburn et al., 1983).
- an event that results in a disruption within the entire system, which can affect the basic directions of its functioning and its designated mission. The definition developed by T. Pauchant and I. Mitroff emphasizes the systemic approach to crisis in an organization. According to the authors, simple causality, i.e. the conditioning of the crisis by a single variable, is not justified in this case. Instead, special attention should be paid to the issue of the dependence of the system on multiple variables (Pauchant, Mitroff, 1992).

As noted above, the emergence of a crisis in an organization affects both the management process, as well as its members and the environment in which the entity operates. It is difficult to determine the exact moment when a crisis occurs, but nevertheless a successive analysis of conditions and circumstances makes it possible to assume that it will occur at all. A crisis carries with it the likelihood of certain repercussions to stakeholders and the brand promoted by the organization in question (Marsen, 2020). It affects all sectors of the economy, entire organizations and their management, and the social environment. Contrary to the fact that it cannot be predicted, it is characterized by its universality. By definition, it is characterized by a negative impact on an entity. It disrupts basic business processes, and in extreme cases can lead to collapse. Crisis can take a variety of forms such as natural hazards (e.g. epidemics, natural disasters), abnormal hazards (e.g. act of terrorism, cyberattack, economic corruption) normal hazards (financial meltdown, strike, technical equipment failure, industrial accidents) (Mitroff, Alpaslan, 2003; Frandsen, Johansen, 2017).

The term "crisis" should be considered comprehensively. This is evidenced, among other things, by the literature on the subject, where there is no clear definition of the term. In general, it can refer to various areas of the organization's functioning, i.e. economic, organizational, legal or technological. Its scope can include the entire global economy, the economy of a country, businesses, communities or individual units. Among the most commonly cited characteristics of a crisis, it refers to:

- a watershed moment that forces change or a moment of choice that results in rapid transformation,
- a complex situation that is occurring or is yet to occur. It arises from a dynamic environment, and therefore violates existing operations and halts further development,
- an uncertain situation, followed by rapid change. This, in turn, conditions the instability of the system, within which the existing regulations cease to operate and the accepted rules are modified. This situation creates chaos and indecision in the functioning of the organization,
- a situation that is the result of unexpected events of varying degrees of severity, or a situation that is the result of previously made decisions or adopted policies. In this case, the crisis is viewed in process terms, i.e. as a cause-and-effect relationship, with its successive stages and phases differentiated in terms of: the intensity and number of negative consequences. Moreover, the individual's ability to notice and distinguish these consequences and implement mitigating measures (Zakrzewska-Bielawska, Grądzki, 2009).

Common to all crises is the presence of a sudden, unexpected critical event and a sense of uncertainty about the future, as well as the sudden disruption of routine ways of doing things, or the need to change existing methods of operation. Crises such as war, civil unrest, acts of terrorism, natural disasters or COVID-19 are commonly viewed as exogenous shocks that disrupt routine business practices and processes, increase uncertainty and reduce available resources (Brown et al., 2020; DesJardine et al., 2019; Hu, 2020; Kwong, Poon, 2019).

A crisis is a predictable event, within which its beginning and end are particularly noticeable, while it ceases to be significant shortly after it is contained. In general, it is treated as a danger of violation of the social system of values, which involves the need to implement necessary measures under conditions of uncertainty (Boin et al., 2021).

As past practice shows, many reasons for the occurrence of the crisis can be identified. However, due to the complexity of this phenomenon and the specificity of the functioning of individual entities, it is difficult to make an accurate identification of all possible motives for its occurrence. At this point, attention should also be paid to the manifestations of the crisis as a consequence of its causes. The occurrence of a crisis can be associated with, among other things: (Chen, Biswas, 2021; Jasinska, 2018; Wang et al., 2020; Zakrzewska-Bielawska, 2008):

- a decrease in economic activity,
- a decline in income for businesses and the population,
- increase in unemployment,
- bankruptcy,
- the impetus for change,
- an opportunity for enterprise renewal,
- opportunity to take advantage of opportunities in the market.

With the emergence of the crisis caused by the COVID-19 pandemic, this topic became the leading issue of scientific publications. Much more frequent reference has also been made to Winston Churchill's words, which he uttered during the deliberations on the establishment of the UN, just after World War II[1] , namely: 'Never let a good crisis go to waste'. With his statement, he argued for treating crisis as a stimulant. Analyzing how a crisis can be transformed into positive change has always been of interest to various stakeholder groups, especially when referring to a crisis as an opportunity for: beneficial transformations; revitalizing processes that have stagnated; challenging existing norms and rules and attempting to impose new ones. The concept of crisis as opportunity was also discussed much earlier by Thomas Kuhn, according to whom the emergence of a crisis heralds an opportunity for reorganization (Gkeredakis et al., 2021).

Given the problematic nature of this article, and thus the consideration of the crisis in the category of opportunity, the continuation of the considerations contained in the next part of the article is related to the approach to opportunity, attempting to bring its theoretical aspects closer.

3. Opportunity - an overview of definitions and approaches

There are many approaches and views in the literature regarding the concept of opportunity. According to M. Casson and M.I. Kirzner, it represents a favorable circumstance of perceiving market needs by creatively combining resources to provide higher value (Casson, 1982; Kirzner, 1973). L. Kornish and K. Ulrich, on the other hand, define it as an innovation idea that can have value (Kornish, Ulrich, 2011). According to D. Dutta and M. Crossan, an opportunity is an objective, external situation, later often described as a subjective idea (Dutta, Crossan, 2005).

An opportunity is a chance to "introduce" something, but it also remains an opportunity after it has been introduced, as long as it generates profit (Eckhardt, Shane, 2010). It is defined as "desirable" and "feasible," with some opportunities eventually being abandoned because entrepreneurs no longer believe in them (Wood, McKinley, 2010). It is considered an opportunity to introduce innovative (rather than imitative) goods, services or processes, although there are also "imitative opportunities" (Gaglio, 2004). Moreover, it is closely related to the moment in time - it appears, lasts for a while and then disappears (Krupski, 2013).

[1] https://www.oecd.org/agriculture/never-waste-a-good-water-crisis/

An opportunity is defined as the difference between the expected or mandatory level of performance and its current level. It occurs when the adequate potential is present (Isaksson et al., 2022). M. Grillitsch and M. Sotarauta citing the Oxford Dictionary emphasize that it is "a time or set of circumstances that make it possible to do something". These circumstances (conditions and time) trigger change and are called the "opportunity space". Opportunities can be subject to variation, which is influenced by both time and place. It should also be noted that the way they are perceived can vary (Grillitsch, Sotarauta, 2020).

A different approach to the issue in question is presented by Ch. Sutter et al, according to whom opportunities should be considered from the point of view of the entrepreneurial process, where special attention is paid to their identification and exploitation. Identification of opportunities implies finding or creating resources in the market of imperfect competition. In contrast, seizing an opportunity involves acquiring these resources, accumulating them into opportunities, and then using these opportunities to gain an advantage (Sutter et al., 2019). Underutilized or untapped resources, as well as new capabilities or technologies, may offer opportunities to create and deliver new value to potential customers, even if the precise forms that this new value will take are not currently defined (Ardichvili et al., 2003).

As F. Knight in his dissertation points out, the approach to opportunity should be considered from the point of view of the organization's uncertain future, which is analyzed from three aspects, namely:

- as a future within which the probability of certain events takes place and is known,
- as a future within which the probability of certain events takes place, but it is unknown,
- as an unknown future that cannot be predicted (Knight, 1921).

In turn, S.D. Sarasvathy et al. (2003) building on the considerations presented by F. Knight consider the opportunity from the perspective of three concepts relating to entrepreneurship:

- opportunity recognition,
- opportunity discovery,
- opportunity creation[2].

An attempt to systematize the concept of opportunity is also made by R. Krupski, who considers it from the perspective of strategic management (Figure 1). Among the main assumptions that enable the classification of opportunities, the author includes:

- the ontological dimension, which takes into account active and passive approaches to opportunities,
- the nature of the opportunity, which indicates the external or internal dimension of the opportunity (Krupski, 2011).

[2] This approaches are presented in more detail in the article by Otola & Szymczyk, 2017.

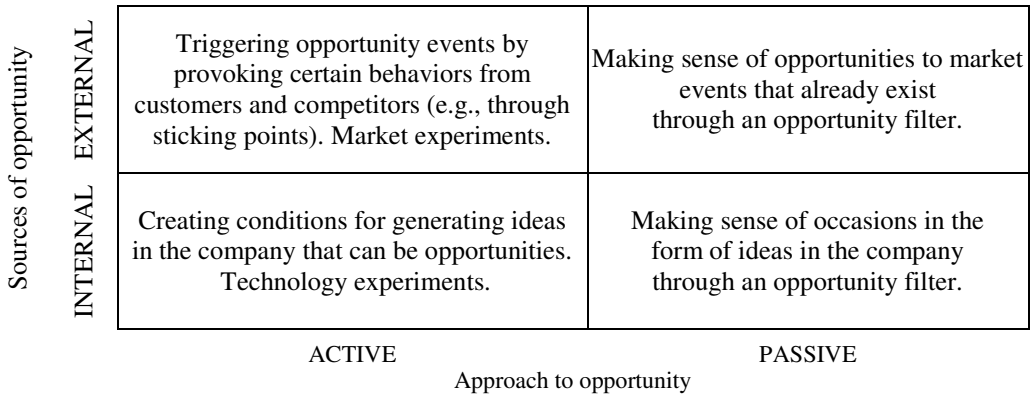

Figure 1. Opportunities in strategic management.

Source: (Krupski, 2013).

Analyzing figure 1, it should be pointed out that the active approach to opportunities involves intentionally triggering such situations, which are then recognized as opportunities. The passive approach, on the other hand, involves attributing the role of opportunities to situations that have already occurred. Internal sources refer to opportunities that have been triggered or observed within the organization. External sources of opportunity, on the other hand, are found in its environment (Krupski, 2011).

The approach to opportunity presented above (Figure 1) reflects the way companies respond to a crisis situation by choosing, in practice, one of four options:

- passive-external approach,
- passive-internal approach,
- active-external approach,
- active-internal approach.

In the case of recent world events, namely the COVID-19 pandemic (2019-2022) and the war in Ukraine (2022-ongoing), one can point to a passive-external approach to the opportunity.

The occurrence of crises conditioned by the aforementioned events has put modern companies in a situation of choice regarding their further development. In the following part of the article, an attempt is made to verify the approach to opportunity (based on R. Krupski's approach) applied by selected IT companies against the background of the indicated global events. Based on the literature review conducted above, this paper asks the following research question: How have IT companies seized opportunities in the face of recent crisis events?

4. Approach to opportunities on the example of selected IT companies - case study

Referring to the widely held view that a crisis should be viewed as an opportunity, it seems reasonable to refer to a survey conducted by McKinsey & Company in 2020. As the report's results indicate, according to the vast majority of the 200 organizations surveyed, they were not prepared to use the COVID-19 pandemic crisis as an opportunity. Although the majority of managers were unanimous that innovation would play a key role, only about 20% thought they had the conditions for further progression, while two-thirds assumed that this would be the most challenging period in their managerial roles. Despite such assumptions, as many as 75% of managers expressed the opinion that changes brought about by the pandemic would be considered opportunities (Bar Am et al., 2020).

The crisis caused by the COVID-19 pandemic initiated many changes throughout the economy, which in practice mainly involved a reorientation of thinking. The circumstances surrounding the operation of businesses determined the role that Internet technologies began to play, and consequently the entire IT sector, which became the leading source of such solutions. It can be said that with the emergence of the crisis, its development has become even more dynamic and it should be assumed that it will not slow down its pace.

Based on past experience, the forecast for the IT industry can therefore be described in several dimensions, namely (Rusly et al., 2021; Li et al., 2022):

- remote work development,
- the growth in demand for cloud computing,
- growth of solutions based on: IoT, Big Data, AI,
- machine learning (ML),
- augmented reality (AR),
- virtual reality (VR) in retail,
- information systems security,
- increasing the level of digitization of the economy and public services.

Due to the COVID-19 pandemic, the adoption of cloud-based business analytics software is expected to increase in the forecasted period as companies are accelerating their digital transformation strategies and adding more business analytics use cases in their daily activities as they trying to stay afloat in an increasingly competitive market (Borasi et al., 2022).

In order to discuss the issue of various approaches to opportunities, a case study method was chosen and three IT companies (DataWalk S.A., LiveChat Software S.A., Ifirma S.A.) listed on the Warsaw Stock Exchange were analyzed. In this context, an analysis was made of their approach to opportunities, which is often directly related to the crisis and its accompanying circumstances. The study was based on data obtained from the companies' management reports, industry information and press releases.

4.1 Passive - external approach

DataWalk acts as the parent company of a group of companies based on: development, improvement, sale and implementation of an extensive analytical system. In practice, this system is a type of tool, included in the group of so-called graph analytics, which is distributed in the form of Commercial Off-The-Shelf ("COTS"). The company's main business areas include R&D activities on advanced data analysis methods, sales execution and implementation of the DataWalk platform in Europe, Asia, Africa and the Middle East, and effective management. Priority activities also include sales and implementation of the platform in North and South America (DataWalk Capital Group, 2022).

The DataWalk analytics platform, thanks to its integration of standard analytics, graph analytics and artificial intelligence, enables complex graph analytics. It allows for the immediate collation of a large amount of data obtained from various sources, and consequently the determination of previously invisible patterns, dependencies or potential dangers. The obtained results are presented in graphical form (on charts, knowledge graphs, maps), tabular form, as reports, time series analysis or in the form of a dashboard. It should be noted that the tool is particularly suitable for conducting investigative analysis, mainly with a focus on the public and financial sectors. It is used, among others, in the activities of: US government agencies (crime prevention), the UN (seeking to maintain peace and guarantee international security), the public sector, the financial sector, including banking, corporations (fraud analysis) (DataWalk Capital Group, 2022).

It can be said that the occurrence of the crisis caused by the COVID-19 pandemic contributed to the expansion of DataWalk's offerings, with the platform's new functionality from 2020 being a central repository and a wider range of services. The development of these areas was driven by the need to introduce analytical support for activities aimed at stemming further development and countering the effects of the COVID-19 pandemic (DataWalk, 2020). Among the most important applications of the repository were:

- the ability to create publicly available records, including: patient information, vaccine supply details, hospital data, access to medical resources, local infection statistics, demographic analysis, summary of emergency numbers, information available in white intelligence databases, i.e. Open Source Intelligence, etc.,
- determining delays in the distribution process and the vaccine supply system. Based on this, it is possible to take an immediate response to the shortages noted in the system,
- the ability to identify individuals who should be prioritized in the context of COVID-19 vaccination (e.g., based on statistics of individuals classified in specific groups at risk of coronavirus infection, such as the elderly, people with comorbidities, etc.),
- automatic verification of quarantined areas, with an emphasis on identifying those who have violated the quarantine,

- the ability to identify potential territories where a high increase in COVID-19 cases is assumed, and thus optimize the allocation of personnel and medical resources in these areas,
- ongoing updating of data (including from new applications) based on which hypothesis verification is carried out,
- recognizing zones and, based on this, developing maps characterized by high risk of virus spread (DataWalk, 2021).

As with the COVID-19 pandemic to expand its services, DataWalk also took advantage of the circumstances created by the war in Ukraine. Their result was the development of software to identify espionage activity in relation to the ongoing armed conflict (DataWalk, 2022).

DataWalk's press release, published on February 17, 2022, included a hyperlink to a several-minute demo, which outlined the specifics of the platform's use for intelligence purposes. According to the press release: "the simulation shows a hypothetical example of the use of intelligence data to identify individuals involved in the escalation of the conflict on both NATO's eastern flank and in Ukraine. DataWalk's technology, through standardized, non-coding queries, graph analytics and machine learning, can help intelligence agencies filter through vast amounts of disconnected data (both public and stored in internal systems), and thus help characterize and monitor potential threats" (DataWalk, 2022).

The system finds its application in the work of national intelligence agencies in Europe and North America. It is also used by government agencies and corporations (DataWalk, 2022).

The development of DataWalk's business, which took place in the face of crisis situations caused by the COVID-19 pandemic and the war in Ukraine, indicates its passive approach to opportunities. The entity took advantage of the conditions created by its external environment (the source of the opportunity) by giving a sense of occasion to emerging events. The circumstances of the outbreak of the coronavirus pandemic and the armed conflict in Ukraine contributed to the development of new solutions.

4.2 Passive-internal approach

The core business of LiveChat Software S.A. includes the production and global delivery of live chat software, which, based on a chat application (placed on a website), enables quick contact between a customer and a company. This tool has its application mainly in the area of online sales and customer service. According to the assumption, it is designed to provide efficient and free communication in the relationship: B2C (business-to-consumer) and B2B (business-to-business), while acquiring data on users. The software is sold as a service, or SaaS (Software-as-a-Service) model. It responds to the demand of all companies whose business is based on online communication with customers. It should be noted that the Live Chat product supports the operation of entities from various sectors, i.e. both e-commerce businesses and units operating in the fields of education, HR or real estate. Currently, the largest group of recipients of the described solution are IT business customers (LiveChat Software, 2022).

The LiveChat Software Company, in addition to the software characterized above, also offers:

- Chatbot - a solution for building chatbots to improve conversation within various business scenarios. The specificity of the chatbot implies automated text communication between businesses and seeks to improve the process of customer service, which takes place in finding solutions to systematically raised issues. It should be noted that this product reflects current trends in the use of artificial intelligence for process automation.
- HelpDesk - conversation with the customer is carried out on the basis of various communication channels, for example: livechat, e-mail. Issues indicated by customers through them take the form of so-called "tickets", handled within the HelpDesk. The presented solution finds its application, among other things, in the area of teamwork, in the segregation and tagging of ticks, or in the process of assessing user satisfaction.
- KnowledgeBase - thanks to the platform, companies gain the ability to create their own knowledge bases, which can additionally be used by both employees and customers. The main idea of KnowledgeBase is to improve the service process, with a particular focus on speeding up communication (LiveChat Software, 2022).

According to LiveChat Software S.A.'s assessment, the effects of the COVID-19 pandemic, including the significant expansion of the e-commerce market, have significantly affected the potential of live chat solutions, contributing to its growth. It should be mentioned, however, that during the initial phase of the coronavirus escalation (i.e., for the first two months), the company experienced an increase in the customer churn rate, which began to decline from May 2020. In turn, the number of potential users of the LiveChat platform (so-called triali) increased during the period, which could reflect the growing demand for online products during the coronavirus pandemic. The Chatbot platform, for which LiveChat Software in cooperation with Infermedica developed a scenario based on the COVID-19 Risk Assesment tool, also played an important role in the period under review. The solution is designed to verify the patient's overall health, determine the risk of coronavirus infection, and then make further recommendations. Interviews conducted by chatbots are designed adequately to WHO guidelines. The creation of the scenarios is based on the collaboration of doctors with Infermedica (LiveChat Software, 2021).

As in the case of the previously discussed company, one can speak of its passive nature, and therefore of an opportunity that was discovered, nevertheless not, as in the previous example, in the environment, but - inside the organization. The opportunity spotted by LiveChat Software involved the use of a solution that had already existed in the company for some time (chatbot), and which could be given additional functionality.

4.3 Active-internal approach

Ifirma's core business is based on the ifirma.pl website:

- Online bookkeeping - which supports businesses in doing their own bookkeeping,
- accounting office - providing online accounting services based on modern solutions and taking into account the strengths of desktop meetings,
- Invoice+ (Ifirma, 2022).

The possibility of integrating the above solutions provided by the ifirma.pl website leads to a unification of the service process and, consequently, to an improvement in the quality of services provided in this area. Undoubtedly, these aspects have a key impact on the shape of the product strategy and, consequently, also on the creation of a competitive advantage. The range of the aforementioned services finds its application in the activities of micro and small enterprises from Poland. Taking into account the entire spectrum of solutions offered, it should be noted that the ifirma.pl service is characterized by the greatest growth potential, and therefore the company is directing its efforts to develop this very area (Ifirma, 2022).

Ifirma, (performing under the name of Power Media) as part of its activities also deals with recruiting and outsourcing of employees in the IT sector. Its main task is to create and fill vacancies in teams of specialists, which is done by assessing their knowledge and qualifications. The third area of the company's operations, in turn, concerns the development of IT products. The company actively participates in the development of enterprise-class applications dedicated to business customers. Solutions from the second and third areas are aimed at medium and large enterprises operating in the domestic and foreign markets (Ifirma, 2022).

An additional scope of Ifirma's activities is contained in the development of the Firmbee system, so far operating under the working name OctoCRM. It is assumed that this solution, in addition to its invoicing capabilities, will also serve to manage stakeholder relations in a broad sense. In addition, it will improve such aspects as project management, human resources management, verification and acquisition of business contacts, and remote working. Among the advantages of the application, one can also point out functions related to recruitment and intake of leads or after-sales customer service. It should also be mentioned that the product in question allows coworking applications based on the Freelance Management System (FMS) model (Ifirma, 2022).

In 2020. Ifirma has abandoned work on the development of Digitape, which was initiated in 2017. Initially, the application was intended to design software for handling and archiving media files stored in the Amazon Web Services (AWS) cloud. The discontinuation of further activities in this area was due to a lack of interest in the solution. The expenditures incurred in the development of this project amounted to approximately PLN 900,000 (Ifirma, 2021; Mackiewicz, 2020).

The product offerings and new ideas aimed at expanding Ifirma S.A.'s business indicate that Ifirma S.A. has a different approach to opportunities than DataWalk S.A. and LiveChat Software S.A. The difference mainly relates to the approach to opportunities, which in this case is active in nature. Drawing on its experience, knowledge and skills, the company seeks to create conditions for developing new ideas in its internal environment (the source of the opportunity). It expects that these ideas, will become opportunities that will guarantee its further progress. In practice, they often represent technological experiments that do not always turn out to be a "shot in the arm" (Digitape system).

5. Summary

The case study carried out as part of this study provided an answer to the previously posed research question. From the examples presented, it can be seen that the way companies view opportunities is not always related to the prevailing crisis. It can be assumed that the approach to opportunities depends on the specifics of the business, the experience gained and knowledge possessed, as well as the ability to find themselves in a dynamic environment and spot opportunities. It is also difficult to determine which approach can generate greater benefits in the context of expansion and the pursuit of competitive advantage.

When considering crisis situations, a passive-internal approach to opportunity seemed natural. However, the case study, indicated that both passive-internal and active-internal approaches to opportunities are feasible in times of crisis. It is worth noting that it is difficult to find examples of active-external approaches in crisis situations, as this is not a time conducive to market experimentation.

It is assumed that companies that carry out market opportunity analyses as part of their activities and develop their offerings based on these analyses are characterized by a definite stability when a crisis occurs and are able to survive it. Such an approach to opportunities is often associated with the spread of an entrepreneurial orientation, within which key importance is attributed to: the search for innovative solutions, a proactive attitude and an inclination to take risks. Innovation and proactivity are treated as issues that contribute to improved performance while risk-laden decisions can generate losses. Accordingly, it should be recognized that innovative and proactive approaches (or a combination of them) positively affect the performance of a company during a crisis (Eggers, 2020).

Despite the many negative effects left by the COVID-19 pandemic crisis, there have been many changes in economic practice that have often been positive. Finding themselves in a situation of crisis, companies began to see opportunities for dynamic development - not only in the area of their business, but also in society as a whole (Liu et al., 2020).

The considerations within the framework of this article prove that the approach to opportunities should not be considered in the category of a decision, but a whole process, embedded in the broader management of the enterprise. It is also insufficient in this regard to rely exclusively on the search for opportunities in the external environment, or to try to create them within the entity. The approach to opportunities requires a whole process that transforms from a conceptual phase into a business model, juxtaposing market demand (value sought) and untapped resources (value creation capacity).

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CONFLICT IN ORGANIZATIONS – COUNTERPRODUCTIVE BEHAVIOR – CAUSES, CONDITIONS AND WAYS OF SOLVING IN POLISH CONDITIONS – HISTORICAL PERSPECTIVE

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Purpose: The presented article is an attempt to compare methods of resolving conflicts in contemporary realities in Polish organizations based on their empirical justification in a time perspective.
Design/methodology/approach: The analysis is based on found empirical research put in perspective.
Findings: Homo sociologicus (collective actor - e.g., large-industry workers) began to give way to individual-achievement logic and changes in the labor code. An orientation toward mediation as a means of resolving organizational conflicts is beginning to dominate.
Research limitations/implications: A survival strategy in the organization becomes the phenomenon of organizational withdrawal, which corresponds to the perception of work in the hierarchy of values. The expectation of a kind of "task instruction" allows to avoid conflicts and at the same time opens a new field of research on the shape and nature of organizational culture - the dominance of collectivist or rather individualistic values.
Practical implications: Changing employee behavior from a collective to an individualistic orientation makes it possible to identify the sources of employee anomie.
Social implications: The analysis and conclusions raise the importance of the social dimension of the organization's functioning and the impact of the external environment on its functioning.
Originality/value: The author emphasizes the importance of shifting attitudes toward the workplace in the formation of organizational culture.

Keywords: organization, social conflict, industrial conflict, trade unions, labor anomie.

Category of the paper: Research paper.

1. Introduction

Conflicts in organizations are an interesting exemplification of a special case of social conflict. They manifest themselves through the taking of collective forms of action, as well as in less spectacular - though equally severe for the organization as a whole - individual behavior of employees (e.g. organizational withdrawal, ignoring the instructions of superiors, disrupting

the flow of information, etc.). The reasons for their formation are often complex in nature - the genesis lies in the subjective dimension (the nature of interpersonal relations) as well as the objective one, inherent in the sociological perspective. The latter can be co-created by internal factors (e.g., improper organization of working time, defectiveness of elements of the personnel process, discrepancy between the goals of the organization and those of its actors) or expectations of the external environment in relation to the inertia of management processes. One of these is the currently articulated demand for the realization of an innovation economy. I understand innovation as the creation of value through the ability to combine things, concepts, ideas, between which no connection was previously perceived. The adoption of the above assumption corresponds with the expectation of a progressive individualization of attitudes towards actors in organizational life. This process takes place in the cultural and social context co-creating the environment of enterprises in Poland - collectivism versus individualism. This also applies to the possible ways of resolving conflicts in organizations.

The presented article is an attempt to compare the ways of resolving conflicts in modern realities in Polish organizations based on their empirical justification in a time perspective. The author puts forward the thesis that the way of resolving conflicts in an organization is conditioned by changes in its environment and the nature of the company's ownership. The two variables indicated continue to be cognitively interesting inferential indicators of the relevance - from a scientific point of view - of the cultural characteristics that co-create the environment of the enterprise - collectivism versus individualism. Considering - in the context of conflict in the organization - counterproductive organizational behavior - it is necessary to take into account the importance of attitudes "brought" by employees from the socio-cultural environment. This is related to the issue of organizational culture.

A research problem of interest from the point of view of organizational life emerges: does the observed process represent a cultural-organizational redefinition of the organizational identity of Polish enterprises (cultural context - collective versus individualistic values) or is it a manifestation of the rationality of organizational actors corresponding to the game paradigm as defined by Michael Crozier and Erhard Friedberg (Crozier, Friedberg E., 1994)?

2. Organizational culture, conflict, social anomie – basic concepts – operationalization

I assume that organizational culture can be treated in terms of (Konecki, Tobera, http://qsr.webd.pl/KKonecki/publikacje/publikacja12.html, Chapter in the book Sketches from the sociology of management, 27 09 2023):

1. Independent variable - an external factor that directly determines employee and managerial behavior in a country.
2. Dependent variable - an element of the organization that depends on the functioning of the other organizational elements (e.g., property rights, transaction costs and the activity of the entrepreneur or organizational leaders oriented towards creating positive attitudes to work or building an organizational strategy in which, for example, the company's mission is defined influencing the values and norms recognized throughout the organization).
3. Autonomous entity - not determined by the culture found in the environment of the country and other factors of the internal environment of the organization independent of it.

For the purposes of this analysis, I assume that organizational culture is a derivative of attitudes and commonly accepted values, norms and modes of behavior inherent in the broad tradition and culture of a given society" (Hampden-Turner, Trompenaars, 1998; Rapacki, 1995, pp. 115-25). It is formed by values and patterns that regulate individual behavior, but are crucial for the functioning of the organization. Patterns and values that determine, among other things, people's attitudes toward saving, ownership, propensity to borrow, understanding of work in the hierarchy of life values, and preference for egalitarian or elitist views (Hryniewicz, 2007, p. 19).

Psychology - one of the management sciences accepts that, self-actualization is the constant pursuit of realizing one's potential, developing talents or abilities. Management science emphasizes the process of becoming "who you are". It is a process of individuation in opposition to the process of individualization - the liberation from traditional power structures (forms, ties), the loss of traditional beliefs about action knowledge, beliefs and prevailing norms - leading to a new kind of social ties (Beck, 2002, p. 193). Is there a process of individuation or individualization in an organization?

The hallmark of an organization is the existence of formalized procedures - patterns of mobilization and coordination of activities of specialized groups that aim to achieve desired goals. However, it should be remembered that the behavior of the participants never fully corresponds to the official rules, the goals pursued by them may differ from those of the organization, while the cooperation itself is often disrupted by emerging conflicts. Is it, therefore, a place of rational and conscious type of cooperation between the individuals and groups that make it up, pursuing common goals? Thus, I accept the assumption of "domination of the community over the individual" but do not underestimate the influence of the individual on the community to which he belongs. Choices, preferences and definitions of social behavior situations evolve in the process of social construction of reality (Berger, Luckmann, 1983). According to Gareth Morgan, organizations can be viewed as (Morgan, 1997):

1. A realistically existing place of identification and realization of goals, in which the behavior of its members and the effects of their aspirations are subject to rational description.
2. An area of competition among groups operating within its boundaries (competing for access to internal resource distribution mechanisms to pursue their own interests.
3. A kind of "cybernetic system" that processes what the environment provides.
4. Cultural reality - emphasis on the cultural dimension of creating organizational reality.
5. Political system - participants belonging to various political groupings seek to control decision-making processes in order to strengthen their positions.
6. Instrument of domination - the implementation of tasks requires entering into a process of interaction, which gives rise to the desire to be the best in the group and dominate over other members.
7. Productive system - the creation of a place for the realization of goals and intentions of individual participants. Its activities are symbolically created and sustained by subordinates and management.
8. Loose system - independent individuals perform different roles pursuing goals that do not necessarily correspond to the goals of the organization as a whole.
9. Mental prison - hierarchical structure of power and division of labor, selection and selection of members and precise definition of accepted and unaccepted intra-organizational behavior. Their acceptance leads to voluntary reduction of one's own behavioral choices.
10. Social contract - mutual agreements and expectations generate the realization of certain behaviors in exchange for certain gratifications (remuneration).

The metaphors cited above point to two complementary logics of organizational order: the logic of integration and conflict. Conflict and cooperation are two phases of the same process (Marcinkowski, Sobczak, 1985, p. 16). Difficulties related to the operationalization of the concept of conflict arise from the fact that there are many synonymous terms (e.g. aggression, aversion, domination, antagonism, rivalry) and the lack of unanimity as to its essence: whether we are dealing with a certain state or process. The diverse cognitive perspectives of conflict theory have been analyzed in detail in the literature (Turner, 1985; Baltaziuk, Kotowska, Lipnik, Pajestka-Kojder, 1999, pp. 59-70; Masłyk-Musiał, 1996; Klusek-Wojcieszke, 2020). As Janusz Mucha notes, attempts to unequivocally define conflict are not necessary because in the literature of the subject, understandings of this issue can be separated only analytically (Mucha, 1999, p. 65). In summary, three research perspectives can be distinguished:

- Structural orientation - the objective incompatibility of interests existing in the structure, the exclusion of group goals generated by a limited supply of goods.
- Behavioral orientation - interactions (relations) between two or more parties based on the belief that their goals are irreconcilable.

– Psychological orientation - a state of hostility, a situation/process in which two or more parties are linked by an antagonistic relationship.

We can identify the sources of conflict in (Stoner, Wankel 1992, pp. 332-334):

1. The way resources are distributed;
2. The dissimilarity of goals;
3. Interdependence resulting from the division of labor in the execution of tasks);
4. Differences in values, attitudes or views;
5. Differences in attitudes toward work, age, education and accompanying organizational ambiguity.

I assume that the study of conflict in the organization, as a special type of social conflict, should take into account a comprehensive approach. Its specificity is determined by the subject of the conflict (labor relations), the degree of involvement of the participants, and the institutionalized course of the conflict (patterns of behavior and legally defined ways of resolving it.).

Robert K. Merton (1982, p. 196) defined the concept of anomie by linking it to an emphasis on the importance of two elements of social and cultural structure:

- culturally defined intentions, or interests that take the form of sanctioned life goals,
- customarily or legally institutionalized ways of achieving these goals.

According to Merton, cultural goals and institutionalized norms that shape the spectrum of dominant behavior need not be closely related because cultural pressure for certain goals is evolving, leading to independence from institutionalized means of achieving them. Possible strategies of action are: **conformism**: acceptance of goals and institutionalized means; **innovation**: acceptance of goals while rejecting means to achieve them; **ritualism**: rejection of goals and acceptance of means; **disengagement**: negation of goals and means; **rebellion**: rejection of goals and means and proposal of their alternatives (Merton, p. 203). The socio-cultural changes taking place in the organization's environment are also related to the transformation of the value system and its consequences. E.g., data from 1999-2021 show an increasing number of economic crimes committed - 1999: 60,393, 2020 - 198,163, 2021 -224,775 (https://statystyka.policja.pl/..., 27.09.2023). Between 2013 and 2021, the indebtedness of Poles aged 18-25 increased (rising from PLN 42.8 million to PLN 453.9 million). The total indebtedness of Poles increased more than 3 times (an increase from PLN 13.7 billion to PLN 44.1 billion). At the end of 2021, there were nearly 2.4 million bad debtors aged 18 (https://ciekaweliczby.pl/dluznicy..., 22.09.2023). Between 2013 and 2022, the number of suicide attempts by children and adolescents in the 13-18 age group increased about 6 times (in 2013 - 348 attempts, in 2022 - 2008 (https://ciekaweliczby.pl/proby_samobojcze..., 30.09.2023). In 2013, people in this age group made 348 suicide attempts, while in 2022 - 2008 (https://ciekaweliczby.pl/proby_samobojcze...).

In light of the data cited (according to the assumptions made), the empirical data on the sense of organizational justice seem interesting. Organizational justice is the sum of the perceptions of organizational actors about the methods of decision-making, the quality and results of these decisions and the treatment of those affected by the decisions. In other words - a subjective, descriptive assessment of the level of ethical behavior of individual members of the organization and the organization as a whole, which co-creates the attitudes and behavior of employees (Colquitt et al., 2001, pp. 425-445). They most often concern distributive, procedural, interactional and informational justice (Turek et al., 2014, pp. 113-139). 61% of respondents believe that the value of their competencies is higher or definitely higher than the value of the salary they receive, 29% of people felt that the value of their competencies is comparable to the salary they receive, while 10% believe that the market value of their competencies is lower or definitely lower than the salary they receive. Is the salary fair: 50.35% - definitely yes or rather yes, 49.63% - definitely no or rather no, 12% - definitely unfair, 4% definitely fair (https://wynagrodzenia.pl/artykul/..., 25.09.2023). Doubts about the issue of specific material gains derived from work - the amount of wages and the quality of social security - are confirmed in other surveys (Research Communication, 2021). 80% of executives declare that they have used or continue to use negative motivation and/or have also been subjected to it themselves in their careers (Klimkiewicz, Cierpis, pp. 219-234).

The data cited above also explain the growing phenomenon of employee anomie - which manifests itself, among other things, in intentional and systematic behavior resulting in widely defined losses for the organization (Kowalewski, Moczydlowska 2020, pp. 28-29). The phenomenon of social anomie, co-creating the environment of the organization, is reflected in the organizational dimension: employee anomie. Its manifestations are counterproductive behaviors, e.g. abuse of co-workers, theft, deviant production, organizational sabotage and withdrawal (Turek, 2012, pp. 20-21).

3. Conflicts – ways of resolution – a historical perspective

Tadeusz Szawiel, while analyzing the attitudes and social orientations of Polish Catholics, confirmed the opinion of the culturally conditioned collectivist attitude of Poles (Szawiel, 1996). It can be concluded that the trade union in the social consciousness of the 1980s and the beginning of the period of change in Poland went far beyond the statutory duties inherent in such corporations in stabilized market systems. It satisfied not only the requirements of participation in decision-making, but also the need for action and group identification. It exemplified the fulfillment of cultural values. Values that differentiate the impact of culture on organizations: collectivism - individualism. Considering the ways of resolving organizational conflicts, there was a reevaluation of the opposition between individualism and

collectivism? The labor union, which is a formula for collective action, ceased to be an important element of collective organizational identity. Members of labor organizations were more often those employed in state-owned enterprises - least often in the private sector. In other words, the highest percentages of those working in enterprises with labor unions can be found in economic sectors characterized by the highest share of state ownership (Research Release, 2019).

The decisive factor driving union activity was the form of ownership and size of industrial organizations. Already in 2001, it also turned out that trade unions were no longer perceived as an adequate representative of workers' interests - 68% of respondents were convinced that no one represents workers' interests well. The hitherto traditional formula for defending the interests of the organization's participants (the strike) did not find recognition in the eyes of the vast majority of respondents - a negotiating orientation dominated, with 47% of respondents (Research Communication, 2001). An important differentiating variable in this case was education: the higher the level of education of the respondents, the higher the percentage among them who perceived the possibility of asking for and obtaining help. Among respondents who said they had someone to turn to for help, more than half (55%) pointed to their immediate supervisor, while only 6% said they could count on trade unions for help if they got into trouble at work. Workers with secondary and higher education were almost twice as likely to rely on their immediate supervisor for help than the least educated. Workers with primary and basic vocational education were relatively more likely to turn to trade unions for help (Research Communiqué, 2001). The social perception of the role, function and importance of the trade union in enterprises (a form of collective action) has been corrected. In the opinion of the respondents, it is primarily the direct superior who is the person who can be trusted. Relationships - superior - subordinate - are beginning to refer, as it were, directly to the archetype of the patriarchal model of the family with an authoritarian structure. Corresponding with the above thesis are the results of Lukasz Sulkowski's research on identifying the most common configurations of organizational cultures in a given society (Sulkowski, 2001). The indicated cultural trait correlates positively with familialism, signifying the strength of an individual's connection to family in the organizational field. Polish companies were characterized by the dominance of a communal orientation and an ambivalent attitude toward authority. Respect for strong authority began to be accompanied by distrust, distance, criticism and passive resistance. Subordination and formalization involved roles rather than procedures or organizational rules. There was an apparent focus on interpersonal relationships, not on the ease of economic transactions. However, negotiating the most profitable terms of participation in the organization was still done under conditions of strong group identification. According to the Polish Central Statistical Office, in 2017 there were 1,556 strikes in Poland, involving 29,700 workers. Their participants accounted for 0.3% of the total number of salaried workers in Poland (34.3% of employees of organizations where protests took place). 1520 of the 1556 strikes (97.7%) involved the education sector. In 1991, one in five Polish adults (19%) belonged to trade unions, and in 2017 only one in 20. In 2003, 41% of workers

declared that their workplace had at least one union organization. In 2017, it was 31%, while 12% of respondents were unable to say whether a union was active (6% in 2003) (https://praca.gazetaprawna.pl/artykuly/1419534..., 28.09.2023). In 2021, 5.5% of Poles - about a tenth of wage earners (10.5%) - declared union membership. They mostly belong to unions that are part of large organizations: NSZZ "Solidarity," the All-Poland Alliance of Trade Unions and the Trade Union Forum (Research Communication, 2021). Homo sociologicus (collective actor - e.g., large-industry workers) began to give way to individual-achievement logic and changes in the Labor Code. Labor relations in Polish small and medium-sized enterprises are characterized by strong individualism of entrepreneurs - which generates low potential for self-organization of the environment and paternalistic relations - the dominant style of management is autocratic. The working environment is characterized by a relatively low level of social capital, a consequence of which is a limited ability and willingness to create networks of business cooperation. There is a noticeable reluctance on the part of entrepreneurs to have organized employee representation (Czarzasty, 2014, pp. 135-153). The already signaled orientation to mediation as a means of resolving organizational conflicts is also beginning to dominate (Kozina, Malkus, Pieczonkanka, 2019, pp. 11-19; Cichobłaziński, 2019). As early as 2007, Janusz Hryniewicz noted that the desirability of peace at work is linked to intellectual activity. "The attitude to tranquility at work shows a very strong connection with an aversion to intellectual activity. The greater the demand for tranquility at work, the stronger the acceptance of the thesis - "I prefer a manager who does not require the disclosure of his own opinions, and tells exactly what to do and how to do it". Thus, for example, among those who believe that calmness at work is definitely not important, only 18% would like to have such a supervisor, while among those who believe that calmness at work is very important, the demand for such a style of leadership rises to 70%. Attitudes toward calmness at work are related to education. People with higher education value calmness and constancy slightly lower than the rest of the population" (Hryniewicz, 2007, p. 141). Employees expect emotionally positive colleague-family relationships and stability. Individual achievements are valued low - acceptable as long as they do not violate informal hierarchies of prestige, popular opinion, etc. One does not show to the environment that one is doing something better than others, while achievements have the character of internal experiences (e.g., the opportunity to learn something new (Hryniewicz, 2007, p. 57). Currently, this takes the form of so-called organizational withdrawal. Although involvement in current duties is declared by 79% of respondents, only 39% of working respondents are convinced that in their work additional involvement pays off for the employee. 37% of respondents declared focusing solely on formal duties (https://www.proto.pl/aktualnosci/..., 27.09.2023). Employees perceive themselves as reliable professionals, although for some of them this is not combined with a readiness to carry out additional tasks - to go beyond the rigid framework of the daily schedule. Appreciation in the current workplace is declared by only 48% of respondents, 53% that they feel such appreciation of their work duties from family and friends. 73% are not afraid of losing their current job although a quarter (23%) reckon with such a possibility

(https://biznes.interia.pl/praca/..., 27.09.2023). Therefore, it is not surprising that work (good job, job security, stable employment) in the hierarchy of values gained 8% of indications (Research Communication, no. 160. CBOS 2020). Thus, organizational withdrawal becomes an individual strategy of conflict avoidance, although remaining in the organization and at the same time "next to it" constitutes counterproductive legal behavior. This is a kind of reconciliation of the logic of integration and conflict.

Summary

The presented article indicates the importance and evolution of attitudes to a special case of social conflict - organizational conflict. They are manifested through the taking of collective forms of action as well as the individual behavior of employees. The actions of the collective actor give way to individual-achievement logic, changes in the labor code and individual expectations of the workplace. The phenomenon of organizational withdrawal becomes a survival strategy, which corresponds to the perception of work in the hierarchy of values. The expectation of a kind of "task instruction" avoids conflicts and at the same time opens a new field of research into the shape and nature of organizational culture - the dominance of collectivist or rather individualistic values.

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MODERN TECHNOLOGIES IN SHAPING STRATEGY IN THE CLOTHING INDUSTRY – A CASE STUDY OF THE 4F BRAND

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Purpose: The purpose of the paper is to review modern technologies present in building the strategy of contemporary clothing companies and to conduct a case study of the 4F brand (one of the leaders in the use of modern technologies in shaping the product offer in the clothing industry in the Polish market), to present the application of the use of these technologies in the Polish market.
Design/methodology/approach: The paper conducts a case study of the 4F brand from the point of view of the use of innovative technologies in improving strategies for meeting the needs of buyers of clothing products. It was preceded by a literature review on the occurrence of these technologies in the surrounding market reality and their development prospects.
Findings: Innovative technologies are a constant element in building the strategy of the 4F clothing brand. With them, the brand develops such parameters of its offerings as antibacterial, hypoallergenic or adequate moisture wicking. It also uses technologies to present new product lines: 3D and augmented reality (AR). It allows it to optimise the entire sales process and reduce the number of returns. It is part of the company's strategy to shift to circular sales models in line with sustainable development.
Research limitations: The diversity of possible solutions from modern technologies, resulting from their nature and unique specificity, makes it difficult to generalise the results obtained. Each successive example of the use of modern technologies is outstanding in its way, does not lend itself to standardisation and requires individual analysis.
Practical implications: The results of the study indicate that the business operations of apparel companies are becoming more technologically advanced, which will require increasing investment on their part in IT infrastructure and the implementation of new technological solutions.
Social implications: Modern technology is being used in the fashion industry to build relationships with stakeholders through increasingly modern marketing communication tools, forcing expenditures in this area as well. The tools for building these relationships are derived from the instruments used by stakeholders in their personal lives (e.g., social media), and the two areas will intersect and complement each other.
Originality/value: The originality of our study is to comprehensively present the current use of modern technologies in the apparel industry, to isolate the most popular tools used by entities in this industry on the Polish market and to diagnose the attitude of the audience towards them, as well as to determine the development directions of this trend.

Keywords: modern technologies, clothing industry, sustainable development, 3D and augmented reality (AR), 4F brand.

Category of the paper: case study.

1. Introduction

Technological improvements are giving modern providers of goods more and more opportunities to improve their offerings, serving to more fully satisfy buyers' needs. For years, innovations could be seen primarily in the technological process of producing a new product (Kartajaya et al., 2019). Modern technology is used at every stage of the customer's purchase path (Wojciechowska, 2020; Stasiuk, Maison, 2021). Advanced technology helps in marketing research, learning about consumers' expectations and assessing their reactions to the company's actions (Morin, 2011). Thanks to innovations, goods providers can streamline the production process and dynamically improve their products, flexibly responding to further changes in market expectations (Kamboj, Rahman, 2017). Modern marketing also makes heavy use of technological advances (Davies et al., 2020). The idea of Marketing 5.0 cites (Kotler et al., 2021) date marketing, predictive marketing, contextual marketing, augmented marketing and agile marketing as critical components. Through their use, it is possible to build an ecosystem of data, anticipate demand for better targeting, and further create a personalised sensory experience using human interactions supported by technology(Patora-Wysocka, 2014). And all this at scale and a rapid pace. Incorporating these aspects into the strategy of the modern enterprise is becoming a necessary condition for competitiveness. It can be observed in an increasing number of industries that operate in the market.

The clothing industry is also implementing these elements in its operating strategies. The clothing industry is worth about $2.4 trillion in US dollars, employs about 75 million people worldwide, and is multiplying constantly (KPMG, 2018). Its operation is linked to the use of many new technologies. An example of an entity in this sector that relies on technology in all areas of its operations is the 4F brand.

The purpose of this paper is to review modern technologies present in building the strategy of contemporary clothing companies and conduct a case study of the 4F brand (one of the leaders in the use of modern technologies in shaping the product offering in the clothing industry in the Polish market), to demonstrate the application of the use of these technologies.

The text uses available literature on the subject and empirical materials from the company.

2. Literature review

Modern technologies in the clothing industry are present at every stage of the company's operation strategy (Valaei, Nikhashemi, 2017). To systematise the presentation of the place of use of modern technologies, they can be divided into the following areas:

- manufacturing technologies,
- marketing communication techniques,
- sales techniques.

The materials used in the production of garments and their manufacturing techniques are the first areas where technological innovations began to be applied on a mass scale (Rinallo, Golfetto, 2006; Patora-Wysocka, 2014). As a result, the functionality of products was systematically improved, design and manufacturing times were reduced, the costs of these processes were lowered, and environmental performance was improved (KPMG, 2018). Among the most valuable solutions are 3D design and sampling (Hugo Boss, Tommy Hilfiger) - there are no physical prototypes of products, no wasted materials and no shipping costs. At the same time, it is possible to respond more quickly to market trends and consumer expectations. Printed models make it possible to assess the feasibility of designs. There is no need to take photos of the collection, as its design is already digital (Pflaum, Golzer, 2018). The whole process is less harmful to the environment.

Optimisation of the sales process itself is also achieved through the use of:

- Blockchain - makes it possible to track the movement of clothes throughout the production and supply chain.
- Predictive analytics - algorithms that make it possible to predict what demand will be and, thus, reduce product transportation.

In today's marketing communications, technologies are primarily tools for personalising contact, quickly presenting offers, facilitating the selection of the best option, and promptly completing the purchase transaction (Taranko, 2015; Wiktor, 2013). Hyper-personalisation is becoming more and more popular (Jain et al., 2021), which, thanks to Machine Learning and Deep Learning, makes it possible to create advanced predictions about the consumer's future behaviour (Bagherian et al., 2021), both in terms of the products purchased and the shopping experience, customer service methods, offers used, discounts, e-mail marketing, etc (Mortimer, 2017).

The improvement of the sales process with new technologies can be observed in both traditional stores and online stores (there is also a virtual clothing marketplace). The basis for satisfaction with the purchase transaction is the product's fit to the customer, which requires trying them on in the case of clothing products. While this hasn't been a problem in traditional commerce for a long time, it has been a difficulty in online sales until recently. At the moment, artificial reality offers the opportunity to try on products that are often not yet physically made

- all that is needed is a digital visualisation of them. Studies show that the virtual fitting room contributes to a 27% reduction in the rate of returns, resulting mainly from a mismatch in size or the wrong cut of a product.

In the sales process, companies are also using electronic tags, which enable a more seamless management of distribution, warehousing and sales processes, as well as observing the fate of a product after purchase (e.g. using RFID, as in the case of the Spanish brand Inditex, or the Polish LPP) (https://www.newsweek.pl/..., 20.09.2023). Stores are being equipped with progressive lighting and air-conditioning systems that respond to customer movement in the store and adjust the facility's climate conditions accordingly.

The logistics of the sales processes are carried out using automation of the process. Algorithms are responsible for collection planning, the number and type of garments in stores, or discounts. It makes it possible to dispense with a person supervising individual stores. But at the same time, it requires the expansion of IT departments in clothing companies (for example, LPP employs 400 people in its IT department) (https://filarybiznesu.pl/..., 20.09.2023).

Wholesalers increasingly use virtual showrooms to help evaluate the products on offer and make more accurate purchasing decisions without making additional trips and shipping prototypes.

Not long ago, it seemed pure fiction to buy virtual products, and today, there is already talk of digital fashion in social media, which appears to be an ideal solution for influencer marketing, primarily from the point of view of ecology.

The presented list of technologies in the clothing industry is not complete. There are undoubtedly many more tools that individual companies use in their sales processes. However, this selective list of technologies shows that the fashion market is changing radically and gives hope that shopping in this sector will become easier and greener.

3. Characteristics of the studied entity – the 4F brand

4F is a Polish brand owned by OTCF. It also holds 4F Junior, Outhorn, Under Armour, SportStyleStory.com and 4F Fuel (https://www.otcf.pl/marki, 20.09.2023). The initiator of the company and founder of the 4F brand is Igor Klaja (Klaja, 2016). Its prototype was the 4Fun brand established in 2003 (the next version of the name was 4F Sport Performance and since 2010 - 4F) (https://mambiznes.pl/..., 20.09.2023). Over the years, the brand has systematically expanded its commercial offer and adapted its activities to the requirements of the environment. Currently, the company is thriving in the country, with more than 240 stationary stores in various locations, and is developing its activities in the foreign market through a wholesale network (https://www.otcf.pl/marki, 20.09.2023). The brand's products can be found in as

many as 42 European and Asian countries (Sieńko, 2020). OTCF's turnover is about 400 million euros, and half comes from the 4F brand.

The 4F brand, in its extensive commercial offer, has an assortment for children, women and men designed for both amateur and competitive physical activities, such as running, skiing, snowboarding, swimming, cycling, yoga, trekking or fitness. The range also includes casual clothing characterised by versatility and functionality. The assortment comprises T-shirts, sweatshirts, jackets, fleeces, pants, leggings, dresses, skirts, swimwear and underwear. In addition, there are also accessories such as backpacks, bags, goggles, helmets, scarves, hats, goggles, gloves, socks, bidons and specialised training equipment. The 4F brand also produces footwear, including winter boots, shoes designed for running, flip-flops, sandals and versatile sports footwear models.

"The brand's mission is to inspire customers to find a passion for action - not only in sports, and to persevere and go one step further every day" (https://4f.com.pl/fundacja-4f-pomaga, 20.09.2023). In pursuit of this mission, the brand specialises in producing representative and starting outfits for people participating in sports competitions (Klaja, 2016). Foreign Olympic committees appreciate it. In a ranking conducted by "300Gospodarka", 4F ranked second in the list of clothing manufacturers for athletes participating in the 2020 Games (Siedlaczej et al., 2020), where as many as eight national committees performed in clothing created by 4F (https://terazpolska.pl/..., 20.09.2023).

The brand cares a lot about its image. It intensively develops its marketing communication, which includes not only direct activities accompanying the sale of products and the development of business but also, among other things, social and environmental activities. An example of activity undertaken by the brand in this area is participation in World Clean Up Day (https://4f.com.pl/blog/..., 20.09.2023). The brand also partners in activities organised by Aktywni dla Autyzmu or the DKMS Foundation. Meanwhile, an independent initiative undertaken by 4F is the 4F Helps Foundation, whose initiative was born in 2019 as a reaction to the emergence of the COVID-19 pandemic (https://4fpomaga.org/about-us/, 20.09.2023). As a provider of products dedicated to sports, the brand is keen to sponsor sports teams and events of this nature (e.g., an agreement with the Polish Volleyball League). The brand's marketing communication is supported by a group of its ambassadors (the common slogan of this group: "We make a team"), which include Robert Lewandowski, Anna Lewandowska, Wilfredo Leon, Paulina Fialkowa, Łukasz Kubot, Martyna Kotwiła, Kamila Żuk, Adriana Sułek, Sebastian Kłosiński, Milda Valciukaite, Saulius Ritter (https://4f.com.pl/ambasadorzy, 20.09.2023). The 4F brand also uses mass communication tools such as TV, radio and print ads. Communication activities are complemented by mailing and extensive loyalty programs.

4F constantly expands its commercial offerings to adapt to changing market expectations. Its negative impact on the environment and the deteriorating state of the planet has contributed to the brand's innovative efforts to protect the environment (https://4fchange.com, 20.09.2023). Since 2022, 4F Charge has been operating a "Wear_Fair" program to reduce the adverse effects

of overproduction of clothing and unused purchases. A ski outfit rental business has been launched. Interested customers can rent unique 4F winter clothes for a fee and return the products after use. In addition, special zones have been opened in some stores, where customers can return used and unwanted 4F brand clothes to the so-called second circulation. They are thoroughly cleaned and refurbished. Then, marked with a unique "Wear Fair" tag, they go on sale again.

The next step in developing the 4F Charge program is a joint project between the 4F brand and Viamoda University called Circular Design 4F x Viamoda (https://media.otcf.pl/..., 20.09.2023). In this project, students will strive to turn substandard products into exceptional products, using second-circuit clothing, repair, recycling and upcycling. Precious in this initiative is the involvement of an external entity, such as a university and its students. It ensures greater promotional resonance and pro-environmental education for the brand's potential customers, the school's students.

4. Modern technologies in the activities of the 4F brand

One of the most critical elements of the 4F brand's operating strategy is concern for the development of the products offered. The company constantly invests in designing successive collections of products to align with the latest fashion trends. This process involves the company's employees and ambassadors, who create their collections that are later sold under the 4F brand (e.g. RL9, Anna Lewandowska "DOPAMINE BOST").

The brand has also been investing for years in innovative materials for the brand's products. Thanks to this, the comfort of use of these products is increasing - new technologies used in the process of manufacturing materials make the garments sewn from them have increasingly better breathability and moisture-wicking properties (underwear, T-shirts and leggings are made from materials containing quick-drying fibres in 4FDry technology), protection from wind and moisture (outerwear, especially for winter sports). Such measures also increase the durability of products, which, together with a higher level of satisfaction with the innovations contained in the company's products, results in customers using the products they buy for longer. The leading technologies and materials used in 4F products are (https://www.asport.pl/technologie/..., 20.09.2023):

- AQUATECH PRO+ - a high-quality technical material with PU impregnation protects the wearer from environmental moisture. It can have different varieties and technical parameters, and thanks to the millions of micro-holes in the Aquatech Pro+ material, it has a triple property: it blocks wind and water coming from the environment and expels sweat and moisture resulting from the increased physical exertion of the user.

- THERMODRY - a high-quality knit fabric created specifically for customers who demand more practicality from sportswear for their active lifestyles. THERMODRY knitted fabric wicks sweat to the outside of the fabric, where moisture can evaporate quickly. The intricate construction of these fibres ensures that the underwear dries quickly. This thermoregulation effect allows the wearer to stay dry and provides greater freedom.
- MICROTHERM - a high-quality knitted fabric that maintains the body's natural temperature with a low material weight. It has an anti-pilling finish, so it retains its properties and appearance much longer than conventional fabrics.
- INNER-TECH - a high-quality product that protects from wind and moisture while expelling sweat and moisture generated by increased physical exertion.
- MERYL SKINLIFE - bacteriostatic polyamide fibre, which, thanks to the content of silver ions, maintains the bacterial balance regardless of the intensity of physical activity. The fibre's active silver ions have bacteriostatic, anti-fungal, anti-odour and anti-allergenic properties. These properties make Meryl Skinlife ideal for garments that come into contact with the human body. The material has passed tests in contact with the mouth, skin or eyes. By reducing the growth of bacteria and quickly absorbing moisture from the skin's surface, the BODY 4F collection performs thermoregulatory functions in all weather conditions, protects against the formation of dangerous odours and reduces the risk of allergies.
- POLARTEC CLASSIC® - is known for its lightweight, breathability and ability to keep you warm. Polartec® is air permeable, keeping the body warm, thanks to the velour construction used in the material. In addition, the material maintains its insulating ability and proper appearance without pilling, even after repeated washing.
- WINDPILE - a new generation climate-responsive fabric that provides maximum protection against wind and cold. It is a breathable fabric, giving a feeling of comfort while being outdoors.

Individual clothing components can come in very different versions; for example, a membrane that provides waterproofing, windproofing, breathability and sweat-wicking comes in versions 3000, 5000, 10000, 15000 and 20000 (https://4f.com.pl/blog/post/jakie-zalety..., 20.09.2023). As a result, its advantages can be appreciated by amateur athletes and professionals training in very harsh weather conditions. The brand sometimes looks for sources of inspiration for its products in very unusual places; for example, Primaloft insulation (synthetic down) was invented in the 1980s for US Army soldiers (https://4f.com.pl/blog/post/jakie-cechy..., 20.09.2023).

Before the final product is created, a testing phase and presentation of newly developed models is necessary. It is also the space where the brand uses modern technologies. An example is the collection created by the brand in cooperation with Robert Lewandowski. Technologies

were used to present the collection: 3D and augmented reality (AR). 4F's cooperation with this footballer is based on creating joint, innovative collections designed to combine the latest trends and functionality. The products in this collection use materials that have properties known from professional sportswear, such as antibacterial, hypoallergenic and adequate moisture wicking. In addition, they are characterised by extended durability. The 4F x RL9 collection comprises 38 items, including sweatshirts, pants, shorts, long sleeves, t-shirts and baseball caps. The entire collection is available in muted colours that can be combined. (https://mycompanypolska.pl/..., 20.09.2023).

In designing the products of this collection, care was taken to ensure their aesthetics, quality and uniqueness at the same time, e.g. the special edition of sports shoes is only 200 pairs of shoes (in black and white; numbered and signed with Robert Lewandowski's signature) (https://www.vogue.pl/..., 20.09.2023)

The 4F x RL9 collection has been digitised, so the products can be seen in the 4F app using augmented reality (AR). You can also use the 4F app and view each product in a 3D scan of Robert Lewandowski's silhouette. With the help of modern technology, the 4F brand allows its customers to visit the e-fitting room, where Robert Lewandowski's avatar enables them to choose the right clothes size without leaving home. With the help of 3D technology and augmented reality, it is possible to see each garment from the collection on the silhouette of the ball champion. In addition, the brand's customers can visualise the products on their own silhouette in the e-fitting room. An individual avatar can be created using basic silhouette information, i.e. by providing measurements such as height, chest, waist and buttock circumference. All thanks to the use of technology developed by the Polish startup WEARFITS, supported by the Lodz-based gas pedal S5. Using these technologies is also possible because customers of the 4F brand can also shop through a particular app dedicated to it.

The technologies used are designed to bring customers of the 4F app closer to the shopping experience they know from stationery stores. The ability to display Robert Lewandowski's silhouette is a bonus provided by 3D technologies. Augmented reality is one of the technologies the 4F brand is testing to optimise the business's environmental impact. One of the main problems that WEARFITS technology addresses is optimising sales and reducing returns, which can be reduced by more than 20% thanks to AR Digitization at every stage of the production and supply chain, allowing for greater experimentation with marketing and product forms.

Confirmation of the right direction for the 4F brand's business strategy in the Polish market is that the company is growing very well and recording higher sales results yearly. 708,000 (https://4f.com.pl/, 20.09.2023) Internet users have liked its profile on FB, while its profile on Instagram has 153,000 followers, and there are 11,500 followers on TikTok (https://www.tiktok.com/@4f_global, 20.09.2023). The brand and its managers also enjoy industry recognition in Poland and worldwide, as exemplified by the awards they receive. Here are some examples (https://4f.com.pl/, 20.09.2023):

- 2016 - “Retailer of the Year” (“Retailer of the Year”), as part of an international competition, won in as many as three categories - Retailer of the Year, Fashion Retailer of the Year and Debutant of the Year.
- 2020 - Igor Klaja - Entrepreneur of the Year 2020 - for not giving up when the pandemic closed most stores.
- 2022 - Top Brand 2022 - awarding 4F brand as a leader in the clothing industry in 2022.
- 2023 - CEE Retail Award 2022 in the Fashion Retailer category (stores under 600 sqm).
- 2023 - Mobile Trends Awards 2022 - nominations in three categories for two apps: Outhorn and 4F, with the Outhorn app nominated in m-commerce and business mobile-based solution categories.

5. Conclusions

In summary, the multitude of modern technologies used in the clothing industry is truly impressive. As specialists note, the technologies have often been known before, and only how they are used is new. The direction of their development is set by the desire to make fashion more sustainable and help more fully satisfy human needs in the long term. It is crucial because, according to the European Economic Commission, the clothing industry accounts for 20% of the world’s water waste and 10% of global carbon dioxide emissions. 85% of manufactured textiles end up in landfills (https://biznes.newseria.pl/, 20.09.2023). Fashion Industry Charter for Climate Action, in which they pledged to reduce greenhouse gas emissions by 30% by 2030 and to achieve climate neutrality by 2050 (https://nowymarketing.pl/..., 20.09.2023). Modern technologies will be of great help in achieving these results. One can even argue that the future of the fashion market is digital (fash-tech).

Fortunately for the climate, the desire of customers in the clothing sector to save money, simplify the buying process and have a more satisfying product is entirely in line with the market’s need to reduce waste, pollution and water consumption in this sector.

The 4F brand also fits in well with the observed trends. The brand’s managers are fully aware that the clothing industry impacts the ongoing climate change and that the transition to circular models is one of the critical directions for corrective action. The brand’s initiatives address this need while making the company’s operations more profitable. Skillful use of established brand ambassadors (e.g. Robert Lewandowski) helps convince a broad group of customers of these activities. The brand is recognised by customers and professionals, as evidenced by its high interest in it on social media and periodically awarded.

The main threat to using technology in purchasing processes that help match a product (e.g., e-fitness), make sales processes more flexible, or optimise proper product allocation is the security of the data that flows during these activities. For example, to use an e-fitness room,

a customer must share all of its dimensions (Pflaum, Golzer, 2018). And optimising store supply uses information and the movement of customers and their purchases. The discomfort of realising that one is being tracked may not be outweighed by the shopping convenience accompanying it.

An equally important factor is the high cost of these innovations, which makes purchasing offers prepared with them more expensive. It may happen that an uneducated customer will not appreciate these innovations and will abandon the purchase in favour of another cheaper offer (Tezel, Giritli, 2019; Nguyen, Nguyen, 2021). The times ahead will not be easy for customers. For their purchasing decisions (as well as other market decisions) to qualify as relatively pro-environmental, they will require knowledge of the technology used to produce the good in question and the implementation of different processes in the company of its offerer, etc.

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REVERSE VENDING MACHINES VS. OTHER WAYS OF SELECTIVE WASTE COLLECTION – RESEARCH RESULTS

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Purpose: The paper presents outcomes of the qualitative research on the use of reverse vending machines (RVMs) as equipment to facilitate the segregation and disposal of beverage packaging in Poland, in comparison with other ways of selective waste collection. The topic of innovative tools to support waste management gains particular importance in the context of the introduction of the deposit system for packaging in Poland.
Design/methodology/approach: Our qualitative research aimed at identifying consumer behaviour and preferences regarding the selective waste collection. Simultaneously we evaluated experiences with the RVMs and related incentive programs. The research technique was focus group interview, supported by perceptual mapping. 5 interviews were conducted with citizens of Malopolska & Silesia Provinces, in localities where recyclomats from the pilot program were installed.
Findings: The results show positive attitudes towards the RVMs among participants of pilot testing of such devices. RVMs are perceived as easy-to-use and environmentally friendly. Compared to other methods of selective waste collection, the highest rated in terms of cost to the user and suitability for the user were the containers for segregated waste. When evaluating incentive systems, respondents accepted only financial benefits. It can be assumed that RVMs can support the newly introduced deposit system for beverage packaging in Poland.
Research limitations: Most of the focus group participants had been familiar with RVMs from the pilot program, but the mobile app dedicated to the devices was inactive during the study. This affected the overall user experience.
Practical implications: The outcomes suggest that the comprehensive waste collection and recycling system in Poland should be supported by RVMs, and that such devices should be popularized.
Social implications: RVMs could play an important role in environmental education for children and young people. The dissemination of recyclomats by retail chains and local governments will increase their availability and influence the formation of pro-environmental behavior of other consumer groups.
Originality/value: The originality of our study is based on identifying Polish individuals' views toward innovative waste management technologies and demonstrating their influence on sustainable consumption.

Keywords: reverse vending machines, recyclomats, consumer behavior, selective waste collection, research, Poland.

Category of the paper: research paper.

1. Introduction

Municipal waste management continues to be a focus of the European Commission (EC), particularly in the transition to a circular economy (CE), which is a priority of the European Union's (EU's) economic policy (Smol et al. 2020).

Countries that want to enhance their waste management systems should also focus more on promoting sustainable consumption and manufacturing (Chow et al., 2017). This requires the cooperation of various stakeholder groups: business, administrative and individual, as well as coordination of actions taken at the local, regional and national levels (Dagilienė et al., 2022; Puntillo, 2023). A substantial amount of study has been conducted on the practical elements of municipal waste management (transport, treatment, and disposal), as well as how individuals feel about waste segregation, recycling or incineration (Wilson et al., 2001; Alwaeli, 2015; Minelgaitė, Liobikienė, 2019). Understanding the factors that explain individual acceptance of different waste management policies and circular economy in general is essential for implementing proactive approaches to improve sustainable consumption and consumer involvement. (Triguero et al., 2016; Puntillo, 2023)

The result of unsustainable consumption is the overproduction of packaging, which requires the implementation of effective and widespread tools for its disposal (Siddiqui, Pandey, 2013; Idumah, Nwuzor, 2019, Khan et al., 2022; Hordyńska et al., 2023).

The purpose of the study is to obtain an answer to the question of whether and to what extent the Comprehensive Waste Collection and Recycling System in Poland (Kutyna-Bakalarska et al., 2020) should be supported by reverse vending machines for selective waste collection (RVM, 'recyclomats'), and whether the dissemination of such equipment should be expanded on a regional scale (Małopolska-Silesia), and in the long term, throughout the country.

Based on currently available knowledge, it can be concluded that reverse vending machines (Kaplan et al., 2016), are already supporting waste collection and recycling systems in the European Union (Scandinavian countries, Lithuania, among others). It should be noted, however, that these solutions operate in conjunction with the deposit system for bottles or cans, so the motivation for residents to use RVMs is the expectation of deposit recovery for the packaging, previously paid in the price of the product. Deposit systems are already in place in countries such as Croatia, Denmark, the Netherlands, Iceland, Finland, Germany, Norway, Sweden, Lithuania, Estonia, Slovakia and Latvia, and work is underway in another 15 countries. (Spiller, 2022). In Poland the system, under which a certain deposit will be added to the price

of a bottle or can, is due to come into force at the beginning of 2025. Customers will be able to reclaim the deposit upon returning the packaging (Wiński et al., 2023).

RMV is a device which automatically sort packaging (plastic bottles and beverage cans) and the central IT system records data about waste and rewards the user for segregation by assigning the appropriate number of points to user's account (Stronczek, Waksmundzki, 2020). "Eco-Points" are exchanged for prizes and discounts offered by business partners, as part of municipal loyalty systems or crowdfunding campaigns. To be able to use the system in a given area, it is enough to install a mobile app dedicated to the RVM. The first observations of the pilot testing of RVMs in Poland indicate a favorable attitude of Polish users towards this type of device (in the context of evaluation of technical solutions).

Preliminary assessment of the preferences and attitudes of the residents of the Malopolska and Silesian provinces allows us to conclude that from the perspective of individual users, such technical solutions seem promising (among other things, thanks to the possibility of reducing the amount of unsegregated waste and linking the devices to a bonus system, attractive to young people and young adults (up to about 26 years of age), who are rather "resistant" to traditional ways of influence).

Currently, one of the motivations for using recyclomats is the measurable gratification for the collected packaging, which would otherwise simply be thrown to traditional segregated waste bins - without any compensation. Other motivations for using such devices need to be verified through social research.

It is necessary to verify how the transition to a deposit system in Poland (e.g., for food and primary product packaging) will affect Poles' attitudes and preferences with regard to waste management and attitudes toward selective packaging collection and recycling facilities.

Features of the national waste collection and recycling system, such as the universality and general availability of waste collection outlets, stability of collection, costs for the user and the public sector, externalities (impact on the landscape and nature), etc. have a holistic impact on the quality of the functioning of the economy, society and the environment. Therefore, taking into account the potential target group of the study's participants from the Małopolska and Silesian Provinces, it is important to recognize that society as a whole can gain from the development of new, reliable, attractive, user-friendly and environmentally friendly waste collection solutions.

2. Research methodology

The study was aimed at assessing the knowledge and experiences of residents from the Małopolska and Silesian provinces related to the use of reverse vending machines (RVMs, recyclomats), which are intended to support the Comprehensive Waste Collection and Recycling System in Poland.

The subject of the study, therefore, was users' experiences and attitudes toward innovative devices (recyclomats) supporting selective waste collection.

The purpose of the survey was to obtain an answer to the question of whether the Comprehensive Waste Collection and Recycling System in Poland should be supported by innovative reverse vending machines for selective waste collecion (so-called recyclomats), what incentive programs associated with recyclomats are attractive to users, and whether such devices should be popularized - in the context of the respondents' perceptions of the possibilities and limitations of selective waste collection devices. Consequently, the following specific objectives were identified:

- comparative assessment of the societal satisfaction with currently available segregation and waste management solutions,
- assessment of social acceptability of RVMs (recyclomats) and the perceived benefits and limitations associated with their introduction in the whole country,
- comparative assessment of RVMs and other currently available waste collection solutions,
- assessment of the propensity and willingness to use RVMs - depending on their location and supporting incentives,
- evaluation of incentive programs associated with RVMs - with reference to current programs and the possibility of introducing a deposit system and philanthropic programs.

In the research we used qualitative and quantitative research methods build an in-depth picture of citizens' behavior and preferences towards selective waste collection, as well as expectations of innovative solutions to support Circular Economy. This article presents the result of the qualitative study on the evaluation of recyclomats against other methods of separate waste collection.

The qualitative research and its results described in this article were directed at identifying routines and preferences concerning selective waste collection. At the same time, RVMs and related incentive programs were evaluated. The qualitative research also aimed to recognize the experience of using recyclomats and mobile applications dedicated to these devices, and to prepare a cognitive platform for conducting quantitative research.

The research was conducted in the form of focus group interviews with residents of Malopolska province: in Krakow (FGI1) and Klucze (FGI2), and with residents of Silesia province in Zawiercie (FGI3) and Ruda Śląska (FGI4). In each group, the participants were diverse in terms of age, gender and socioeconomic position, while adhering to the condition that each group included students and people over 60 (seniors). In addition, one focus group interview (FGI5) was conducted only with a group of students in Krakow. In each group there were respondents who previously had been users of EcoTech recyclomats. The research scenario included a multimedia presentation with an explanation of the idea of RVMs, followed by a video presenting the incentive system connected to recyclomats. Supportively, a perception mapping and other heuristic techniques were used during these focus groups (Maison, 2020; Glinka, Czakon, 2021). The interviews were conducted in June 2022.

During the evaluation of the innovative solutions supporting the use of the recyclomats, a text mining technique was also used to extract data from comments and opinions of app users, available in the Google Play store and App Store.

During the research period (May-August 2022), 10 EcoTech recyclomats and dedicated ECO-wallet mobile application (as a pilot program for the project: Comprehensive Waste Collection and Recycling System in Poland) were tested in Poland These recyclomats were available in Silesia and Małopolska provinces. According to Prymon-Ryś et al. (2022) several brands or retail networks also conducted their pilot testing of RVMs i.e. Coca Cola's (Warsaw), Żabka retail network (Poznan and Warsaw), Lewiatan retail network (Włocławek), Decathlon stores (Legnica). These programs used a variety of incentive and reward programs that could be obtained for the points collected.

In the first stage of the research, we obtained information on the waste management and segregation systems used in Silesia and Małopolska provinces, we gathered respondents' opinions on recyclomats and the incentive systems currently in use, as well as suggestions for their own new solutions.

3. Research results

According to the interviewers, waste segregation is *good*, *important* and *beneficial to the environment*. The statements are dominated by positively-oriented opinions on the need or even *necessity of segregation*, which, according to respondents, is *is in high demand*. Negatively-oriented statements occur much less frequently - there are individual opinions that it is "inconvenient" or even unnecessary – which is justified by the lack of knowledge about the waste sorting and recycling processes.

In the Silesian province, the waste collection system was evaluated positively, *nothing is missing in it*. In respondents' households waste is segregated. Several interviewers claimed that in their settlements, garbage had to be thoroughly segregated. Otherwise, the garbage would not be collected by the cleaning-service providers.

The waste collection system in Małopolska is not evaluated very positively due to the high price of the services, higher than in other municipalities or provinces. However, it is worth noting that the perception of high costs is very subjective - a comparison of waste collection prices in Małopolska and Silesia provinces shows that there are no significant differences between regions.

There is a belief that *by segregating waste, residents increase their workload without any benefit*. Nevertheless, citizens generally encourage their children to sort waste. Teachers also pay attention to educational projects in this area.

A major problem for residents is the lack of space for waste separation bins. This is a practical and challenging aspect of sorting. In many individual households, containers for segregated waste require a significant amount of space to be set aside. This is a problem that occurs in both apartments and homes. Therefore, respondents note that, *not everyone segregates waste. People throw garbage into forests*. This behaviour is perceived as harmful by all focus participants.

The overall assessment of the solutions available in Poland is positive: "Despite everything, waste management in Poland is also changing. In the past, there was no segregation at all".

3.1. Evaluation of recyclers based on presentations during focus groups

Recyclomats are perceived by focus participants as a trendy, modern solutions environmental-friendly; they should be universally available, but the list of material benefits should be expanded. According to interviewers, positive aspects of RVMs include an incentive system for segregation, simplicity of the solution, positive impact on the environment, speed and automation of operation, 24/7 availability, ability to retrieve the deposit without contacting a shop assistant.

On the other hand, the disadvantages of recyclomats pointed out by focus participants include low availability of RVMs (*There is an inconvenience here, because if I have a Coke bottle with me I'll throw it in, and that's not a problem, but if I had to bring a bag of uncrushed bottles from home, it's more difficult. I wouldn't want to do so*), low popularity, large space occupied by recyclomats and possible breakdowns. Several people pointed to the high cost of purchasing/implementing and maintaining RVMs. Several seniors noted that it is a problem for the elderly to operate the recyclomats, as well as to use the app. They also noted that dropping a package into the recyclomat requires scanning a barcode, which is a hassle. *The recyclomat will accept a bottle without a barcode - but it won't charge a point* - which automatically limits the attractiveness of using RVMs. There were frequent statements that without tangible benefits, there is no point in using such devices.

The target audience for recycling solutions according to participants is basically everyone, but the most common suggestions are young people, smartphone owners who can handle the technological side of the solution, buyers of beverages in plastic bottles; but also stores and local governments.

According to respondents, interest in recyclomats depends on *the size of the city, the population and the amount of waste generated*, on environmental awareness and on the individual mobility. Thus, the aspect of the availability of recyclomats and the reluctance of users to "*walk around town with a bag of bottles*" resonates again.

According to interviewees, the best motivation for using recyclomats would be awareness of the need for selective waste collection. Several people suggested that in order to increase interest in recyclomats, the public should be made more aware of them. One person suggested something like a state law that would make segregation mandatory, thereby increasing the demand for RVMs. In general, interviewers suggested introducing a deposit system and supported this idea.

A suggestion from respondents was to educate the younger generations, and that *they [recyclomats] should be better promoted*. Suggestions for an advertising and information campaign appeared quite often - the example of a school where a RVM was installed on a pilot basis was given as an argument: *Before, the children didn't even know what a recyclomat was. Now everyone in and around the school knows*.

3.2. RVMs vs. other ways of selective waste collection

Participants in the focus interviews were asked to mention the most convenient ways of selective waste collection. Opinions varied widely. In addition, there was a divergence between convenient and eco-friendly solutions. For example, many young people consider ordinary trash cans as environmentally friendly *Why? Because they are available everywhere*", "*if there are a lot of them it is more likely that someone will not throw in the bushes*, *if I have some papers to throw away, I will not look for a container for segregated waste*. The responses of young adults shows that ease of use is the biggest advantage of *user-friendly* ways of segregation: *what is suitable for students must be easily accessible*. Older people, on the other hand, emphasize more the economic aspect: *Thrash bags are not accepted because they are not very environmentally friendly and the average cost is so high*.

The use of the perception map technique (Glinka, Czakon, 2021) made it possible to compare recyclomats with other methods of separate waste collection. Participants were asked to evaluate the following methods of waste disposal:

- K - Trash cans (available to the public, e.g., on streets, at stores).
- PZ - Containers for mixed waste - next to a residential building or inside.
- PS - Containers for segregated waste (green, yellow, blue) next to a individual family house or multi-family residential building, e.g., next to chutes or separate containers for residents.

- D - Publicly accessible containers for segregated waste so-called "dzwony" – bells.
- SK - pick-up points for recycling materials.
- R - RVMs (recyclomats).
- L - Garbage sorting plant [in Polish "lamusownia", KSZOK].
- W - Thrash bags in different colors (yellow, green, blue).

The respondents' task was to mark on the map the evaluation of each way of separating and collecting recyclable waste (plastic, metal, glass) according to the following criteria:

- A1. Environmentally friendly/Not environmentally friendly.
- A2. Very user-friendly/Little user-friendly.

Map A (Figure 1) shows the summary of all responses concerning recyclomats. A size of circles is determined by number of repeated ratings.

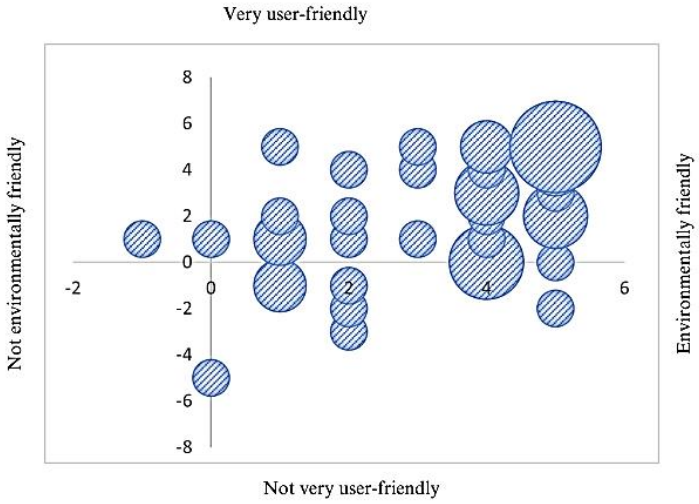

Figure 1. Perception map (A) for recyclomats - summary of findings of focus participants, [rating scale from -5 to +5; circle size determined by number of repeated ratings].

Source: own research – using software available at www.perceptualmaps.com

According to the combined criteria in this group, recyclomats are rated as both environmentally friendly and user-friendly (see Figure 1), as the overwhelming number of ratings fall within the range of positive ratings.

With SPSS software, an analysis of the ratings of the focus participants was carried out, creating scatter plots. However, when compared with other ways of waste collection, recyclomats (Rx, Ry) do not dominate in areas of positive perception. By far the best perceived are containers for segregated waste (PSx, PSy).

Compared to other waste sorting and disposal methods, recyclomats according to environmental friendliness are rated quite positively - and better than other solutions (see fig. 2) - Rx-median = 4.0. Containers for segregated waste (PSy) are rated highest here in terms of "user friendliness". The analysis conducted using the multidimensional scaling method confirms the convergence of the survey participants' ratings.

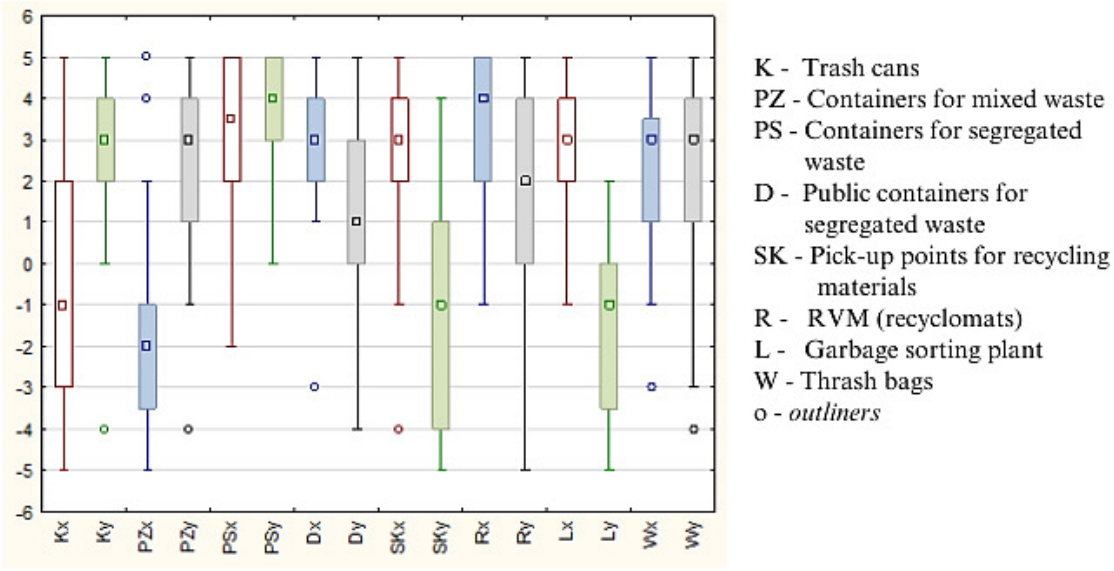

Figure 2. Box-and-whisker chart for the variables environmental friendliness (x) and user friendliness (y). Source: own research.

The following factors evaluated were the eco-friendliness of the studied solutions and the cost of use, see Map B (fig. 3) with criteria:

- B1. Environmentally friendly/Not environmentally friendly.
- B2. High cost of sorting for the user/Low cost of sorting for the user (ie., cost of waste collection, cost of trash bags, cost of getting to the bin, opportunity cost of time, etc.).

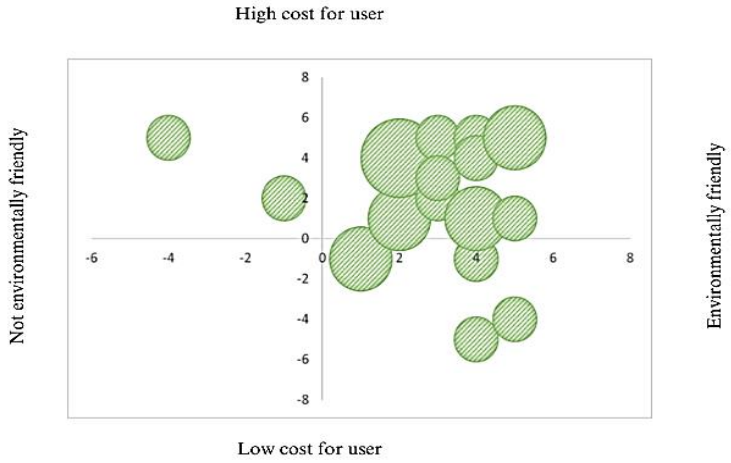

Figure 3. Perception map (B) for recyclomats - summary of findings of focus participants, [rating scale from -5 to +5; circle size determined by number of repeated ratings].

Source: own research – using software available at www.perceptualmaps.com

Again, the evaluation of RVMs' environmental friendliness was positive, while in terms of cost, recyclomats were rated as expensive solutions; respondents' evaluations were located in the 1st quadrant of the map: positive – high (see fig. 3).

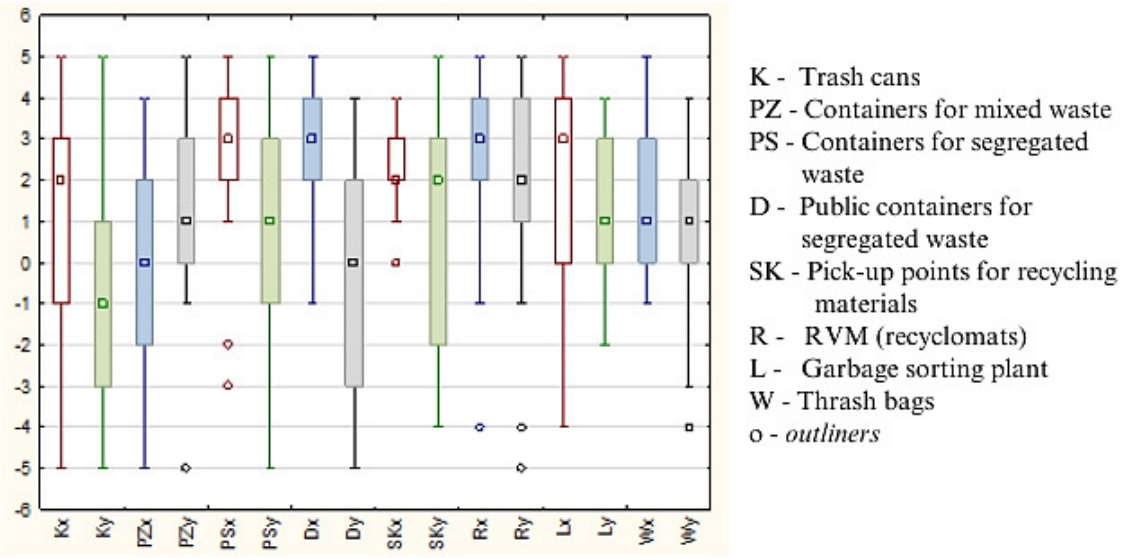

Figure 4. Box-and-whisker chart for the variables environmental friendliness (x) and cost (y).

Source: own research.

Overall, however, most solutions tend to be rated lower (see Figure 4). In any case, the median does not exceed the value of 3. As for the variables PSx, PSy (containers for segregated waste), Rx and Ry (RVMs), they are rated quite well in comparison, although there are a few outlier observations. Lx (garbage sorting plant) and Dx (publicly accessible containers for segregated waste) in terms of environmental friendliness also received good ratings.

The last perceptual map C (as seen on fig. 5) covered the following criteria:

– C1. Environmentally friendly/Not environmentally friendly.
– C2. Suitable for me form of sorting/Not suitable for me form of sorting.

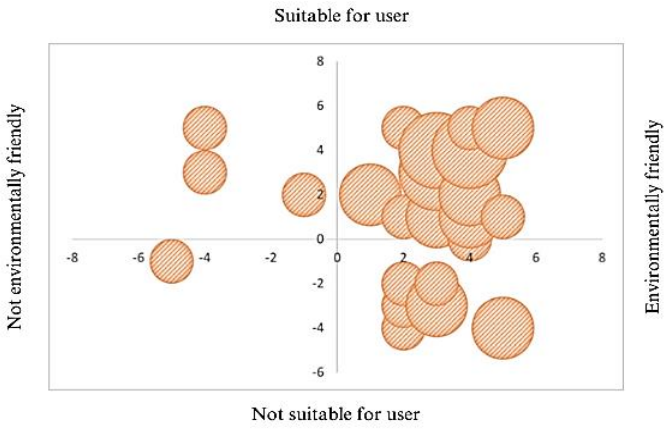

Figure 5. Perception map (C) for recyclomats - summary of findings of focus participants, [rating scale from -5 to +5; circle size determined by number of repeated ratings].

Source: own research – using software available at www.perceptualmaps.com

As shown in Figure 5, the ratings of the focus group participants are less clear and the range of ratings is wider. There were more negative responses – some respondents felt that recyclomats were unsuitable for them and therefore less environmentally friendly. At the same

time, there were more very positive statements (ratings of 4 and 5), which ultimately confirmed similar results to the analysis of Map A (see Figure 6).

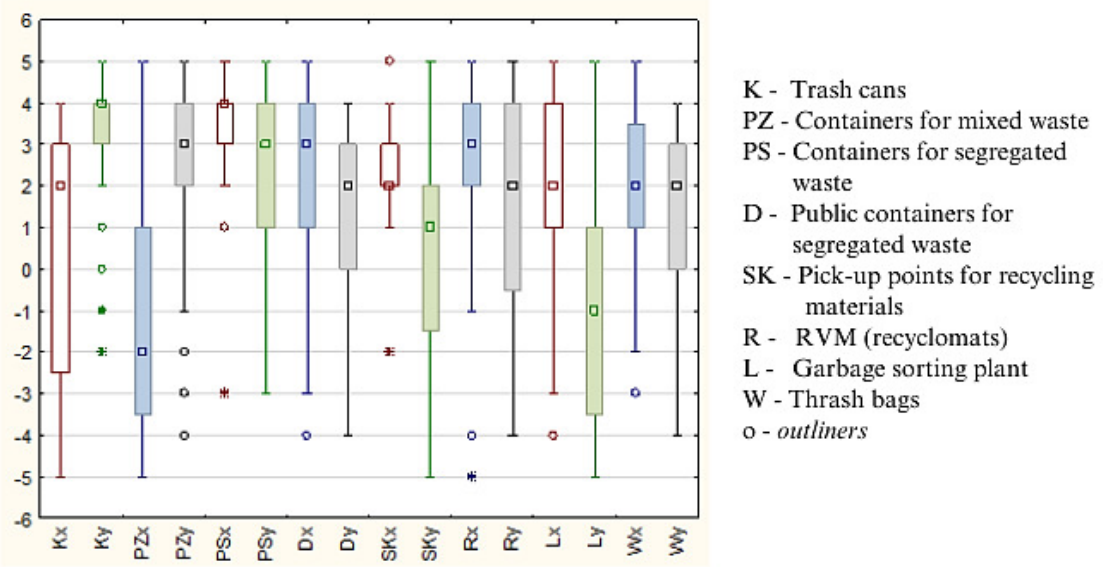

Figure 6. Box-and-whisker chart for the variables environmental friendliness (x) and suitability for user (y). Source: own research.

In this part of the study, the responses obtained give a similar picture to the results of the perception map A. The best ratings were given to the PSx (containers for segregated waste) and Ky (trash cans) variables (with a few outliers and extreme responses). The high ratings for regular trash cans confirm the results of the focus interviews, where particularly young respondents indicated ordinary trash cans as the most user-friendly. Recyclomats in this evaluation were rated quite positively (Ry-median = 2.0).

4. Conclusions

Improving waste management strategies through more collaborative participation of consumers and the introduction of innovative tools is of increasing concern to researchers and policy makers. Obtained results, combined with the outcomes of our quantitative research (Prymon-Ryś et al., 2022), indicate the extent to which recyclomats can support the implementation of a deposit system in Poland. The presented research is innovative not only because of the technical novelty of the described devices, but also because of the relevance of the use of RVMs in selective waste collection systems.

Waste sorting, according to respondents, is both required and beneficial to the environment. Waste is separated in the majority of Małopolska and Silesia households. Respondents indicate that they sort rubbish in accordance with the guidelines established by the municipality in which they live. Those who do not follow standard sorting criteria explain this mostly through

practical factors: a lack of segregation conditions in the household and a lack of separated waste bins in the region. Young people (students) prefer easily accessible ways to dispose of trash - whether they use selective waste collection or simple trash cans placed by the sidewalk.

For the majority of focus participants, the most environmentally friendly form of trash selection was the containers for segregated waste. Similarly to recyclomats, they were also described as user friendly. Negative eco-friendliness ratings were given to containers for mixed waste. In terms of cost to the user, the RVMs received the highest ratings, although, obviously, interviewers did not refer to the cost of installing the devices or servicing them. Recyclomats are the only devices that provide tangible gratification for disposed waste. Interestingly, ordinary trash cans were indicated by respondents as the most convenient form of garbage disposal. Also, containers for mixed waste and containers for segregated waste received high scores. The small number of recyclomats, long distances to these facilities and the need to install a mobile app contributed to RVMs' lower ratings.

According to respondents, increasing residents' willingness to segregate requires the following incentives: material benefits (e.g., free garbage containers or garbage bags) and financial benefits (deposit system), more solutions to facilitate segregation and publicly available equipment/containers, financial penalties for those who evade segregation and consistent enforcement of selective collection, and supporting citizens' awareness and knowledge through educational programs and information campaigns. While the study results revealed favourable opinions regarding separate waste collection, respondents claimed that they would be more likely to do so if they received tangible benefits, such as discounts or financial bonuses, and if it was cheaper and simpler.

Recyclomats, as devices supporting the waste collection and recycling system, have a very positive image among those who have had the opportunity to get to know the idea of their operation. At the same time, however, not all respondents who rated the RVMs positively considered them suitable or necessary in their local community.

Recyclomats are seen as easy to use, encourage separation and are environmentally friendly. Respondents indicated that the availability of these devices and their ease of use were the most important factors in persuading them to use recyclomats. An analysis of the following responses shows that the possibility of receiving cash is more attractive to respondents than other material rewards. This is indeed an expected attitude, in the context of the introduction of a deposit system in Poland. Consequently, the spread of recyclomats will require them to be adjusted to pay a deposit for disposed beverage packaging.

Although these devices are unlikely to become the primary method of waste disposal, given the interest in gamification-based programs (Santti et al., 2020; Hsu, Chen, 2021), it is crucial to note that recyclomats may play an important role in the environmental education of children and young people.

Surveys show that residents are favorably disposed to recyclomats as devices that could support the Comprehensive Waste Collection and Recycling System.

Features of the national waste collection and recycling system, such as the universality and general availability of waste collection sites, stability of collection, costs for the user and the public sector, externalities (impact on the landscape and nature), etc. have a holistic impact on the quality of the functioning of the economy, society and the environment. Therefore, regardless the sample of the survey participants from the Małopolska and Silesian provinces, it can be suggested that the whole society can gain from the development of new, reliable, attractive, user-friendly and environmentally friendly waste collection solutions.

As with any innovative solution, reverse vending machines require a number of improvements to be a significant alternative to "traditional" means of selective waste collection. However, the basic condition here is the widespread availability of these devices. A cost-benefit analysis (Cygler, Dubel, 2022) and an analysis of the financial effectiveness of the investment associated with the expansion of the network of reverse vending machines should answer the question of the economic sense of such an investment from a national perspective. However, based on the research conducted, it can be concluded that there is a "green light" for such solutions.

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IMPROVING THE COMPETENCIES OF MANAGERS IN THE MEDICAL DEVICES INDUSTRY FROM AN INTERNATIONAL PERSPECTIVE

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Purpose: The subject of the presented study concerns the improvement of the competencies of managers in the medical devices industry. The presented research aimed to identify and evaluate the improvement process and forms of improvement used in the analyzed enterprises.
Design/methodology/approach: Empirical research was conducted using the diagnostic survey method and survey technique in 2018-2020. The research covered 130 managers representing various medical device industry companies from four selected European countries, i.e., Germany, Great Britain, France, and Poland.
Findings: The analysis of the research results showed that 71% of organizations care about improving the competencies of their management staff. The most popular forms of manager development were learning by practice, short training, and mentoring. Most of the surveyed managers felt the need for development.
Research limitations/implications: The research was limited to four selected European countries, which does not allow the generalization of the results to the entire population. In the future, more in-depth and extensive research on competency development among managers in the innovative medical device industry will be worthwhile.
Practical implications: The analysis of the results of the conducted research makes it possible to develop recommendations for the management and owners of enterprises in the medical device industry regarding the pragmatics of improving managerial competencies.
Originality/value: The research findings provide insights into specific trends related to improving the competencies of managers in the medical device industry.

Keywords: competence development, improvement methods, managers, medical devices industry.

Category of the paper: Research paper.

1. Introduction

Contemporary organizations operate in an environment of constant change, influenced by many factors (Hanelt et al., 2020; Aldrich, 2008; Khaw et al., 2022). Among these, the most significant are the processes of internationalization, demographic shifts (such as aging populations and the emergence of multicultural societies), capital flow, unprecedented technological advancements, and extraordinary natural events like floods, earthquakes, tornadoes, and the Covid-19 virus pandemic (Centobelli et al., 2021; Cavus et al., 2021; Brammer, Clark, 2020). These conditions bring both benefits and challenges. Therefore, they necessitate adaptability and continuous exploration and implementation of new solutions to facilitate development, efficient operations, and achieving set objectives effectively.

Within organized life, the highest expectations are placed upon the management cadre. Managers are responsible for efficiently utilizing an organization's resources, including its most valuable asset – its workforce. The outcomes and measurable results of managerial work depend on their skills, knowledge, attitudes, and experience (Shet, Pereira, 2021). Consequently, these factors are primary drivers of a manager's effectiveness, indirectly impacting the organization's overall success (Anwar, Abdullah, 2021).

In the face of the evolving conditions under which businesses operate, the competencies of managers should be continuously developed. Contemporary literature emphasizes that efforts to enhance employee capabilities should be strategically planned within organizational activities (Hamadamin, Atan, 2019) and should have a dual focus: 1) addressing the needs of the specific organizational unit and 2) responding to the needs expressed by employees (Tokarska, 2018). Professional development serves the interests of both employees and employers. Through action, an employee, especially a manager, strengthens their position within their current role and enhances their market value. Employers, on the other hand, with a skilled workforce, elevate the potential of the entire organization (Dachner et al., 2019).

The subject matter of the presented research revolves around improving the competencies of managers. Professional development can be defined as deliberate and planned actions to acquire new competencies that will enable the effective execution of future tasks (Walkowiak, 2007). The improvement process often occurs without a formal plan, naturally focusing on the learner and the learning processes (Rakowska, Sitko-Lutek, 2000). Contemporary literature underscores that continuous improvement requires a manager's open-mindedness toward change and motivation for constant learning and self-improvement (Rytelewska, 2013; Blanchard, Thacker, 2017).

Employees' and managers' improvement and professional development yield numerous benefits for organizations and individuals in enhancing their skills (Mello, 2019). Among the most significant advantages are increased integration with the organization, enhanced motivation and job satisfaction, improved engagement, better communication, reduced

conflicts, increased trust, improved efficiency, organizational adaptability to changing markets, enhanced innovation, competitiveness, and an improved corporate image (Białasiewicz, 2011; Zbiegień-Maciąg, 2006; Hamadamin, Atan, 2019; Azeem et al., 2021).

The focus of this article centers on enhancing the competencies of managers within the medical devices industry. This area of the economy was chosen due to its unique characteristics, characterized by high levels of innovation, developmental potential, and an international scope. Often referred to as industries that "support" the healthcare system, the medical device and pharmaceutical sectors play a pivotal role in safeguarding public health. The effectiveness of achieving objectives related to public health protection hinges on using medical devices encompassing a diverse array of products crucial for diagnosing and treating patients (Feliczek, 2016).

The medical device industry, also known as the medical technology sector, encompasses entities and their activities associated with the production and trade of medical devices. A medical device, by definition, meets the criteria set forth by the European Commission Directives (for European countries). These encompass a broad spectrum of instruments, apparatus, devices, implants, in vitro reagents, calibrators, software, and similar items manufactured for individual use or in combination with others to diagnose, prevent, monitor, treat, or alleviate the symptoms of diseases (World Health Organization, 2003). These include well-known everyday items like bandages, syringes, or latex gloves, as well as more innovative solutions such as diagnostic tests, adaptive eyewear, technologically advanced scanners, monitoring devices, ultrasounds, life support machines, implantation devices, and so forth (Mark, 2015).

The medical devices industry is often described as diverse and innovative, with a trajectory for further growth and increased significance in the future (Ramakrishna et al., 2015). Key factors driving the industry's development include advancements in medicine, the rise in chronic diseases, demographic aging, and new medical conditions. These determinants and increasing societal affluence result in heightened demand for healthcare services, leading to escalated healthcare costs (Mark, 2015). Consequently, there is a need to explore avenues for cost reduction while optimizing clinical value, which involves enhancing patient diagnosis, treatment, and rehabilitation through efficient utilization of advanced technologies. This categorizes the medical devices industry as high-tech, witnessing particularly vigorous growth in countries with highly industrialized, innovative economies and high per capita national income (Gacek, 2013).

The medical devices industry is not limited to production or commercial activities alone. Its innovation and technological advancement are closely linked to extensive research and scientific endeavors. The tangible products of this industry often stem from years of scientific research, frequently carried out in active collaboration with the academic and scientific communities. This robust scientific foundation necessitates the creation of highly specialized and well-remunerated positions within the industry and its allied sectors.

Despite its positive socio-economic impact, the medical devices industry is often challenging. The sector comprises significant initial investments, extensive scientific involvement, and a broad spectrum of potential customers, including public entities, private organizations, and individual clients. Consequently, many companies need help to meet market demands, shelving numerous ideas or failing to achieve the anticipated return on investment. Furthermore, stringent regulatory requirements pose a significant barrier to market entry, making the medical device sector one of the most heavily regulated industries. Additionally, variations in legislation across different countries impede the smooth international trade of products (Eatock et al., 2009).

2. Methods

The presented article is based on the quantitative approach the research aimed to identify and evaluate the improvement process and forms used in the analyzed enterprises.

After analyzing the literature on the subject and the reports and materials provided by organizations related to the medical devices industry, the research questionnaire was designed.

The presented research is part of a broader research project on the competencies of managers in the medical devices industry and diversity management in the companies they represent. The amount of the questionnaire devoted to improving managerial competencies contained twelve substantive questions. They were concerned about the applied practices of managerial competencies in the analyzed organizations, forms of improvement and their assessment by participants, and the needs of respondents in the field of competence improvement. Quantitative research was conducted in English, in direct contact. Only the survey of managers of Polish nationality was shown in their native language. The questionnaire was translated from Polish into English and backward into Polish to ensure conceptual equivalence and transparency.

Empirical research was conducted in 2018-2020 using the diagnostic survey method with the survey technique. The study covered the management staff of enterprises in the medical devices industry. These were mainly high- and middle-level managers, primarily small and medium-sized enterprises, due to the sector's structure, in which approx. 95% are small and medium-sized entities. It is assumed that the design of the surveyed sample in terms of gender, age, and nationality reflected the sector's structure.

The research was conducted in selected European countries, i.e., Germany, France, Great Britain, and Poland. Apart from Poland, countries with high activity in the medical devices industry were selected for the study. Germany, France, and Great Britain are among the six countries with the most significant number of registered business entities dealing with medical devices and also have the highest percentage of people employed in the industry in Europe.

The selection of the sample was intentional. It is estimated that Europe has approximately twenty-six thousand companies in the industry. The study covered 130 managers, about 0.5% of the population.

The survey was conducted among 130 managers from 130 different organizations. Among the respondents, 21% work in micro-enterprises, 46% in small enterprises, 25% in medium enterprises, and 8% in large enterprises. At the same time, 71% of these enterprises operate in the global arena, 18% in the European theater, and 11% in the national stadium. The structure of origin of the surveyed organizations is as follows: 32% are registered in Germany, 19% in Great Britain, 26% in France, 18% in Poland, and 5% in other countries.

Among the surveyed managers, 11% are at a low management level, 67% at a medium or high level, 18% work under a managerial contract, and 5% did not answer. The study involved 38 women and 91 men. Among them, 19% represent the Baby Boomers generation, 43% represent the X generation, and 38% represent the Y generation.

The conducted research provided empirical material that was subjected to statistical analysis. The obtained data were entered into a database established in an Excel spreadsheet. Relationships between qualitative variables were assessed using the Chi-square test of independence. The analyses were performed at the significance level of $\alpha = 0.05$. Respondents expressed their opinions on diversity management using a 5-point scale, where 1 was the lowest value, and 5 was the highest. For comparative analyses, items for which respondents chose answers at level 4 or 5 were considered.

3. Results

The questionnaire began with a question about whether the competencies of managers in the analyzed medical product industry companies were being improved. In most surveyed organizations (71%), such actions are being carried out, while in 21%, they are not.

It was also interesting whether competencies related to diversity management were being improved in the companies represented by the respondents. It turned out that only 1/3 of the surveyed organizations develop this type of competencies, and 45% of them still need to. Every fifth respondent had no knowledge of this subject.

When characterizing the process of improving competencies, it should be stated that in half of the analyzed enterprises, it takes place on an ad hoc basis (from time to time). In 28% of organizations, improvement occurs systematically (regularly), while 23% of respondents believe that competencies are not improved at all in their organizations.

The next issue analyzed was the training needs in the analyzed organizations. Most respondents (58%) admitted that the companies they represent analyze their improvement needs. Every third respondent indicated that such practices need to be implemented in their

organizations. Similar results were achieved regarding answers to the question about setting improvement goals. In 56% of the analyzed enterprises, improvement goals are set, while in 1/3 of the organizations, no such activities are carried out.

The next question concerned the nature of improvement activities in the analyzed enterprises. In the majority of the surveyed enterprises (57%), individual actions are carried out to improve competencies, while in 32% of the surveyed companies - addressed to all employees of the organization. Every tenth respondent stated that in the company he represented, improvement activities were organized only for subunits, e.g., individual departments of the company.

The respondents were also asked to indicate what forms of training they used. The most significant number of respondents (63%) said they used learning by practice. In terms of frequency of use, the following forms of competency improvement were ranked next: conferences/seminars (59%), short training courses (53%), product training courses (50%), self-development (46%) and reading books and magazines (45%). The least popular among the respondents turned out to be other forms of long-term training, e.g., MBA studies (14%), foreign internships (10%), and other (including webinars, conversations with experts, workshops, development in the field of ISO implementation and quality management – 5%). The results regarding the forms of improvement used by respondents are presented in Figure 1.

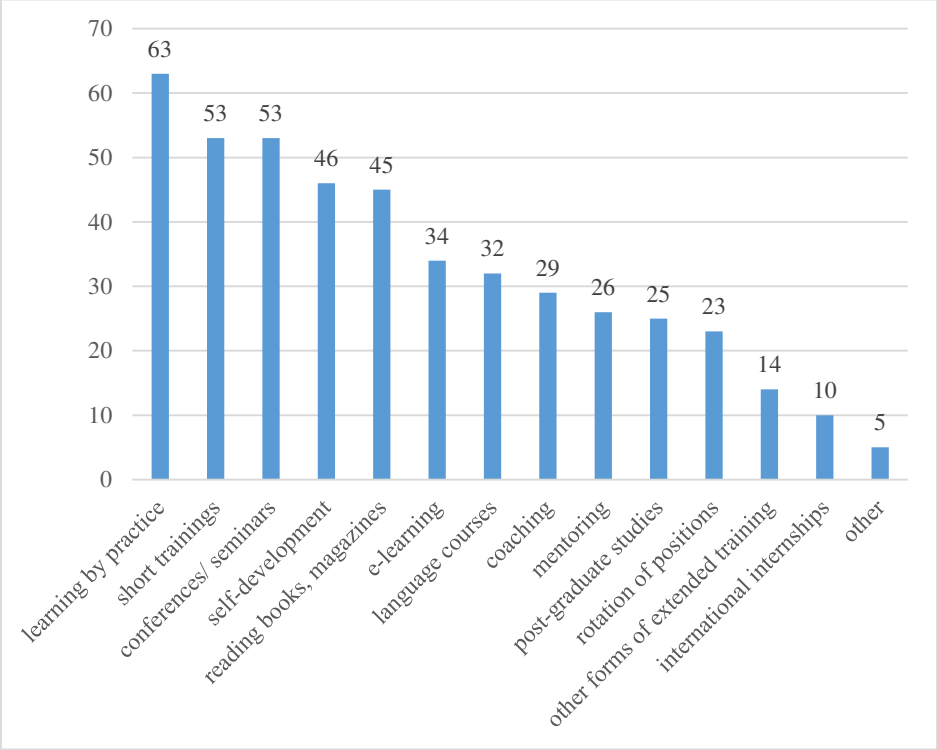

Figure 1. Forms of improvement used by respondents (%).

Source: own elaboration based on research results.

When asked to assess the effectiveness of forms of education (Figure 2), respondents rated learning by practice the highest (average rating 4.4 on a 5-point scale). The following places were taken: short training, self-development and mentoring (with a rating of 3.9), coaching (3.8), and conferences/seminars (3.7). The following were rated slightly worse: other forms of long training, e.g., MBA studies (3.6), reading books and magazines (3.6), language courses (3.6), postgraduate studies (3.6), and foreign internships (3.6). 5). The least effective were job rotation (3.4) and e-learning (3.4).

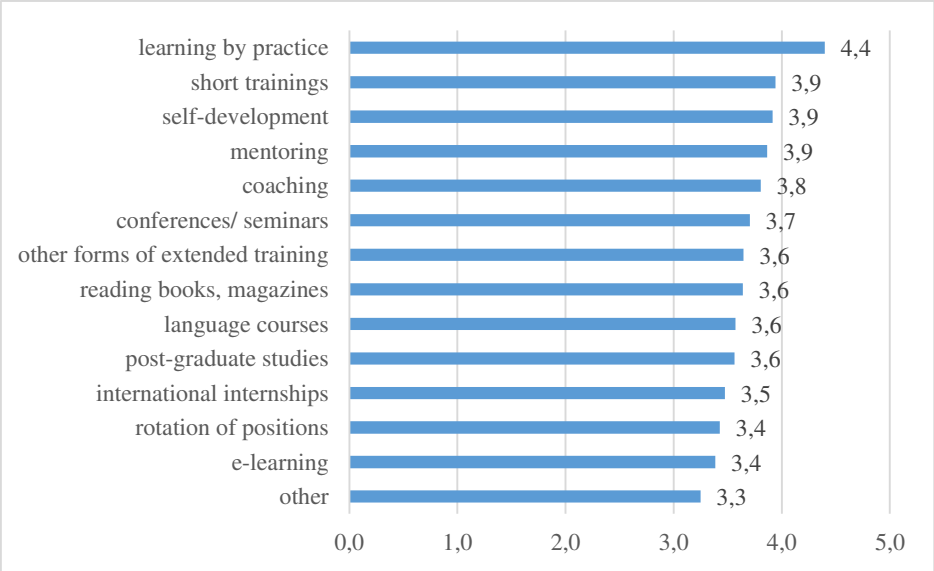

Figure 2. Effectiveness of the analyzed forms of improvement in the opinion of respondents (on a scale from 1 to 5, 1 is the lowest and 5 is the highest).

Source: own elaboration based on research results.

The analysis conducted regarding the evaluation of competency development methods by managers from different countries revealed that the assessments of managers from Poland, Germany, and the United Kingdom are the same. They considered the most effective training methods to be 1) learning by practice, 2) short-term training, and 3) coaching. However, while agreeing on coaching, the French value 1) postgraduate studies and 2) job rotation much more highly than learning in action or short-term training (Table 1).

Table 1.
The evaluation of competency development methods by managers from different countries

Forms of improvement	Poland		Germany		Great Britain		France	
	Av.	Rank	Av.	Rank	Av.	Rank	Av.	Rank
Learning by practice	4.52	1	4.39	1	4.39	1	3.66	8
Short training	4.17	2	4.02	2	4.02	2	3.59	9
Coaching	4.09	3	4	3	4	3	3.91	3
Self-development	4	4	3.93	4	3.93	4	3.75	6
Conferences/ seminars	3.87	5	3.89	6	3.89	6	3.26	13
Mentoring	3.83	6	3.89	5	3.89	5	3.56	10
Reading books, magazines	3.78	7	3.7	7	3.7	7	3.67	7
Language courses	3.74	8	3.5	8	3.5	9	3.56	11
Other forms of extended training	3.7	9	3.47	9	3.47	10	3.78	5

Cont. table 1.

Post-graduate studies	3.48	10	3.36	12	3.61	8	4.41	1
Rotation of positions	3.36	11	3.19	13	3.19	13	3.97	2
E-learning	3.3	12	3.45	10	3.45	11	3.88	4
International internships	3.23	13	3.37	11	3.37	12	3.5	12

Note. On a scale of 1 to 5, 1 is the lowest and five is the highest.

Source: own elaboration based on research results.

The surveyed managers were also asked whether an assessment of competency development is carried out in the companies they represent, including an evaluation of content, format, and the degree of achieving set goals. More than half (52%) of the respondents answered affirmatively to this question, while one-third of those surveyed responded negatively. Among the respondents, 15% admitted that they did not have knowledge of this matter.

Figure 3. Development needs felt by the respondents (on a scale from 1 to 5, 1 is the lowest, and five is the highest).

Source: own elaboration based on research results.

The block of issues related to the improvement of managerial competencies was closed with a question regarding the development needs felt by the respondents (Figure 3). It can be concluded that managers feel the need for development, mainly in terms of personal competencies and knowledge (average score of 3.7) and slightly less often in interpersonal competencies (3.3). According to respondents, issues related to diversity management attracted the slightest interest. Thus, the need for development in diversity management competencies and attitudes was assessed at 2.9, and diversity management practices at 2.8.

4. Discussion

The analysis of the research results conducted among managers of the medical devices industry showed that 71% of organizations care about improving the competencies of their management staff. This means that more than 2/3 of enterprises recognize the need for manager development and try to meet this need. Therefore, one in three respondents admits that their organizations need to develop managers or learn about it. There are two ways to try to explain this. Managers responding negatively may have included employees of micro or small enterprises in which the employee development strategy needs to be systematized. They often need HR departments or individuals responsible for HR matters or human capital development. The second explanation assumes that managers are left out of the development process. The medical devices industry is a highly specialized, modern industry with strong ties to science. In many companies, however, great emphasis is placed on developing employees directly responsible for creating products and services and sales and marketing department employees who must successfully present these products to customers. Often, managers, the so-called generalists who are not directly related to products or work with clients, are neglected in developing their competencies or continuing their education "on their own".

The results of the presented research confirm the literature's findings regarding the most popular forms of manager development (Szewczyk, 2018; Sitko-Lutek, Jakubiak, 2020). According to the respondents, learning by practice, short training, mentoring, and coaching were the most effective. Therefore, the claim that job rotation is one of the most effective forms of improvement (Szewczyk, 2018) has been refuted by this research.

The research showed that surveyed managers felt the need for development, which confirmed the research results by other authors (Frankowska, Głowacz, 2011; Sitko-Lutek, Jakubiak, 2020).

Only 28% of the respondents stated that managerial competencies in their organizations are regularly improved. In companies where managerial competencies are enhanced on an ad hoc basis, it is recommended to verify whether the indicated frequency is sufficient for the managerial staff's effective and efficient performance of tasks (Serafin, 2011). Similarly, it is worth examining the training needs assessment process, as research shows it is absent in every third company. As indicated in the relevant literature, the effectiveness of the improvement process can be ensured through a more systematic approach to this issue (Hamadamin, Atan, 2019; Frank et al., 2018).

5. Summary

One of the most valuable assets entrusted to managers is their workforce, the people working for the organization. Therefore, in managerial practice, new solutions are constantly sought to maximize the utilization of employees' potential to stimulate their activity, engagement, and satisfaction with their tasks. However, for the managerial staff to be able to support the personnel in their development, they should continuously enhance their competencies. This article focused on improving managers' competencies in the medical device industry. This industry effectively operates in the current economic environment, and its products and services support national healthcare systems.

The presented research was limited to four selected European countries, which only allows the generalization of the results to some of the population. However, the research findings provide insights into specific trends related to improving the competencies of managers in the medical device industry. They may also serve as a basis for future, more in-depth, and extensive research on competency development among managers in the innovative medical device industry.

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FORMS OF COOPERATION AIMED AT IMPLEMENT SUSTAINABLE DEVELOPMENT IN URBAN AREAS

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Purpose: The aim of this paper is to identify opportunities for cooperation and to show the role it plays in the context of sustainable development in urban areas.
Design/methodology/approach: Based on a review of the available literature and the current legislation, the paper discusses the basic concepts of sustainable urban development and addresses the key objectives of cohesion policy in this regard. Thanks to the information made available in the EU websites, the European Urban Initiative, a portal providing solutions aimed at promoting cooperation between cities and supporting them in the implementation of sustainable development measures, has been characterised. Using the case study method, a detailed description/analysis of three selected projects (implemented as a response to challenges of a local nature and in line with the objectives of cohesion policy) was carried out. The projects have been recognised as innovative and easily replicable by other entities.
Findings: The deliberations presented in this paper have made it possible to point out opportunities for cooperation, both between cities and partnerships within them. In this respect, particular emphasis has also been placed on the benefits of cooperation in developing solutions to the challenges of the local environment.
Research limitations/implications: The study is qualitative in nature. Among the main limitations, it is worth mentioning the shortcomings of the projects' documentation used in the case study. It should also be assumed that the next study in this area will be of a quantitative nature, where the interrelation between the use of territorial instruments and the degree of implementation of strategic objectives will be verified.
Social implications: The contents discussed below prove the validity of disseminating the principles of sustainable development in urban areas, both from the point of view of developing the various aspects of economic life and of involving residents in this process. At this point, it is also worth referring to the solutions indicated in the case studies, which have been introduced to meet the needs of the local community.
Originality/value: The paper presents the cities' possible options of implementing innovative solutions in the field of sustainable development. In this regard, digital platforms were pointed out, where relevant knowledge is gathered and disseminated, including know-how.

Keywords: Sustainable urban development, partnership, European Union.

Category of the paper: Case study, literature review.

1. Introduction

On the basis of legal regulations currently in force, available scientific literature as well as strategic documents relating to local development, it can be concluded that the issue of strategic urban development is being gradually developed in each of the mentioned fields. Local authorities, facing the challenges of today's environment, have to meet the ever-increasing expectations of all the involved entities, including not only the European Union, but also other local authorities and, above all, the local community; i.e., the main recipients of public services. Urban development affects every sphere of economic life. Undoubtedly, it should be thought of as improving accessibility to and quality of provided services, which in effect increases the attractiveness and competitiveness of cities against other entities. As shown by the hitherto practice of local government units, initiating cooperation between cities turns out to be particularly effective since it results in a constructive interaction producing beneficial effects to all the participants.

This cooperation is an aspect particularly emphasised in the field of sustainable urban development, where it can take place at local, regional or international level. What's more, it does not have to be limited to local and regional authorities, but can also involve entities with a completely different forms of activities, for example: private companies, universities, social organisations, etc. The cooperation brings many benefits, not least of which is the innovative approach to working out and implementing the solutions.

The issue of urban development, including the integration of the governance process and the territories under the administration of local authorities, is a current topic of deliberations across the entire European Union. This study addresses the issue of sustainable development of the aforementioned areas. In this regard, the objectives of cohesion policy are particularly highlighted and the role of the European Union in the dissemination of innovative urban projects is emphasised. The aim of this paper was to point out opportunities for cooperation and to show the role it plays in the context of sustainable development in urban areas.

2. Literature Review

2.1. Sustainable Urban Development (SUD) in the context of cohesion policy

According to the European Commission, urban development takes place in many different spheres, encompassing environment, economy, society and culture. As these areas are being improved simultaneously, achieving success in the development of a city as a whole requires the implementation of an integrated approach. For example, processes that aim to improve the physical functioning of cities, through infrastructure development, must interact with other

areas. Thus of key importance in this respect is the well-established cooperation that takes place at every level of economic life and occurs between citizens, businesses and public authorities. It should be mentioned that this way of working responds to the challenges cities are currently facing, and this is related to, among other things, the transformation from a linear to a circular economy, the development of the digital transformation, the demographic changes brought about by the influx of migrants in individual countries, and also the economic changes caused by fluctuations in the labour market and the development of society (European Commission).

In this context, it is worth pointing out the role of cohesion policy, which sets out the European Union's investment guidelines. Its primary task is to ensure that the aforementioned digital and environmental transformation takes place in an equitable manner. The time horizon of the current guidelines covers a period from 2021 to 2027. Urban development also has its place within these endeavours and is being implemented in line with the objective to bring 'Europe Closer to Citizens.' Cohesion policy aims at supporting development strategies at a territorial level, that is at the level of cities and local communities, and at the same time indicating their potential for development. It specifies the investments which are to be effectuating projects previously defined in strategic documents. The strategy of sustainable urban development requires collective participation and the implementation of integrated actions relevant to the needs of the designated territories. In practice, these strategies help to achieve sustainable development goals in the local context (European Commission, 2022).

Local development is seen here as a complex process of managing changes, based on the cooperation of all stakeholders aiming to improve and expand public services at community level. It enables participation in defining and verifying specific tasks and, at a later stage, also evaluating the results resulting from these tasks (Brasili, 2011).

As already observed, the international context for considering issues related to sustainable urban development is grounded in the strategic assumptions developed at EU level. It ought to be noted that it is the result of input from all levels of public authority; i.e., from the international, to the national, regional and ultimately local. Particularly emphasised in this approach is the role of the public authority at the national level, the one which is responsible for shaping national policies. It serves as a bridge between entities, assumptions and instruments of an international nature and the units of a lower level; i.e., those directly involved to the implementation of assumptions in urban areas (Handbook of Sustainable Urban Development Strategies).

Tasks aimed at achieving sustainable urban development are by definition striving for social and economic growth that does not harm the environment and maintains a balance between the local community and resources. Achieving this balance shows how the integration of citizens' actions and the involvement of the scientific community brings positive results. It is an added value that distinguishes the indicated approach to urban development from the classical approach to sustainable development. Challenges posed by urban environment mean that cities are subject to constant and successive changes. Thus, planning plays here an important role.

In practice, it is regarded as a process for presenting an entity's vision in the form of priorities. Well-worked out, detailed development guidelines can lead to attracting new investors and initiating additional investment, which contributes to the attractiveness of cities. From this perspective, planning can also be seen as participatory management (Rasoolimanesh et al., 2011).

Many approaches to the issue of sustainable urban development can be found in the literature. But whatever the interpretation, the fact that it is tackled in several urban systems at the same time; i.e., environmental, economic and social, is considered a common feature (Zhang et al., 2011). T, Dixon and M. Eames perceive it as a development for the sustainable improvement of the social and ecological condition of cities (Dixon, Eames, 2014). According to A. Abu Bakar and K. Cheen, sustainable urban development takes place at the environmental, social, economic, cultural and technological levels. The authors also emphasise the aspect of housing, which in their opinion can be considered sustainable when each resident has their own dwelling, which is an expression of self-reliance and social cohesion (Abu Bakar, Cheen, 2013). According to the BEQUEST protocol, the objective of sustainable urban development is to improve the living conditions of the residents, especially as the urban population continues to expand (Deakin et al., 2007). It is pointed out that the measures implemented in this field should correspond to top-down standards, which in practice facilitate the evaluation of sustainable urban development (Deakin, Reid, 2014). D. Mazutis and L. Sweet emphasise that all transformations towards sustainable urban development are the result of direct involvement of local communities in self-initiated projects, so-called social innovations. Among the barriers to the implementation of accepted assumptions, they see a spectrum of interdependent reactions; i.e., institutional, concerning standardisation, team and individual responses (Mazutis, Sweet, 2022). The concept of sustainable urban development seeks to even out disparities between the aforementioned areas, which become sustainable when they are characterised by (Amoushahi et al., 2022):

- stable and competitive economy guaranteeing a high quality of life for residents;
- promotion and dissemination of measures to protect the environment and reduce the consumption of its resources;
- applying solutions to minimise greenhouse gas emissions;
- working towards eradicating poverty and social inequality.

Achieving the aforementioned balance, inter alia, by promoting the participation of different groups of stakeholders in the development planning process, increases social inclusion in urban areas (Rasoolimanesh et al., 2012).

Given the importance of sustainable urban development and its consequent influence on the shape of the local, national and international economy, the 2014-2020 Cohesion Policy has defined regulations to ensure its implementation in each Member State. It was decided that the implementation of the strategic objectives follows an integrated approach based on territorial investment; i.e., integrated territorial investment (ITI) and community-led local development

(CLLD). These tools make it possible to combine the financial aspect (eligibility for various funds) with the social aspect (local community involvement). It should be noted that the objectives of the current cohesion policy, for the years 2021-2027, are exactly the same as in the previous period, with an increase of the minimum amount of funds allocated for these projects from the European Regional Development Fund (ERDR) (Pertoldi, Busti, 2020). In addition, the range of available tools has been expanded to include other territorial instruments (Minister of Development Funds and Regional Policy, 2022). It is worth mentioning that the introduction of the aforementioned instruments stems from the necessity of having a more integrated policy in urban areas (Tosics, 2017). Table 1 presents the different approaches to the core and purpose of the territorial investments, with the most widespread solutions being indicated; i.e., ITI and CLLD.

Table 1.
Characteristics of selected territorial investments

Integrated Territorial Investments (ITI)
It is pointed out that ITI have been introduced with the intention of financing the sustainable development of territorially demarcated areas, including urban districts and entire cities, metropolitan areas, as well as partnerships of local and regional self-governments (Gaman et al., 2015).
The investments are directed towards solving various problems affecting demarcated territories. The ITI funds are a form of subsidy for public entities, thus guaranteeing their participation in the development process of the given area. Multi-level participation is particularly emphasised. The high effectiveness of these measures is due to the fact that all the described aspects must be coherent with each other within an integrated management strategy (Garcia-Ayllon, 2018).
ITI lead to the elimination of problems of territorial differentiation caused by the disparity between the formal (legally regulated) and actual conditions under which cities operate. They enables development planning according to a strategic approach (Tosics, 2017).
The main goal of ITI is to implement the principles of territorial governance, where the nature of cooperation plays a particularly important role. In practice, the form of participation between local authorities can affect the extent to which the objectives are achieved, including the strategic planning and management of cities. (Kociuba, 2018).
J. Krukowska and M. Lackowska identify the use of the ITI as a necessity to introduce top-down changes dictated by the process of Europeanisation, which ultimately results in the implementation of specific solutions at the local level. The authors also draw attention to the bottom-up dimension of Europeanisation, which starts in urban areas as their response to the needs reported for the implementation of sustainable development projects (Krukowska, Lackowska, 2017).
Community-led local development (CLLD)
Managing urban development on the basis of CLLD, i.e., a territorial tool in which local community involvement plays a dominant role, results in a lack of direct participation of public and private entities in the decision-making process. This way of implementing sustainable urban development projects takes into account the participation of citizens in the planning and implementation process, mainly in the districts in need of special support (in this case activities are limited to specific sectors and not entire areas). This tool implies a more democratic way of planning city development (Tosics, 2017).
CLLD can be funded from many sources and is therefore multi-funded. It enables effectuation of community-led projects responding to the needs of specific places. This approach leads to the integration of residents and deepening of interrelation between individual entities. CLLD is recognised as a particularly useful approach in the face of uncertainty, as it emphasises the possibility of involving the public in local development decision-making processes (Bumbalová et al., 2016).
The implementation of CLLD results in the so-called 'soft' benefits, among which increasing social capital and undertaking cooperation with previously uninvolved residents (e.g. unemployed youth) are particularly emphasised. It encompasses a wide range of activities and is characterised by a high degree of flexibility in adapting to the problems being tackled. In the long time, it leads to increasing the role of self-governments and greater number of projects being undertaken throughout the European Union (Miller, 2014).

Cont. table 1.

With the arrival of the new financial perspective (EU multinational financial framework 2021-2027), CLLD offers an opportunity to increase citizens' participation in the urban development process. The bottom-up nature of this tool means that it responds to the greatest needs of specific sectors. The works being undertaken simultaneously in different places create an integrated strategy presenting an innovative approach to solving local problems (Olszewski et al., 2021)
According to the Committee of the Regions, CLLD is '*a key instrument for the harmonious development of urban and rural areas, enhancing the capacity to develop relations with surrounding peri-urban and rural areas*' CLLD's scope encompasses solutions put forward by residents who are struggling with local problems; participation of all stakeholders, from the local community to those in authority, and also the business community; an integrated approach that aims to solve the problems affecting the whole community rather than selected groups, such as problems concerning education. This instrument provides rapid results due to the direct involvement of people who have their local community's best interests at heart (Săracu, Trif, 2019).

Apart from the legal regulations in force in a given Member State, it is generally recognised that the objective of integrated territorial instruments is to support local authorities involved in their territories development process and to promote diverse forms of cooperation between units. As stated in the Ministry of Development Funds and Regional Policy's study entitled, "Principles for the implementation of territorial instruments in Poland in the EU financial perspective 2021-2027" (Polish: *Zasady realizacji instrumentów terytorialnych w Polsce w perspektywie finansowej UE na lata 2021-2027*), these tools contribute to (Minister of Funds and Regional Policy, 2022):

- creating and strengthening links between units of specific functional areas and supporting their participation at different levels (from regional to international);
- improving the qualifications and skills of those involved in planning and implementing development strategies;
- facilitating the implementation of adopted solutions and seeking various sources of funding.

Particularly important in the implementation of sustainable urban development is the cooperation of regions, which, thanks to the efforts of the European Union, takes place through the European Urban Initiative. As shown later in this paper, the EUI platform supports cities in sharing ideas and worked out solutions.

2.2. European Urban Initiative as a support for EU cities cooperation

As noted previously, the introduction of integrated territorial development in the EU Member States implies the obligation to support cities in the area of their sustainable development, as specified under Cohesion Policy Objective 5, i.e., *A Europe closer to citizens.* It is worth mentioning that the minimum ERDF allocation for these purposes is at the level of 8%, assigned only to projects that are coherent with the objectives adopted under the Sustainable Urban Development Strategy. The process of supporting these entities is multidimensional, and in order to tackle specific problems and needs of cities, the European Commission has proposed the creation of the European Urban Initiative (EUI) funded by the ERDF. Its aim is to promote cooperation between and within cities, and to propose unified

solutions, thus eliminate major differences in the approaches or tools used by individual cities so as to achieve cohesion policy objectives. The success of this endeavour is based on synergy and cooperation between regions that takes place within the URBACT programme. Activities undertaken in the context of the EUI focus on supporting:

- innovative actions (IA),
- capacity building and knowledge building and works enabling an assessment of the impact on territorial development (The European Urban Initiative).

The main goal the EUI is to build a close relation between the indicated fields of activity, i.e., innovative actions, capacity building and knowledge building. In practice, this leads to the development of lasting principles of cooperation through the initiatives introduced in cities under the Cohesion Policy (About Innovative Actions).

Innovative actions

From the point of view of the European Union which covers the most extensive area in terms of urbanisation, cities play a strategic role in the pursuit of sustainable development. They stimulate local and global economy, they are the hubs of innovation, centres science and culture and are facing numerous challenges, including environmental, infrastructural, social, technological, etc. Special attention should be paid to the fact that meeting these challenges requires the introduction of an innovative multilevel approach. However, in the practice of local government, this process is obstructed by many barriers, which most often relate to limited financial resources, authorities' unwillingness to accept innovative solutions characterised by a high level of risk, or due to their lack of experience in implementing such projects. It is worth noting that city authorities' reluctance to undertake bold initiatives spurred the European Commission to create a tool offering support for the implementation of innovative solutions in urban areas, i.e., EUI-IA (European Urban Initiative – Innovative Actions). As intended, the purpose of this instrument is to support cities across the EU in implementing previously well-tried innovative urban solutions. In addition, it is tasked with creating favourable conditions for taking the risks involved in turning unconventional ideas into pilot projects that can be put in place in today's cities. This tool enables an uninterrupted flow of information on successful innovations, so that the relative knowledge regularly reaches all the interested entities, where it can then be applied. The EUI-IA ultimately aims to accumulate extensive knowledge and build trust, which is a prerequisite for the dissemination of implemented projects. It is pointed out that any solution presented within the IA creates benefits for the EUI as a whole. In the longer time term, it is expected to strengthen the innovative potential of cities and increase their attractiveness, which, regardless of their geographical conditions, should comply with European standards. Importantly, all the relevant information is uploaded onto the urban knowledge platform – *Portico* - developed by the EUI to be used for capacity building and for knowledge building (About Innovative Actions).

Capacity building

It leads to the enhancement of cities' capacities and the streamlining of their process of formulating policies, strategic plans and sustainable development solutions. It should take place in an integrated way and promote various forms of participation, including at local, regional and national level. Capacity building is based on cooperations of cites interconnected through URBACT IV networks. In addition, it promotes a peer learning approach and contributes to the capacity building of the Urban Development Network. The target audiences of the activities are mainly to city managers, politicians and other actors directly involved in the implementation of cohesion policy and in developing sustainable urban development. The individual activities fall into three main areas, namely:

- sharing knowledge and experience between cities,
- evaluation of implemented solutions,
- initiating projects enhancing cities' potential (Capacity-Building for Cities).

Knowledge building

The activities in this area are directly related to the role of the EUI, which is to disseminate knowledge on sustainable urban development, collected in the form of know-how during the implementation of urban solutions. It is worth mentioning that works are currently underway on upgrading this platform, which in practice is intended to support sustainable urban development already at the stage of planning strategic objectives. Particular attention is given to issues:

- related to supporting the work on the Urban Agenda for the EU,
- concerning cooperation at governmental level to make the knowledge and skills developed so far available in an efficient way and thus improve the urban policy-making process (Knowledge for Cities).

It is intended that the involvement of individual entities at city, regional and national level will be supported by a network of contact points located in specific cities (Knowledge for Cities).

Portico

It is described as "the gateway to urban learning" *(Portico - the Gateway to Urban Learning*) This platform has been created to collect and share knowledge with a view to promoting sustainable development in European Union cities. It provides access to up-to-date solutions and information on the actual results of projects implemented to achieve the objectives of cohesion policy, which includes building accessible, greener and more equitable cities. In addition, it integrates the whole Portico community, interconnects urban practitioners and provides tools to share their experiences. It is important to note that the resources gathered here (based on practical experience) constitute a starting point for shaping new policy, which can be propagated through the network of Urban Contact Points (UCPs) located in the Member States.

The EUI's initiative to create the aforementioned UCP network aims at integrating in one place as many participants as possible, including both urban policymakers and practitioners. Furthermore, it aims to increase their capacity to implement urban projects and to disseminate output and results at local, regional and national levels (Knowledge for Cities).

Based on the case study method, three initiatives selected from the innovative actions supported by European Union funding are presented further on.

3. Examples of innovative action projects – case study

The European Commission's decision to create the European Urban Initiative was aimed at supporting urban policymakers in developing innovative solutions to meet local challenges. It should be pointed out that the projects that received funding from the ERDR were subject to prior evaluation by a panel of experts, who assessed several hundred ideas submitted by cities in the calls for innovative actions. It is also worth noting that the proposed solutions had to fit into urban thematic areas identified by the European Union, with particular emphasis on their development potential and ease of implementation in other cities. Table 2 contains basic information on three selected projects from three different urban areas (out of a total of 16). These solutions were chosen randomly, while considering their duration (projects in progress or completed relatively recently) and the number of projects submitted within a given area (attention was paid to particularly developed areas). The table also indicates the amount of ERDF funding for the project and its partners.

Table 2.
Characteristics of three examples of ERDF-funded innovative action projects

City	Verona	Sofia	Vantaa
Subject matter	Demographic Change	Air Quality	Jobs and Skills in the Local Economy
Full name of the project	S.T.E.P.S Shared Time Enhances People Solidarity	INNOAIR Innovative demand responsive green public transportation for cleaner air in urban environment	Urban Growth -GSIP Vantaa - Growth and Social Investment Pacts for Local Companies in the City of Vantaa
ERDF funding for the project	EUR 4 million	EUR 3.7 million	EUR 4 million
Planned period of validity	01.07.2020-30.06.2023 (extended to 06.2024)	01.07.2020-30.06.2023	01.11.2018-31.07.2022
Partners	City of Verona 1 social housing agency 1 university 5 social cooperatives 1 local association	Sofia Municipality 2 universities 2 non-profit organizations 2 private companies 1 national public institution	Vantaa Municipality 2 universities 2 higher education research institutes 1 business network 4 private companies 1 public company

Source: (Projects; Sofia - Air Quality - INNOAIR; Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa; Verona - Demographic Change - S.T.E.P.S.)

The role of partners involved in the implementation of these innovative projects, listed in Table 2, was of key importance. It can be said that the partnerships were largely determined by the projects' subject matter. The project proposed by Verona responds to the challenges posed by demographic change and is geared towards the development of a social model, so that cooperation is mostly limited to social actors, without including private companies. In the case of Sofia, the project's partners were involved in different types of activity. Although the project responds to the needs of the community as a whole, the use of the know-how of private enterprises seems to be crucial in this respect, as, among other things, it requires the development of pertinent software for mobile devices. The third example – Vantaa - presents a very different nature of cooperation, i.e., strongly supported by private companies and oriented towards improving the skills of local community members. It should be noted that the diversity of actors in various partnerships is a result of the nature of the challenges faced by city authorities. In addition, such extensive cooperation leads to various suggestions on how to improve different aspects of current urban needs.

A more detailed description of projects featured in Table 2 is presented hereafter.

3.1. Verona - S.T.E.P.S Shared Time Enhances People Solidarity

The circumstances that motivated Verona to develop and then implement the project under discussion stemmed from the numerous and successive changes in family structures, which were mainly related to gradual reduction in the number of medium-sized family members, and hence inevitable ageing of the population, resulting in larger proportion of people living alone. These changes are both demographic and social in nature. The results of the 2018 Verona survey showed a decrease of the average family size, and an increase in the number of single-member households, in addition to a high rate of elderly people and low fertility rates. These demographic changes obliged to examine the underestimated and complex consequences such as loneliness, which has no age and affects health, wellbeing and quality of life. The challenges to be met were therefore:

- to detect/qualify loneliness making it a measure of wellbeing/malaise;
- to improve individual/collective wellbeing;
- to prevent the erosion of the social fabric, through a set of interventions aiming at fighting lowliness conditions and its interrelated aspects of life (material conditions, quality of life and sustainability of living) (Verona - Demographic Change - S.T.E.P.S.).

The proposed project is about developing and implementing a social and territorial model. It is assumed that it will be adapted to demographic changes and is aimed at the prevention and treatment of loneliness, with the belief that a welcoming, inclusive, caring environment helps to prevent degenerative states of wellbeing/health. Starting from the analysis of the causes triggering loneliness, the project will define the dimensions of loneliness that will contribute to the Levels of Loneliness Index. (LoLix – Levels of Loneliness Index). Specific actions on the field will trigger the "loneliness management" with a specific focus on prevention and

treatment, reaching key aspects of life, namely material conditions, quality of life, sustainability of living. (S.T.E.P.S. Project). These actions will be structured through:

- the integration of physical spaces (whose function of meeting is to be restored) - the condominium complex, green areas, etc;
- relationships (between peers/neighbours, intergenerational, ...), digital space that facilitates the connection of physical spaces/relationships;
- digital space that facilitates the connection of physical spaces/relationships.

The main expected results are:

- creation of preconditions for new social interactions and social generations;
- reduced urban decay and reduced perception of degradation;
- a growth in the number of hours spent in relational contexts for recipients with an initial Lolix rating on the threshold of criticality;
- improved attractiveness of the territory and neighbourhoods made more family-friendly;
- improved living conditions of low-income families with equal resources;
- increased virtuous/sustainable behaviour, solidarity practices/non-monetised exchange (Verona - Demographic Change - S.T.E.P.S.).

The STEPS project should be seen as the City of Verona's reaction to challenges of a demographic nature, in response to which a solution aimed at fighting loneliness was implemented.

3.2. Sofia - INNOAIR - Innovative demand responsive green public transportation for cleaner air in urban environment

The main motivation for implementing this project in Sofia was the growing problem of air pollution. Apart from the geographical conditions, among which the city's location on a plateau surrounded by high mountains is emphasised, special attention is also paid to human activities that further exacerbate the problem. We are talking here about an increase in the number of registered cars, which is compounded by the fact that Bulgarians own some of the oldest vehicles in the whole of Europe (Sofia - Air Quality - INNOAIR).

To address this problem, the municipality decided to implement measures aimed at reducing air pollution, including electrification of public transport. The primary objective of the project is to gradually replace the current urban transport by 'green on-demand public transport'. According to this concept, urban transport is provided by e-buses that do not follow pre-determined routes but create route map based on citizen demand submitted via mobile application. The app will leverage machine learning and advanced data analytics to create the most efficient path for each ride, collecting as much passengers as possible. This innovative public transport service will be implemented together with a wide array of initiatives: low emission zones, green corridors, downtown congestion charge. The integration of these measures makes it possible to permanently reduce air pollution in this city. At this point,

it is worth noting that the implementation of the INNOAIR project has already resulted in a wide-ranging transformation that, in addition to cleaner air, has introduced ground-breaking changes in the field of urban mobility (Electric Minibuses Offering On-Demand and Zero-Emission Public Transport Options to Citizens in Sofia; Sofia - Air Quality - INNOAIR).

Upon completion of INNOAIR the city will have a pool of coordinated policy tools, including:

- "On-demand green public transportation", formed by a platform with machine learning and advanced analytic capabilities and mini electric busses;
- congestion charge model;
- low emission geospatial urban zones, preventing vehicles from entering the city centre and certain areas on polluted days;
- green corridors for active transport (INNOAIR Journal 2: Putting the Green Mobility Options on the Road)

It is expected that the project will contribute to significant behavioural change of the local population regarding public transport and broader use of public and active (waking, cycling) transportation. PM and CO2 emissions will be reduced, which in turn will improve the health and wellbeing of residents.

3.3. Vantaa - Urban Growth-GSIP Vantaa - Growth and Social Investment Pacts for Local Companies in City of Vantaa

Companies are currently facing the challenge of the dynamic changes that are taking place during the working lives of employees. It is recognised that in the future, only those companies will achieve a competitive advantage which point above all to a skilled and motivated personnel among their most important assets. It is worth noting that these companies invest in continuous learning at work and prepare for their future competence needs. By developing the competence of personnel, companies can meet the challenges arising from technological changes, as well as support the company's socially responsible growth. The Urban Growth Vantaa project developed solutions particularly for the challenges of working life that Vantaa faces. In Vantaa, companies are facing a challenge due to their low level of competence compared to other large cities in Finland. One third of the workforce is in the labour market without a post-comprehensive school education. At the same time, shifts in working life and technological development change the way we work. The majority of new jobs are in SMEs, but many SMEs find it challenging to support continuous learning (Urbaania Kasvua Vantaa; Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa).

Due to the complexity of the problem, cooperation between different sectors and systemic solutions were necessary. Thus, the joint work aimed at developing solutions for improving the competences of the workforce as well as increasing employment. Undoubtedly, by improving the competences of personnel in the field of automation and digital transformation, the implemented project has accelerated the development of companies active in the local

market. At the same time, it has increased the chances of the unemployed to find employment, and by offering upskilling opportunities protected low-educated employees from potential job loss. The innovative nature of the project concerned the development of an incentive model for companies. The solution introduced (GSIP - Growth and Social Investment Pact) responded to the needs expressed by local companies with about 40 employees, including those operating in the industrial sector (characterised by high employee turnover) and in the IT sector (requiring employees to keep up with technological advancements) (Cooperation and Collective Responsibility for a Socially Sustainable Future in Vantaa; Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa).

The activities began with the development and subsequent implementation of three GSIPs (thematically different) in five specific companies. After a test phase, they were initiated in 60 entities. The result of the works undertaken as part of this project was the joint development of three sets of Growth Deal services, oriented towards supporting the growth of companies and the spread of social responsibility in their activities. This included:

- Growth Deal 1 offered companies services supporting recruitment, as well as training and coaching services supporting growth.
- Growth Deal 2 supported companies in competence development. The service package consisted of company specific group coaching and professional skill development services.
- Growth Deal 3's services supported companies in promoting technological change projects and the development of competence management methods. (The GSIP Project Journal 4: How Has an Innovative Idea Enriched the Local Jobs and Skills Discourse; Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa).

Defining the afforested sets of service was made possible by using agile testing methods. In Initially, these services were implemented in partner companies, where it was then decided to develop them further and implement as pilot projects in SMEs. These services included:

- development of professional competences by conducting information meetings on improving professional competences. The topics of the sessions responded to the specific needs of employees and managers. An additional advantage was the expert's assistance in tailoring an appropriate training programme, enriched by individual discussion panels and advice;
- training sessions, which consisted of thematic meetings conducted in e-learning and on-site. Training subjects included: communication, lean concepts, human resources management, use of Office package, etc.;
- growth coaching. Group coaching tailored to its needs. By enhancing the competence of the whole team, it has contributed to the development of a learning culture;

- technological development services - a key role was played here by external companies, which carried out an assessment regarding the possibility of introducing a new technology to improve competitiveness. This service was about recognising development needs and proposing appropriate solutions;
- coaching competencies for development. This service improved personnel's competencies, among others through the involvement of coaches in the development of new upskilling methods and continuous learning process. The process of assessing/recognising existing competences was also supported;
- recruitment services for SMEs, which covered four main areas, namely: Employee search. Companies received help for finding employees via employment services and networks. Services were also offered related to other areas, such as interviewing; Information and guidance: Companies were provided with information about financial assistance for recruiting, such as pay subsidy, and related services; Recruiting through apprenticeships: Companies were helped with mapping out suitable tasks and students for apprenticeships. Vocational College Varia was responsible for the courses; Reorganising and reformulating needs: Companies received help for clarifying and formulating what kind of skills they need (Urbaania Kasvua Vantaa; Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa).

In the process of upskilling personnel, there were also used digital tools such as: Personal Digital Coach (supporting the learning process of employees); Competence Mapping Portal (support for the company's internal career paths); Dashboard (support for the city's business cooperation), UKV bot (support for charting company needs) (Vantaa - Jobs and Skills in the Local Economy Urban Growth - GSIP Vantaa).

It should be noted that such an extensive range of products and services provided for of the presented projects is due to the nature of the cooperation undertaken to achieve the desired results. Both the number of partners and the specifics of their activities may affect the number and quality of the solutions resulting from various methods and approaches. There is no doubt that cooperation offers far more development opportunities than individual activity.

4. Summary

It is worth noting that the implementation of territorial instruments increases the scope of their impact on the projects undertaken in the cities and their associated functional areas. These are mainly projects following the principles of cohesion policy promoting an integrated approach to development, which implies collaborative problem-solving and aims at the uniform provision of public services to the local community.

The emphasis on the promotion of sustainable development in urban areas, carried out in accordance with the regulations of the cohesion policy, is a consequence of the gradually strengthening view that EU cities authorities are obliged to formulate and implement development strategies in response to the challenges of the local environment. It is pointed out that the specificity and scope of the necessary works in urban areas force public authorities to introduce solutions that do not follow traditional methods but are of an innovative nature. The challenges currently faced by local authorities necessitate the implementation of innovative solutions, based on close cooperation.

A key role in supporting the process of promoting sustainable development in urban areas should be attributed to the European Union, which recommends that it be carried out in accordance with an integrated approach. Taking into account the possibilities resulting from the cohesion policy, it should be pointed out that cities have territorial instruments at their disposal to facilitate and improve the implementation of sustainable development projects. Undoubtedly, the European Union is striving to ameliorate this process, and by using many different ways to reduce the disparities between the cities of the Member States. It is worth mentioning here some of the initiatives undertaken in this direction, such as: the creation of the European Urban Initiative platform, which collects and makes available information on solutions implemented in the field of sustainable urban development. Importantly, the solutions to be shared must have a high development potential and be easy for other cities to apply. A necessary prerequisite for their implementation is cooperation between the city and other entities (universities, businesses, etc.). Partnership provides a range of different opinions and approaches to the problem under consideration and thus leads to a better understanding of the issue to be tackled and the identification of a broad range of relevant activities.

The main limitation of this study is that the information on many completed projects (previously selected by the EUI) has not yet been updated on the innovative actions website. Hence, the lack of data on the final products that were developed during project implementation, the constraints associated with the process of implementing solutions and on the possibilities of applying these solutions in other EU cities.

This study is of a qualitative nature, the main aim of which was to identify the role of cooperation in disseminating the principles of sustainable development, presenting three examples of selected EU cities where innovative solutions have been implemented. It is presumed that subsequent articles will include quantitative research and will be directed towards assessing the interrelations between the use of territorial instruments, the implementation of local development strategies and the well-being levels of local communities.

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DEMAND FOR ELECTRONIC DEVICES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT – EVIDENCE FROM POLAND

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Purpose: The purpose of the article is to identify how the goals of sustainable development in the area of responsible consumption are realized, using the example of demand for electronic devices in Poland, and to identify opportunities for its solution.
Design/methodology/approach: The article undertook to answer the question: how to reduce the negative impact of excessive consumption of electronic devices on the sustainable development goal of responsible production and consumption? The following methods were used: literature review, analysis of the results of research institutions and consulting agencies, deductive reasoning.
Findings: The causes of excessive consumption of electronic devices and the generation of harmful waste are not only the relatively low awareness of consumers, but also the strategies of producers inspired by technological progress and the intensity of global competition. Therefore, in order to reduce this problem and increase the possibility of implementing the principles of responsible production and consumption, systemic solutions involving three parties are proposed: consumers, producers and the state.
Practical implications: Opportunities and courses of action to reduce excessive demand for new electronic devices were suggested, which would better achieve the sustainable development goals in the area of responsible consumption.
Originality/value: The article is a contribution/voice to the discussion of the controversy surrounding the implementation of sustainable development principles in the context of technological progress and the desire of companies to maximize profits.

Keywords: sustainability, responsible consumption, consumer attitudes, electronic market.

Category of the paper: Conceptual paper.

1. Introduction

Socio-economic development inspired by technical and technological progress, has led in highly developed countries to an increase in wealth and the formation of a civilization of consumption. The dominant lifestyle based on consumerism leads to consumption of goods and

services that is excessive in relation to actual needs, which is carried out without regard to social, ecological and ethical costs (Frost, 2009). Excessive and irrational consumption results in adverse effects for society and the environment, such as environmental pollution, adverse climate change, waste of resources, generation of large amounts of waste, often difficult to dispose of waste. Especially dangerous is electronic waste (e-waste), which emits harmful substances into the soil, water and air. Dynamic technical progress in the field of electronics and information technology, especially intense at the turn of the 20th and 21st centuries, influences the shortening of the life cycles of electronic devices, the introduction of newer and newer models and the increase in demand, which generates large quantities of electro-waste that is difficult to dispose of.

The answer to these difficult challenges are the principles of sustainable development, which have been promoted and advocated for many years. The essence of sustainable development is the search for such ways and directions of satisfying needs that take into account aspects of environmental protection, economic growth, social development, spatial economic order and psychological well-being of both the current generation and future generations (Kielczewski, 2012, p. 204). The Sustainable Development Goals are defined in the 2015 UN Resolution - Transforming Our World: Agenda 2030 for Sustainable Development, adopted by member countries (*Resolucja ONZ - Agenda 2030*). One of the goals is responsible consumption and production, which deals with the development of sustainable consumption and production patterns, in line with the model of a circular economy.

The purpose of the article is to identify the problem of demand for electronic devices in the context of the implementation of the Sustainable Development Goals in Poland and to identify opportunities for its solution. In this connection, the following research questions were undertaken:

1) What are the main goals of sustainable development in Poland and how are they implemented?
2) What are the symptoms of sustainable consumption with regard to electronic equipment?
3) What is the demand for electronic equipment on the Polish market in the context of the electro-waste problem?
4) How to reduce the negative environmental effects of excessive consumption of electronic equipment?

The article uses the following research methods: literature review, analysis of the results of research institutions and consulting agencies, deductive reasoning.

The structure of the article consists of the following sections. Section 2 discusses the implementation of sustainable development goals in Poland. Section 3 describes actions taken for sustainable consumption by Polish consumers. Section 4 analyzes the demand for electronic devices in Poland in the context of the electro-waste problem. Section 5 formulates proposals for actions to solve the problem of excessive consumption of electronic devices.

2. How are the Sustainable Development Goals being implemented in Poland?

The 2015 UN Resolution formulated the following 17 Sustainable Development Goals (SDGs): No poverty (SDG 1), Zero hunger (SDG 2), Good health and well-being (SDG 3), Quality education (SDG 4), Gender equality (SDG 5), Clean water and sanitation (SDG 6), Affordable and clean energy (SDG 7), Decent work and economic growth (SDG 8), Industry, innovation and infrastructure (SDG 9), Reducing Inequalities (SDG 10), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), Life Under Water (SDG 14), Life on Land (SDG 15), Peace, Justice and Strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17) (*Sustainable Development Goals. Agenda 2023*). Poland has undertaken to meet these targets with a view to 2030. The level of progress was assessed and presented in a report adopted by the Council of Ministers on 2 June 2023. In the 2022 SDG Index, Poland ranked 12th out of 163 countries assessed (up from 15th place in 2021) with a score of 80.5%. This is a high position considering that in the first edition of the 2016 ranking Poland was ranked 38th. Poland performs best on goals such as poverty eradication (SDG 1), access to quality education (SDG 4), clean water and sanitation (SDG 6), industry, innovation and infrastructure (SDG 9), responsible consumption and production (SDG 12) and protection of sustainable land ecosystems (SDG 15). In contrast, the greatest difficulties relate to: climate action (SDG 13), ensuring the protection of marine resources (SDG 14), the Global Partnership for Sustainable Development (SDG 17), and affordable, clean and accessible energy (SDG 7) (*Realizacja Celów Zrównoważonego Rozwoju w Polsce. Raport 2023*).

According to Eurostat's report "Sustainable development in the European Union. Monitoring report on progress towards the SDGs in an EU context' of May 2022, Poland has made the most progress against the EU average in achieving 3 of the 17 SDGs, i.e. reducing inequalities (SDG 10), combating poverty (SDG 1) and partnerships for the goals (SDG 17) between 2015/2016 and 2020/2021. The biggest challenges are in achieving the goals related to sustainable food production (SDG 2) and responsible consumption and production (SDG 12) (*Sustainable development in the European Union. Monitoring report on progress towards the SDGs in an EU context – edition 2023*).

Responsible consumption is included in a group of 17 Sustainable Development Goals (SDG 12). The main measures to achieve this goal in Poland include (*Realizacja Celów Zrównoważonego Rozwoju w Polsce. Raport 2023*):

- the transformation towards a circular economy, which requires action at all stages of the life cycle: from product design, raw material acquisition, processing, production, consumption, waste collection and management,
- the development of organic farming,

- efficient waste management, with the possibility of secondary raw material or energy use,
- consumer education on the legitimacy of reducing over-consumption, rational use of resources, the need to recycle and selective collection of waste.

According to the government report, as well as the Eurostat report, this goal is being realised too slowly and only partially, and therefore it will not be possible to achieve it by the planned deadline, i.e. by 2030. One of the reasons for this may be the low awareness and knowledge of both the concept and the goals of sustainable development among Polish consumers. According to the results of a 2021 study by CSR Consulting and Bank BNP Paribas, just over half of Polish consumers surveyed (53%) know what the term 'sustainability goals' means, but nothing else; 22% have heard the term but do not know what it means; 19% know nothing about it at all. Only 6% of respondents admitted to knowing a lot about the issue and being interested in it. According to those surveyed, climate change and environmental protection are the two biggest challenges in the world today, and of the 17 Sustainable Development Goals, the most urgent is health and quality of life (SDG 3) (*Znajomość Celów Zrównoważonego Rozwoju przez polskich konsumentów. Wyniki badania. 2021*).

3. Actions for sustainable consumption

From a macroeconomic point of view, consumption has become one of the most important stimulators of economic development, a kind of locomotive driving the economies of individual countries and the world economy. A decline in consumption and market demand leads to a decline in production, which means the collapse of many enterprises, and subsequently results in increased unemployment, reduced taxes, an increase in the deficit of state finances and other problems causing economic downturns. Thus, modern economic development has become hostage to consumption (Bywalec, 2010, p. 8). However, the constant driving of demand has led to excessive, irrational consumption that ignores social, environmental, ethical costs. This lifestyle leads to the depletion of natural resources and the generation of excessive waste, poisoning the environment and consequently reducing the quality of life, as well as hindering human development. According to Thoreau, one of the critics of the consumerist lifestyle, "most of the luxuries and so-called comforts in life are not only not necessary, but are actually an obstacle to human development" (Thoreau, 1991).

Within the framework of the Sustainable Development Goals, sustainable consumption, also called socially responsible or ecological consumption, is postulated. It is consumption determined by pro-environmental values and consumer attitudes that build environmental awareness and lead to ecologically and socially responsible market decision-making (Zrałek, 2013). Sustainable consumption involves the economical and rational use of consumer goods

and natural resources, as well as the conscious and deliberate reduction of consumption of products that require high consumption of scarce, non-renewable resources and generate significant amounts of waste (Kryk, 2013).

The manifestations of sustainable, socially responsible consumption include various trends and courses of action, such as, among others: needs-based shopping (deconsumption), green consumption, buying or selling second-hand items, collaborative consumption (or sharing economy) and smart shopping (Sobczyk, 2018).

Purchasing at the level of needs means to limit it rationally and consciously to the necessary size, conditioned by individual needs, abilities and preferences. The idea is not to buy excessive quantities of goods or unnecessary products, suggesting, for example, attractive promotions, bargains, advertisements or snobbery or show effect. A new phenomenon in consumer behaviour is emerging here, called deconsumption. Deconsumption, defined as the conscious restriction of consumption to a rational size (i.e. resulting from the natural, individual, physical and psychological characteristics of the consumer), boils down to a responsible lifestyle, which means in practice the need to think about one's own needs and to realise needs that are real and not created by various external factors (Mysona Byrska, 2021). Deconsumption manifests itself primarily through: the rationalisation of market behaviour, limiting the volume of purchased and consumed goods in favour of their quality, the servicisation of consumption, the preference for local, regional consumption over international, global consumption, the greening of market behaviour, the propensity to engage in systems and networks of shared consumption, which allows access to products and services, without having to bear the costs of ownership, the consideration of ethical aspects at each stage of the purchasing process, and finally a change in the consumer's lifestyle (Wilczak, 2016).

Green consumption refers to the purchase and use of products (and their packaging) with the least possible negative impact on the environment, the economical use of specific resources (primarily water and energy), the rational use of durable goods, the avoidance of activities leading to devastation and pollution of the environment through, inter alia, waste segregation, packaging disposal, the use of low-emission means of transport, etc. (Witek 2017).

An important manifestation of sustainable consumption is the circulation of second-hand items on the secondary market. It concerns durable items such as clothing, footwear, furniture, electronic equipment, etc., whose useful life is extended, thus reducing the purchase of further products and excessive waste generation. The development of this form of market is facilitated by modern communication tools such as the Internet, social media or mobile devices, which enable representatives of demand and supply to contact each other quickly and easily.

Polish consumers take various actions within the framework of sustainable consumption, or more broadly, sustainable development. The most common of these are segregating waste, saving water and energy, and buying ecological products, according to a number of studies conducted in this area. According to the results of the CSR Consulting and Bank BNP Paribas study from March 2021, cited earlier, the main sustainability actions consumers take systematically are: segregating rubbish, saving water or energy or freezing food (Figure 1).

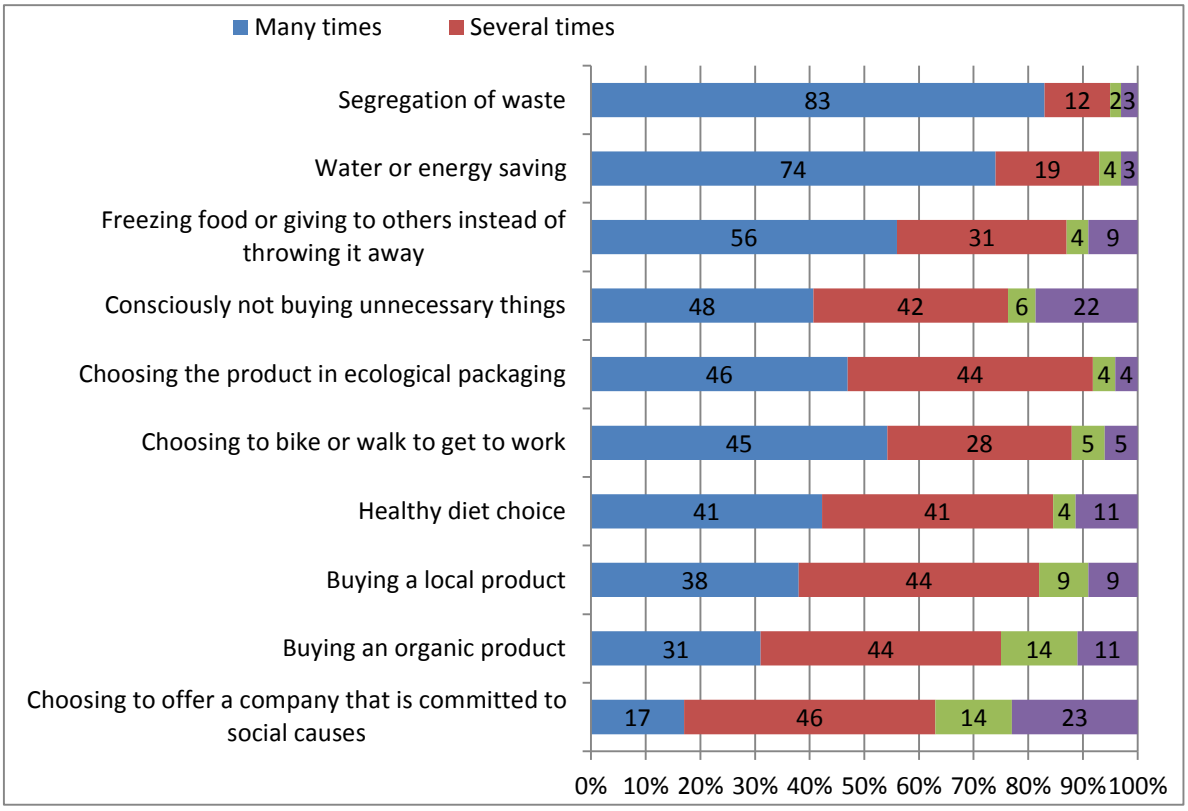

Figure 1. Actions to achieve the Sustainable Development Goals.

Source: *Znajomość Celów Zrównoważonego Rozwoju przez polskich konsumentów. Wyniki badania. 2021.* https://kampania17celow.pl/wp-content/uploads/2021/04/Badanie-Cele-konsumenci-K17C-rozszerzona.pdf

When it comes to buying organic products, these are primarily food items. According to the results of the 2021 study on trends in Poles' eco-shopping[1], the vast majority of consumers (86%) buy organic food products, of which 44% do so at least once a week (*Trendy w ekozakupach Polaków 2021. Raport Farmy Świętokrzyskiej*). The main reason for buying organic food is the belief that it is healthier and of better quality, which is why as many as 67% of respondents are able to pay a higher price for organic products than for conventional products.

4. Demand for electronic equipment and the problem of electro-waste

The electronic equipment market in Poland has been growing dynamically in recent years. Demand is increasing year on year, as evidenced by the growing number of electrical and electronic devices in households. It is estimated that in 2022 there will be an average of around 30 units per household, ranging from washing machines, fridges, TVs, computers, small

[1] The survey was conducted in April 2021 by Nationwide Research Panel Ariadna on behalf of Swietokrzyska Farms on a representative sample of 1,077 Poles aged 18+.

household appliances, power tools to solar panels. This is half the number of more than 10 years earlier (*Czas na zmiany w systemie zagospodarowania elektroodpadów. Puls Biznesu, 2022*). The increase in demand is a result not only of rapid technical and technological advances in electronics and rising consumer incomes, but also of the coronavirus pandemic. Compared to other retail markets, the pandemic has had a positive impact on the electronics market. Restrictions on movement, the need to study and work remotely created a need to purchase and/or replace various types of electronic equipment. According to data from the PMR report, the electronics market reached a value of PLN 36.1 billion in 2020, an increase of more than 15% year-on-year (*Rynek produktów RTV, AGD i sprzętu elektronicznego w dobie COVID-19*, 2022).

According to the forecasts of AB, a Polish IT and consumer electronics distributor, the turnover dynamics of the electronics market will reach 4% (year-on-year) in 2023, and this will be the fourth consecutive year of growth in the Polish market. The reasons for the increase in market demand in 2023 include: digital transformation, government programmes supporting IT spending, such as a project to purchase notebooks for students and teachers, a loan programme for cloud transformation, a programme to develop high-speed internet access or favourable legislative changes in public administration services - mObywatel (*Rynek dystrybucyjny IT oraz elektroniki użytkowej w Polsce wciąż rośnie – AB.*). In turn, according to forecasts from the PMR report "Retail market of household appliances, consumer electronics and audio/video devices in Poland 2022", the market will grow at an average annual rate of 3-5.5% in 2022-27 (*Wartość sprzedaży na rynku RTV/AGD przekroczy 40 mld zł w 2022).*

However, the growth of the electronics market together with dynamic technical and technological advances is shortening the life cycles of these products. This applies not only to the life cycles of the final products, but also to spare parts and components, making it impossible or uneconomic to repair an old device. In this situation, the consumer buys a new model and the manufacturer works on further improved versions. It has been estimated that the restitution demand for electrical and electronic equipment, associated with the replacement of old equipment, is about 80%, and the primary demand, resulting from the need to purchase the first appliances in a household in a given category, is 20% (*Czas na zmiany w systemie zagospodarowania elektroodpadów. Puls Biznesu, 2022*). As a result, large quantities of obsolete equipment are generated which must be managed, disposed of or recycled in some way. In this way, a gigantic e-waste problem arises and grows rapidly.

Electro-waste is waste electrical and electronic equipment, covering a wide range of products, from used batteries and energy-saving light bulbs to smartphones, tablets and laptops to washing machines, cookers and fridges. These products contain many harmful substances, such as mercury, lead, cadmium, Freon, asbestos or bromine compounds, which can seep from a broken appliance into the air, soil and groundwater, and from there into the human body. Produced in 2022 alone, small devices such as mobile phones, electric toothbrushes, toasters and cameras will weigh approximately 24.5 million tonnes. The very rapid growth of electro-

waste in recent years is a global problem. According to estimates, 5.3 billion smartphones will be taken out of use globally in 2022 alone. WEEE Forum research[2] has shown that in an average European home there are 74 products classified as electrical and electronic equipment; as many as 13 of these are broadly defined as electro-waste, four of which are no longer working, nine of which are not in use. The most commonly kept categories of electro-waste are: (Stradowski, 2022)

- small consumer electronics and accessories (e.g. headphones, remote controls),
- small household appliances (e.g. clocks, irons),
- small computer hardware (e.g. external hard drives, routers, keyboards, mice),
- mobile phones and smartphones,
- small food preparation appliances (e.g. toasters, grills).

Statistics on the global e-waste problem have been presented since 2014 in the Global E-Waste Monitor report overseen by the United Nations. The growth rate of e-waste is very high - it is one of the fastest growing waste streams. In 2019, the world generated 53.6 million tonnes of e-waste - an average of 7.3 kg per capita. This is an increase of almost 20% in five years. At the same time, the percentage of e-waste that we collect and recycle has increased globally from 17 to 17.4%. E-waste generation is expected to increase to 74.7 Mt in 2030 and reach as much as 110 Mt in 2050 unless we change our practices (*The Global Transboundary E-waste Flows Monitor 2022*).

One of the important issues concerning the generation of electro-waste is consumers' purchasing habits and behaviour. This problem will be discussed using the example of smartphones, which are among the most popular and most frequently purchased electronic products. According to IDC (International Data Corporation), 11.3 million mobile phones were sold in Poland in 2021, of which 10.9 million were smartphones. Compared to 2020, this was an increase of 27.6% for smartphones. In value terms, sales increased by 48.5%, as customers were more likely to choose devices at the higher end of the price spectrum (*Polski rynek smartfonów trzyma się mocno na tle osłabionego regionu.* 2022.07.14.).

In 2022, Deloitte surveyed Polish consumers on purchasing trends for the most popular electronic devices, including smartphones. It turns out that the vast majority of respondents (89%) choose a new rather than a used or refurbished device when buying a smartphone (Figure 2).

[2] The survey covered 8775 households from Portugal, the Netherlands, Italy, Romania and Slovenia, as well as the UK.

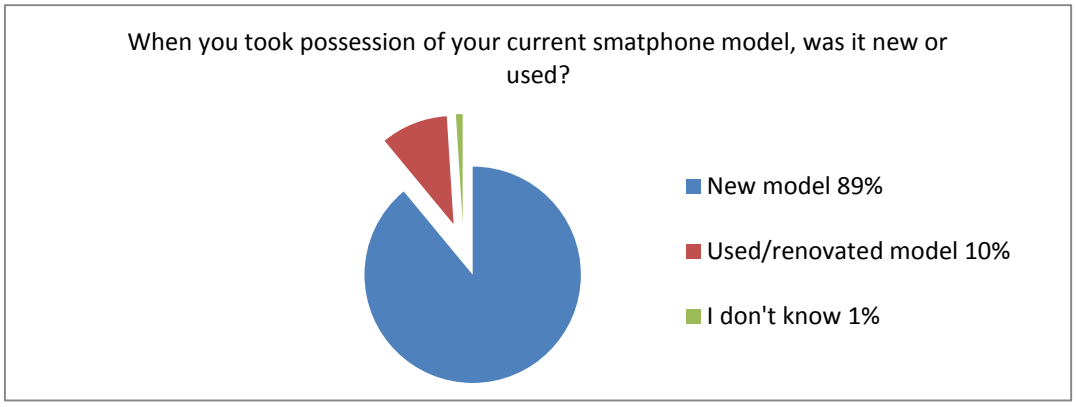

Figure 2. Acquisition of new and used smartphone models.

Source: *Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 27.

Only in the youngest age group is the percentage of people owning second-hand or refurbished appliances higher, at 14% (compared to an average of 10%). This may be due to the lower financial capacity of this group and the passing on of older models within the family.

Respondents explain their decision by a lack of trust in sellers of used or refurbished appliances, the longer lifespan and greater reliability of a new appliance (Figure 3).

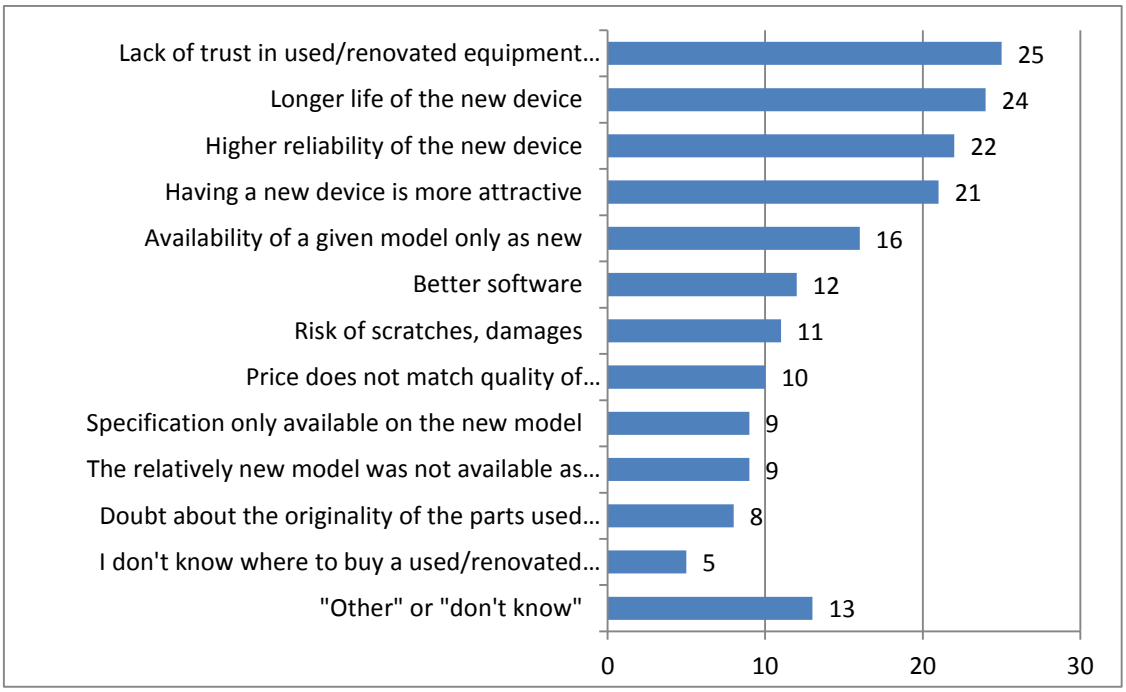

Figure 3. Factors for choosing a new phone model.

Source: *Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 31.

In contrast, when buying a new model of phone, they are primarily guided by: battery life, memory capacity and processor speed (Figure 4).

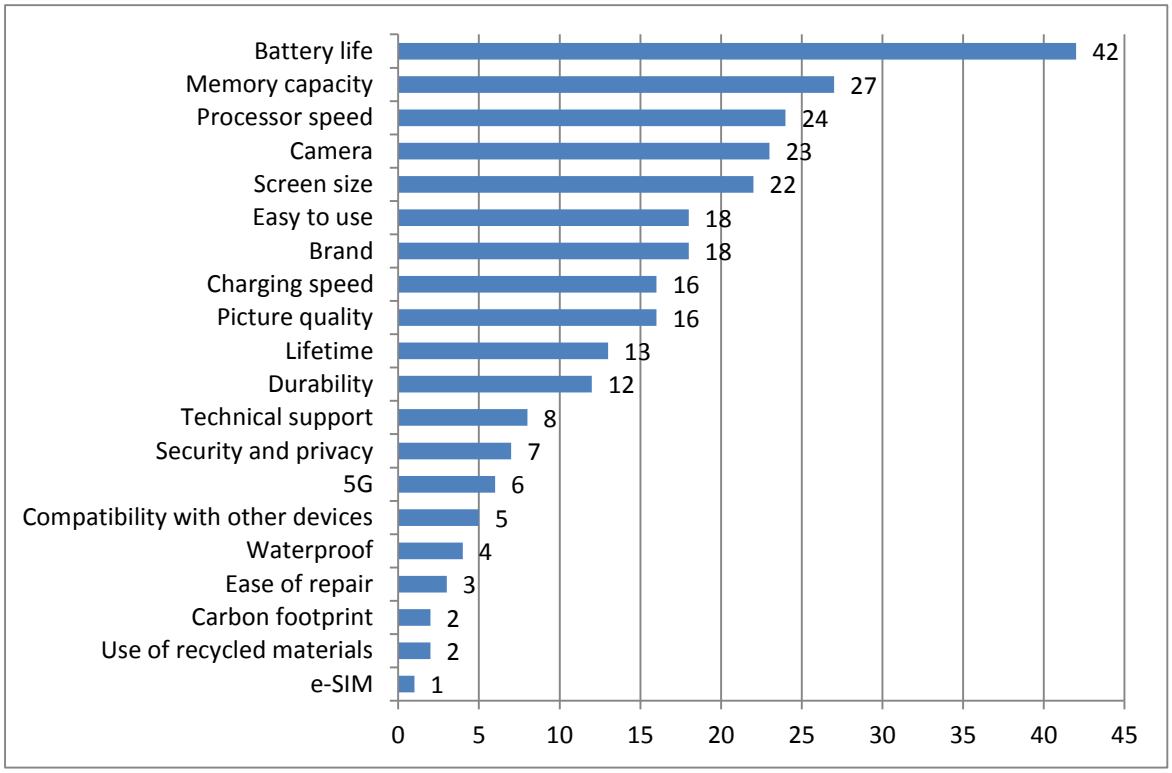

Figure 4. Priorities when choosing a new phone model.

Source: *Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 31.

Respondents do not really know what to do with their old smartphone. The highest percentage of respondents (43%) keeps the old phone as a spare, 19% give it to family or friends, only 18% sell it. Only 3% recycle their old model for free (Figure 5).

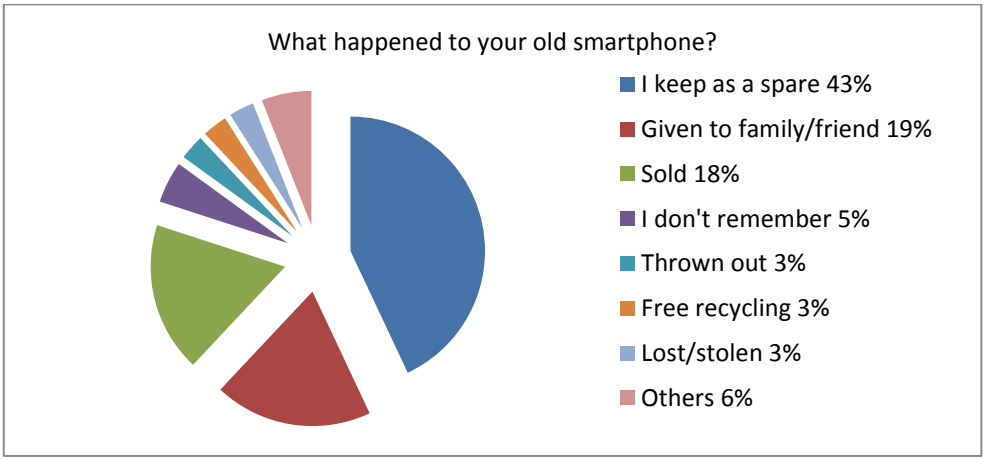

Figure 5. Fate of the old telephone.

Source: *Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 27.

WEEE Forum research shows that consumers do not recycle or reuse unnecessary electronic devices for the following reasons: (Stradowski, 2022)

- I might reuse it in the future (46%),
- I intend to sell or give it away (15%),
- it has sentimental value to me (13%),

- it may have value in the future (9%),
- I don't know how to get rid of it (7%).

The issues of the negative environmental impact of electronic devices are far less important to consumers at the time of purchase than for other products, such as organic food or clothing, for example. This is probably due to the nature of electronic equipment, the many technical parameters that need to be taken into account when making a purchase. Only slightly more than 1/3 of respondents declare their willingness to purchase an electronic device with a lower carbon footprint despite the higher price (Figure 6).

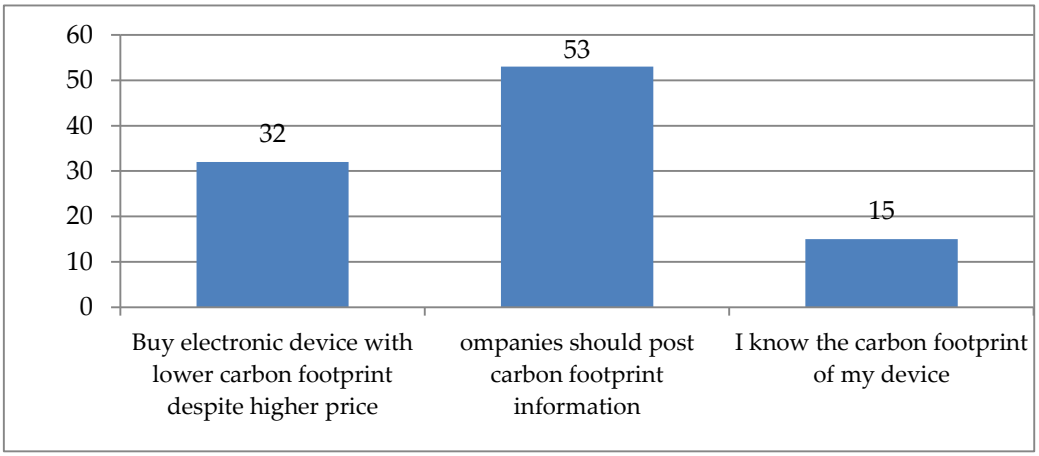

Figure 6. Respondents' attitudes towards their carbon footprint.

Source: *Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 31.

A small percentage of respondents (15%) know the carbon footprint of their device, i.e. they are aware of the harmfulness of electronics and take an interest in this. More than half of respondents believe that companies should post information about the carbon footprint of their electronic products. The above opinions are independent of age, only when asked about knowing the carbon footprint of their phone is definitely higher among younger respondents aged 18 to 20

Although the majority of respondents believe that companies should include information about the carbon footprint of their products, but only 30% have confidence in the information provided. According to the Deloitte Sustainabilty Survey, almost 60% of technology companies surveyed in Poland said they count their carbon footprint and 37% plan to monitor this indicator (*Digital Consumer Trends 2022, Deloitte, październik 2022*, p. 32).

According to the research presented, the problem of electro-waste is exacerbated by the attitudes and behaviour of consumers, who purchase newer and newer models of equipment, are reluctant to use second-hand products, are unaware of their harmfulness and do not know what to do with used equipment.

5. How to reduce excessive consumption of electronics?

The growing and ultimately excessive demand for electronic devices that generate a carbon footprint that is harmful to the environment is the result of several overlapping reasons. Firstly, it is a consequence of consumers' attitudes and behavior and the increase in their wealth. As the presented research shows, buyers prefer to buy new devices due to their longer life and better quality (reliability), but also because of the lack of trust in sellers of used or refurbished equipment. Since they buy new, more expensive models, it can be concluded that they have higher incomes. Although almost 1/3 of surveyed consumers declare their willingness to pay a higher price for a device with a lower carbon footprint, the vast majority of respondents do not know the carbon footprint of their device. Secondly, the objective reason is the very dynamic technical progress in recent years, the development of digital technologies and Industry 4.0, driven by growing competition on a global scale. Therefore, companies aiming to maximize their profits gradually improve their technologies and introduce new product models to the market. Thirdly, manufacturers of electronic devices rarely include information on their products about their harmfulness and carbon footprint, which does not help improve consumers' ecological awareness. In addition, greenwashing is a common practice, i.e. manipulating information and intentionally misleading recipients about the actual impact of the product on the natural environment, which additionally confuses and frustrates buyers (Szabo, Webster, 2020). In the context of these complex causes, the question arises whether and how the negative environmental effects of excessive demand for electronic devices can be reduced.

By analyzing the nature of the causes and conditions of excessive consumption of electronic devices, several basic directions of action can be indicated to reduce it, namely:

1) disposal and recycling, enabling the recovery of valuable raw materials by implementing a closed-loop economy (circular economy);
2) improving products to make them less harmful to the environment through eco-design and extending their life cycle;
3) educating consumers on the principles of sustainable consumption.

A circular economy is postulated as part of the Sustainable Development Goal - Sustainable Production and Consumption (SDG 12). The implementation of such an economy requires taking actions to increase the efficiency of the use of resources and raw materials by minimizing waste and the use of waste from one production process to another. Waste electrical and electronic equipment contains many valuable elements that can and should be recovered to a much greater extent than currently. According to data from the World Economic Forum (WEF) report "A New Circular Vision for Electronics: Time for a Global Reboot", in the case of iron, cobalt or nickel, recycling rates may exceed even 50%, and in the case of lithium (important for battery production) it does not exceed 1%, and in relation to mercury, which is harmful to the environment and human health, it is between 1% and 10% (*Od odpadu do*

zasobu. Zużyty sprzęt elektryczny i elektroniczny w ekonomii cyrkularnej. *Międzynarodowy Dzień bez Elektrośmieci. 13 października 2022*). The implementation of the principles of the circular economy requires a change in the business models of enterprises, which should be stimulated by administrative instruments (international standards, guidelines of international organizations and institutions, such as UN or EU agencies) and economic instruments (policies at the level of nation states).

The second line of action is to improve electronic products to make them more environmentally friendly and extend their service life. The National Waste Management Plan 2028 indicates three actions that are of key importance for preventing the generation of waste electronic equipment: eco-design, extending the life of the product, the possibility of its repair and modernization (*Krajowy plan gospodarki odpadami 2028*). One of the most important activities is ecodesign, which involves taking into account ecological aspects at the stage of project development, selection of raw materials, materials, energy needs and determining the durability of the product (Burchart-Korol, 2010). Actions taken at this stage also determine the life cycle length and possibilities of repairs and modernization of devices. The postulated activities are also the responsibility of enterprises, although they can and should be supported by the state and social organizations, including consumer organizations.

The third direction of action is more effective and efficient education of consumers in making them aware of the harmfulness of electronic devices, the need to dispose of them, and encouraging them to share. The National Waste Management Plan 2028 formulates the following five information and educational activities aimed at shaping conscious consumer attitudes regarding: (*Krajowy plan gospodarki odpadami 2028*)

1) choosing more durable devices,
2) understanding the labeling used on products,
3) knowledge of the principles of proper use of equipment,
4) using repair services,
5) transfer waste electrical and electronic equipment to designated collection points.

Many authors point to the important role of sustainable marketing in consumer education, which, as a pro-social discipline, should shape a new way of thinking resulting in pro-ecological market choices (Haider et al., 2022). Generally, consumer education should be aimed at changing the lifestyle and value system so that consumption and the possession of goods are not a goal or a measure of social status, but a means to achieve more non-consumptive goals. It is worth noting that in recent years there has been a change in consumer attitudes and behaviors, especially among younger groups of consumers who reject traditional patterns of excessive consumption and prefer minimalism, the principles of ecology and sustainable development. According to the principles of the sharing economy, they use and share goods together, using modern tools such as the Internet and social media (Szymańska, 2017).

The implementation of the proposed courses of action requires the involvement and cooperation of three parties: enterprises, consumers and the state, which create a specific "triad" of sustainable development (Figure 7).

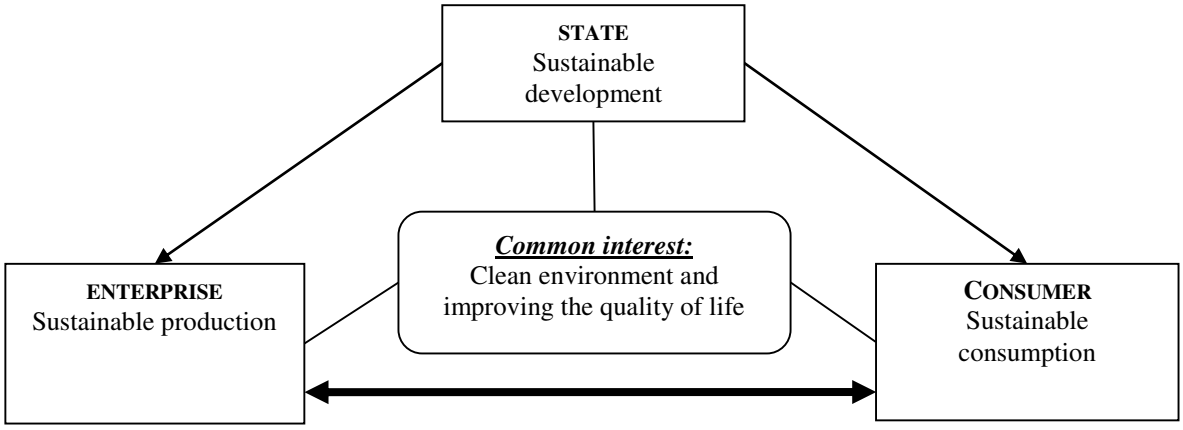

Figure 7. The concept of the "triad" of sustainable development.

Source: Szwajca, 2018, p. 474.

By implementing the principles of sustainable production, enterprises can use resources more effectively, limit environmental degradation, produce ecological products, ensuring profit. Consumers, applying the assumptions and postulates of sustainable consumption, can better and more rationally satisfy their needs, maintaining a clean environment and securing resources for themselves and their successors. However, by pursuing a policy of sustainable development, the state can ensure environmental protection, economical management of resources, public education and the pace of economic development, ensuring an adequate standard of living for current and future generations. The common interest of these entities is to maintain a clean natural environment and improve the quality of life of citizens. A special role in this triad is played by the state, which has many instruments at its disposal to influence enterprises and consumers, ranging from information, educational and promotional activities, through active cooperation, fiscal policy instruments, to legal regulations in the form of orders and prohibitions. The state can therefore perform educational, motivating, integrating and coordinating functions, becoming a kind of "transmission belt" between production and consumption in the implementation of sustainable development goals (Szwajca, 2018). Enterprises and consumers can also stimulate each other: enterprises through the production and promotion of ecological products and the application of sustainable marketing principles, and consumers through their purchasing decisions and various types of actions (including boycotts) with the support of non-governmental and social organizations and international institutions (Karimova, LeMay, 2022).

Finally, it should be stated that the problem of limiting excessive demand for electronic equipment is only one element of the pursuit of sustainable consumption. This is a global challenge for modern societies, governments and policy-makers. Mont et al. (2022) suggest that sustainable consumption can be achieved through three strategies: (1) to reduce consumption,

(2) to change consumption, (3) to improve consumption, implemented with the involvement and cooperation of many social groups and environments at the international level. According to some, achieving the goals of sustainable consumption is only possible by limiting the rate of economic growth (Kallis et al., 2019). However, it seems that a complete solution to this problem is not possible in the context of the dynamic development of civilization, the current lifestyle and valued values - it is a deeper problem of a philosophical nature.

6. Discussion and conclusions

n recent years, there has been a growing demand for electronic devices on the Polish market. This is the result of very rapid technical progress, an increase in the income of real buyers and the desire of producers to increase sales profits. An additional factor was the pandemic, which forced consumers to purchase electronic equipment (mainly computers, laptops, smartphones) enabling learning, professional activity or dealing with various matters remotely. Growing demand and the increasingly shorter life cycle of electronic products generate large amounts of e-waste, which is very harmful to the environment and at the same time difficult to dispose of. The problem of e-waste is a very difficult challenge in the light of the implementation of the sustainable development goals adopted by Poland under the UN Resolution of 2015. This is especially true of goal no. 12: sustainable production and consumption, which is one of the most slowly and not very effectively implemented of the 17 adopted goals.

One of the reasons for this state of affairs is the low ecological awareness of Polish consumers regarding electronic products. According to research, they do not have sufficient knowledge about the harmfulness of e-waste. Consumers buy organic food more often and willingly because they notice its direct impact on their health and physical condition, while when buying durable goods, including electronic equipment, they are not fully aware of their negative impact on the climate and the natural environment. Only a small percentage of surveyed Poles (about 15%) know that products such as smartphones leave a carbon footprint. These are mainly young people, more ecologically aware and sensitive. Moreover, manufacturers do not fully inform consumers about the harmfulness of electronic devices in order to increase sales, and they also deliberately mislead by using greenwashing.

In order to reduce excessive consumption of electronics, the article proposes three courses of action:

- disposal and recycling within the circular economy,
- "greening" of products through eco-design and extending the life cycle,
- consumer education towards sustainable consumption.

The implementation of these activities requires coordination and cooperation of three entities: enterprises, consumers and the state, cooperating within the so-called "triads" for sustainable development. The leading role should be played by the state, which has the most effective instruments to influence other entities.

Finally, it should be stated that the problem of limiting excessive demand for electronic equipment is only one element of the pursuit of sustainable consumption. This is a global challenge for modern societies, governments and policy-makers. Mont et al. (2022) suggest that sustainable consumption can be achieved through three strategies: (1) to reduce consumption, (2) to change consumption, (3) to improve consumption, implemented with the involvement and cooperation of many social groups and environments at the international level. According to some, achieving the goals of sustainable consumption is only possible by limiting the rate of economic growth (Kallis et al., 2019). However, it seems that a complete solution to this problem is not possible in the context of the dynamic development of civilization, the current lifestyle and valued values - it is a deeper problem of a philosophical nature.

The considerations and proposals for reducing the problem of e-waste presented in the article contribute to the discussion on controversies related to the implementation of the principles of sustainable development in the context of technological progress and the pursuit of enterprises to maximize profits. They also have social management implications, as they indicate the directions of activities of government institutions, enterprise management boards and consumer organizations.

The limitation of the conducted research is the narrowing of the analysis to the Polish electronic market and the reliance on secondary data, without conducting our own empirical research. However, the article can be used for international comparisons and may also serve as an inspiration to conduct further research on the topic. Research on the effectiveness and efficiency of activities undertaken in Poland and other UN member countries to implement the sustainable development goals seems to be particularly important.

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ANALYSIS OF PUBLICATIONS ON DECISION-MAKING STRATEGIES IN HIGHER EDUCATION INSTITUTIONS

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Purpose: The aim of this article is to present analysis literature interested in decision-making strategies in higher education institutions. Author keywords contained in the publications were analysed to show links between them and present recent interested areas of strategies in higher education.
Design/methodology/approach: Analysis based on bibliometric data of world literature published in Web of Science and Scopus. The study included a quantitative analysis of publications. The results are presented in tables, graphs and figures.
Findings: The successive part of the publication analyses the 4125 documents in Web of Science and Scopus. Based on the 2886 documents searched in Scopus, author keywords were analysed and connections between them were visualised (software support visualisations). The study identified an increase in interest in topics such as “sustainability”, “instructional strategies”. The analysis of publications interested in strategies, higher education institutions and decision-making showed that 57 publications met the defined search criteria. Only 12 of these were published up to 2012, while the remaining 46 were published in the last 10 years. Recurring author keywords in recent publications are: "strategic management", "strategic decision-making", "strategic decisions". Earlier publications have also included such keywords as “innovation”, “sustainabililty”, “information systems”, “knowledge management”.
Research limitations/implications: Research based on two literature bases, limited to English language. Next step of research can be made in all languages ang more publication bases. The study focuses on quantitative analysis of publications based on author keywords. The research should be expanded of a detailed and qualitative analysis of the publications found and their evaluation in terms of strategies in university decision-making. It would be reasonable in the analysis and interpretation of the results obtained to group or standardize the keywords used in publications, e.g. “decision making” and “decision-making”.
Originality/value: Paper presents bibliometric analysis of publication interested on strategies in higher education institutions decision-making. The analysis has made it possible to identify trends in the literature based on author keywords. The results of the survey shows the growing interest strategies in decision-making in higher education institutions.

Keywords: Decision-making, strategies, higher education institutions, universities.

Category of the paper: Literature review.

1. Introduction

There is no doubt that higher education organizations has strategic importance for society. Given the size of universities in Poland, the vast majority of them qualify for such management, as is the case in large companies (Popławski 2016, p. 423). Even the largest universities are managed by eminent scholars of various specialties and management is intuitive, generally ignoring the methods and techniques used in large business organizations (Dominiak, Leja, 2016, p. 27). Studies carried out in Polish universities showed the problem in the implementation of the strategy and its low usefulness in management (Zeller, 2011; Piotrowska-Piątek, 2015; Popławski, 2016). Antonowicz (2021, p. 22) in his report on the management of research universities, finds that in Polish higher education a substitute for such thinking is created by IDUBs (Excellence initiative - research university). This publications indicate the need for interest in this topic and practical application in higher education.

Recognizing this gap in the Polish literature while finding in it a justification for the need to improve the strategies in decision-making in management of higher education, the author undertook an analysis of the international literature in this area.

The main purpose of article is to analyze of strategies and decision-making in higher education institutions publications. To achieve this goal, a bibliometric analysis was used. Bibliometric analysis implies the quantification of documentary streams of information and the use of quantitative indicators of various databases, reflecting the state of science or its individual fields (Marszakowa-Szajkiewicz, 2009). The use of this method made it possible to conduct a literature review and identify trends in the literature based on author keywords.

2. Methods

The aim of this article is to present the results of a bibliometric analysis of publications meeting certain criteria in scientific publication databases. A diagram of the research procedure carried out is shown in Figure 1.

The analysis was carried out in two stages of work. The first stage was completed in June 2023 with the identification and definition of keyword search queries. Based on the literature review and the keywords used in terms of: strategies, higher education, decision-making.

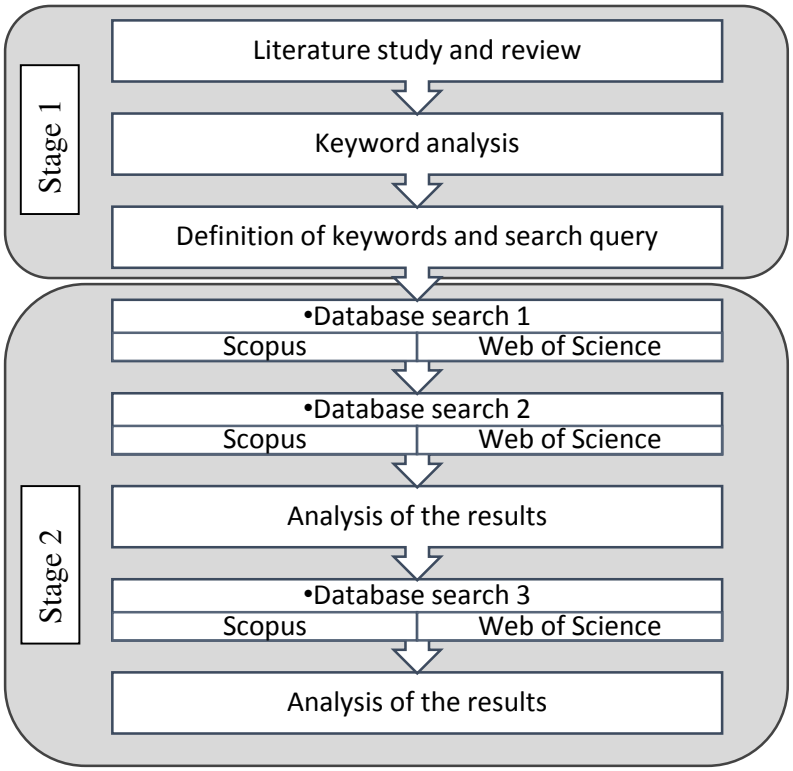

Figure 1. Scheme of the research procedure.

Source: author's own study.

The next stage (conducted in September 2023) of the research was to search the databases for selected author keywords. The analysis began with a search for publications in English in two bases: Scopus and Web of Science. The second search was conducted containing strategies and higher education institutions. Based on the results, a quantitative analysis of the publications, an analysis over time and a keyword correlation analysis were carried out. Using a spreadsheet and a visualisation tool, the results were analysed and presented in the results chapter 3.1. The next step was to deepen the analysis indicated to publications containing decision-making. The results obtained in each database were compared and analysed using a spreadsheet and visualisation tool. Section 3.2 describes the results obtained. The results were illustrated with graph, tables and visualisation views. The analyses carried out focused on quantitative analysis of usage in publications from author keywords over time. This analysis identified areas of interest in publications and their variability over time.

3. Results

First step of publication analysis was carried about language. The search identified the English language of publication as the most popular and widely used language in internationally recognized journals. In both analyzed bases English dominates and it represents more than 95%

of publications (Vera-Baceta, Thelwall, Kousha, 2019, p. 1806). The results were even greater in a survey conducted on 26.09.2023. In Scopus base more than 99% documents has English language 81,129,747 of 81,735,805 (filter on language: English). In Web of Science it is not possible to search the database for all English-language publications. It is necessary to add an additional query. Adding "1" to the search resulted in 97% having English language (22,387,118 out of 23,156,894). Further steps in searching and analysing data are described in the following subsections.

3.1. Strategies in higher education institutions

The first research topic was about strategies. There are a lot of variations to find strategies in the analysed publications: strategies, strategic, strategic planning, etc. It was decided to use the phrase "strateg*", which includes all these possibilities (using the "*" mark for wildcard search). Table 1 presents the search parameters for English-language publications and strategies.

Table 1.
Search parameters for English-language publications and strategies

	Web of Science	**Scopus**
Advance search query	AK=(strateg*) AND LA=(English)	AUTHKEY ("strateg*") LIMIT-TO (LANGUAGE , "English")
Results	186,793	229,881

Source: author's own study.

Finding keywords about higher education institutions was more complicated, authors use different phrases: higher education, universities, education in author keywords. For better fitting and narrowing for higher educations it was decided to use two phrases interchangeably in the search: "higher education" and "universit*" (for wildcard search to account for different variations: universities, university). Table 2 presents the search parameters for English-language publications and strategies in higher education. 2,619 publications (using a total of 16,885 keywords) meeting the criteria were found in the Web of Science database. In the Scopus database, 2,886 publications and 19,886 keywords were found.

Table 2.
Search parameters for English-language publications and strategies in higher education

	Web of Science	**Scopus**
Advance search query	AK=(strateg*) AND LA=(English) AND (AK=(higher education) OR AK=(universit*))	AUTHKEY ("strateg*") AND AUTHKEY ("higher education" OR "universit*") AND (LIMIT-TO (LANGUAGE , "English"))
results	2619	2886
Total number of occurrences of author keywords	16,885	19,366

Source: author's own study.

A comparative analysis of the results obtained for the individual databases showed a duplication of 1353 items in the Web of Science database. The sum of publications from both analyzed databases concerning strategies and higher education institutions was 4152. The analysis of publication years in figure (Figure 2) shows a dynamic increase over the last 20 years.

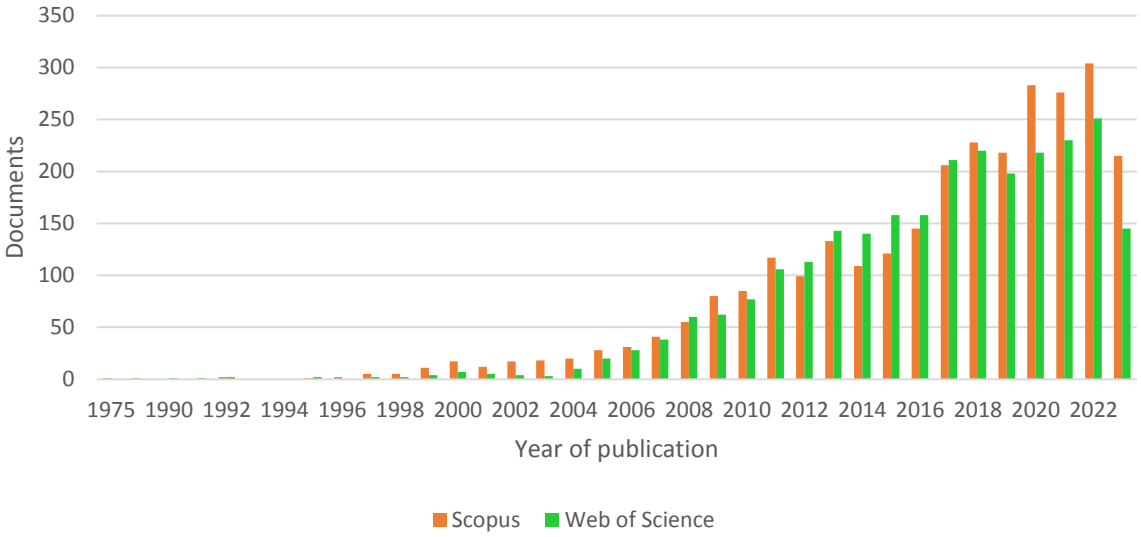

Figure 2. Comparison of the number of publications found in Scopus and Web of Science databases. Source: author's own study.

Among the publications found 67% were Articles, 16% Proceedings Paper, 10% Conference paper (Table 3).

Table 3.
Number of publications by type of publication

Article	Proceedings Paper	Conference paper	Book chapter	Other
3185	782	395	154	359

Source: author's own study.

In the next step of the study, linkage analysis was performed using VOSviewer to visualise the networks between keywords. The creation of a linkage map requires the import of data extracted in the appropriate format from the selected bibliometric database. The system analysed 8905 keywords from 2886 publications. To visualize the data, the minimum number of occurrences was defined as 10. The system identified 211 thresholds (Figure 3).

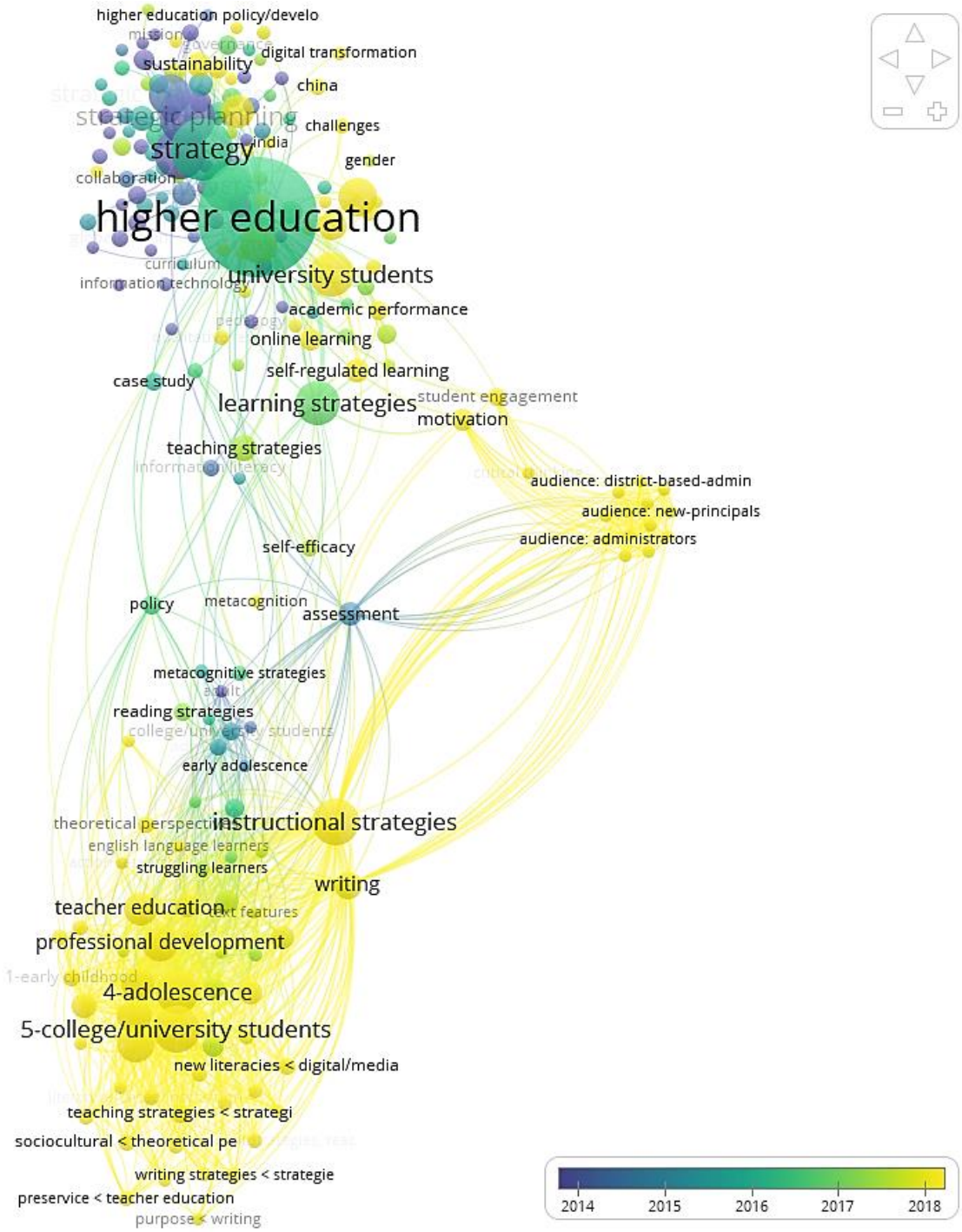

Figure 3. Overlay visualization of networks between keywords of 2886 publications from Scopus base by years.

Source: author's own study.

Analysis of the database allowed the number of occurrences of individual keywords to be determined. "Higher education" were used as a author keyword in 922 publications and next 480 times was element of phrase ("higher education institutions" 91, "higher education management" 10), next "strategy" 256 times, "strategic planning" 199 times, "universities" 167, "university" 165, "instructional strategies" 142. Figure 3 shows the results of the analysis in the form of a visualisation. In the image below, the colours indicate the years of appearance:

the lighter the colour, the greater the number of recent publications with the keyword. The visualisation makes it possible to assess trends in the occurrence of specific keywords in specific years, thus allowing to identify trends in the areas of interest of the publications under study over time. In recent years, there has been a clear increase in interest in topics such as "sustainability": 127 appearances since 2000, including 90 since 2018, or "instructional strategies" 100 appearances since 2008, including 71 since 2018. "Innovation" has appeared in keywords in 162 publications, 127 of them in last 10 years. "4-adolescence" has appeared 121 times, but most publications were from 2017-2020 (98 which is 80%).

The oldest publications found that meet the criteria are from 1975 (Forward, Wells, Canter, Waggoner, 1975) and 1989 (Chapelle, Mizuno, 1989) both of which deal with students rather than university organisations. Two other publications were related to universities, but did not deal with issues of interest to this study (Potworowski, 1990), (Heiskanen, 1991). It was necessary to conduct a search that took into account the issue of decision-making, which is described in the next subsection.

3.2. Strategies in higher education institutions decision-making

Identification of publications related to decision-making required modification of the search. Query had to take include various phrases related to the issue of decision-making. Therefore, the decision was taken to use the phrase "decision*" which would take into account the later forms of writing ("decision making process", "strategic decisions", "decision analysis", "decision process" etc.). Table 4 presents the used advance search query and given results in Scopus and Web of Science.

Table 4.
Search parameters for English-language publications and strategies in higher education

	Web of Science	**Scopus**
Advance search query	AK=(strateg*) AND AK=(higher education) AND AK=(decision*) AND LA=(English)	AUTHKEY ("strateg*") AND AUTHKEY ("higher education" OR "universit*") AND AUTHKEY ("decision") AND (LIMIT-TO (LANGUAGE , "English")
Results	24	57
Total number of occurrences of author keywords	152	317
Number of used author keywords	100	242

Source: author's own study.

Search gives 57 documents found in Scopus and 24 in Web of Science, mostly after 2000 year. The number of publications by years is shown in Figure 4. By comparing the results obtained, it can be concluded that all 24 publications searched in Web of Science are included in the 57 publications meeting the criteria set in Scopus. A keyword analysis was therefore carried out on these 57 publications. Total number of occurrences of author keywords was 317. Number of used author keywords was 242.

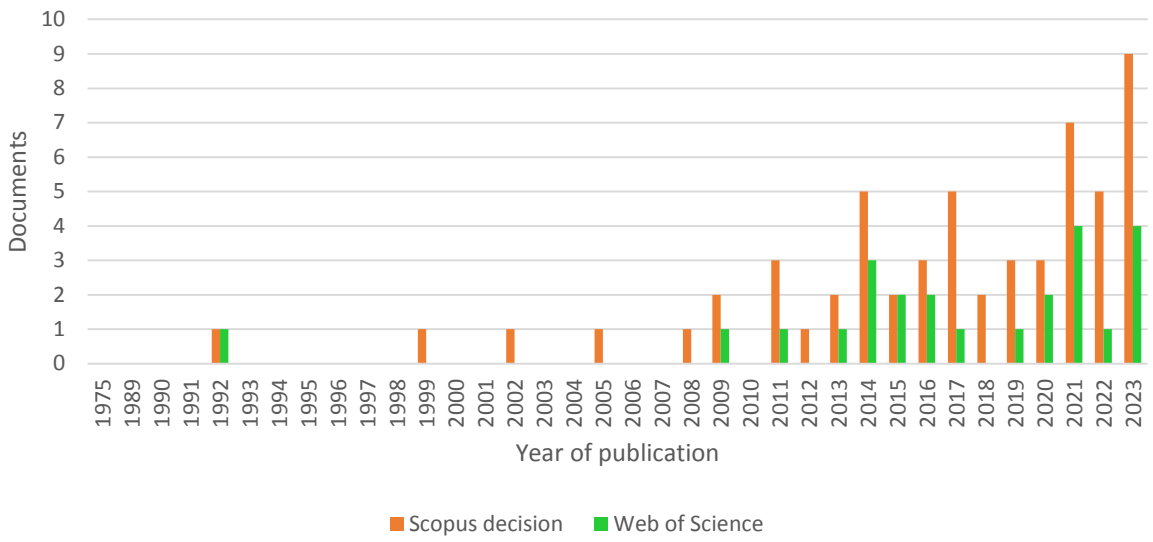

Figure 4. The number of publications found in Scopus and in Web of Science that included the term "decision".

Source: author's own study.

The oldest publication meeting the search criteria dates back to 1992 (Shipley, MF). Another publication was not issued until 1999 (Milton-Smith, Schmidenberg, Klass, 1999). Both publications dealt with the subject of decision support systems which appeared in 3 other publications (Ibrahim, Sundgren, Larsson, 2014; Akhmetov et al., 2018; Zagrajek et al., 2023). By 2012, there were only 11 publications addressing topics in decision-making, strategy and higher education institutions simultaneously. In the last 10 years, 46 publications have been published in this area. The largest number of results is from 2023 (9 publications), despite the study was conducted during its duration, which means that the number of papers meeting the selected criteria is likely to be much higher (especially given the delays in adding publications to the database, the length of publication cycles). The results of the survey shows the growing interest in the topics covered in this publication.

Linkage analysis was performed using VOSviewer to visualise the networks between author keywords for these 57 publications. The Figure 5 shows every single author keyword combination in the publications by years.

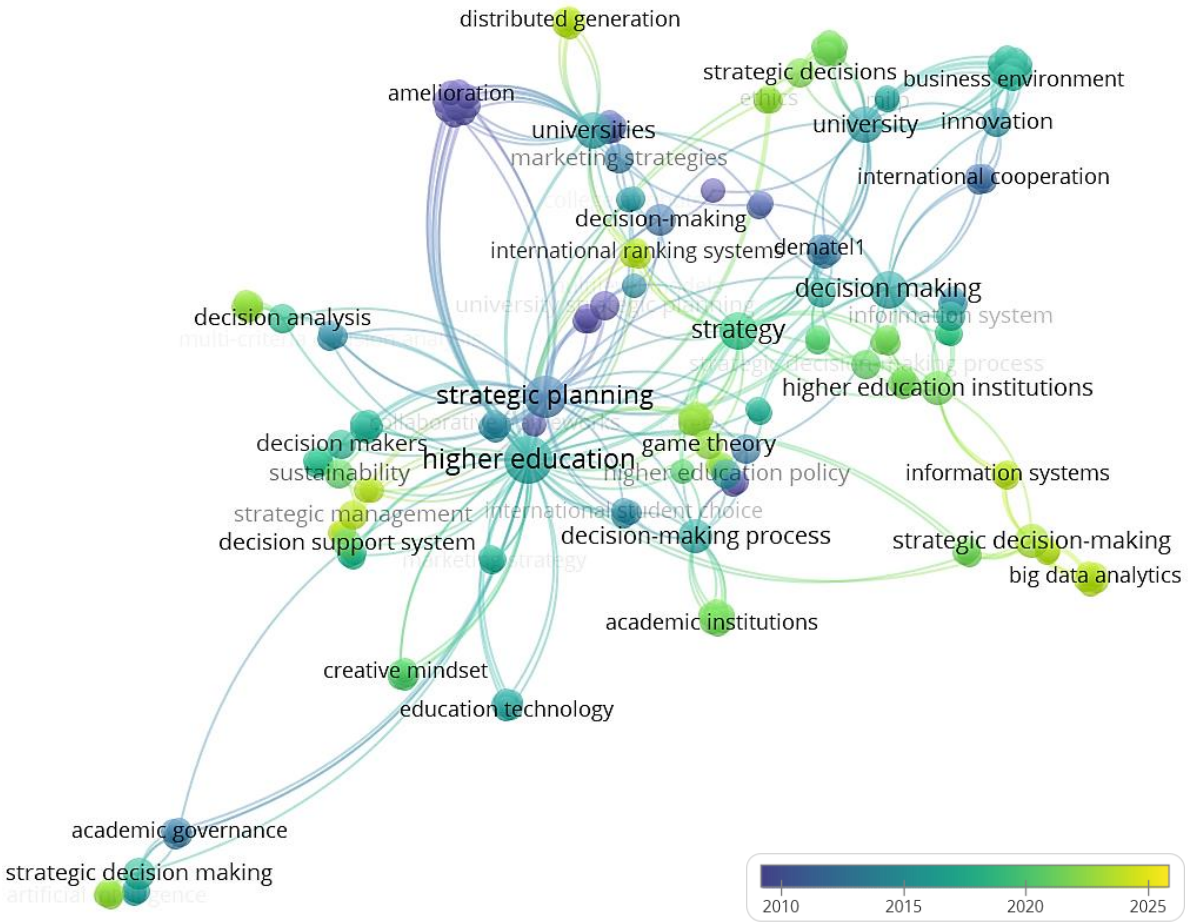

Figure 5. Overlay visualization of networks between 57 publications, 242 keywords base by years. Source: author's own study.

Due to the diversity of keywords and the desire to find links between them in publications, it was decided to generate a visualization showing the links of keywords occurring a minimum of two times. This narrowed the number of keywords to 30. The visualization of links is shown in Figure 6. In the visualization shown, it can be seen that several other keywords reflecting the areas of interest of the authors of the research and publications appeared among the publications in the fields of strategy, decision-making and universities. Issues related to "game theory" were included in 2 of the 57 publications surveyed. Interestingly, in terms of 4125 publications from both analyzed databases concerning strategies and higher education institutions, "game theory" were included in 4. Other keywords recurring in recent publications are: "strategic management", "strategic decision-making", "strategic decisions". Earlier publications have also included such keywords as "innovation", "sustainabililty", "information systems", "knowledge management".

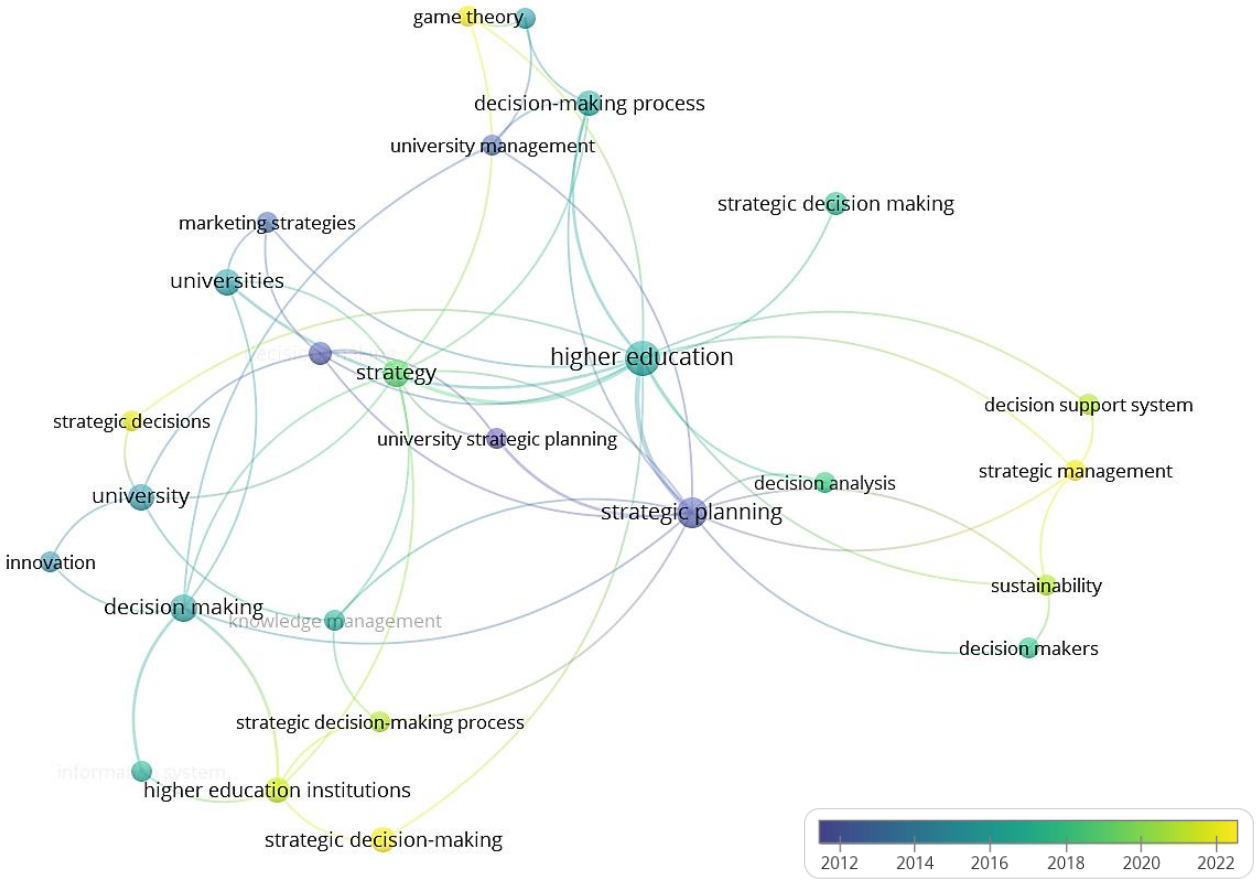

Figure 6. Overlay visualization of networks between 57 publications, 242 keywords (occurring a minimum of two times) base by years.

Source: author's own study.

4. Discussion

A preliminary analysis of the literature revealed the need for interest in decision-making strategies and their practical application in higher education in Poland. Recognising this gap in the Polish literature and at the same time justifying the need to improve decision-making strategies in higher education management, the author undertook an analysis of the international literature in this area. A systematic literature review using bibliometric analysis revealed a lack of similar studies in the literature. Therefore, a research gap was identified and the study is a contribution to scholarship. It is difficult to refer to similar studies as no such studies were found in the literature.

The study is a comprehensive literature analysis of the Scopus and Web of Science databases for the specified author keywords. It shows a growing interest in the topics covered and makes it possible to identify time trends in the topics covered. The study focuses on the quantitative analysis of publications based on keywords. The next stage of the research should

consist of a detailed qualitative analysis of the publications found and their evaluation in terms of strategies in university decision-making.

An analysis of 57 publications showed different keywords with the same meaning were used. Various publications have used the phrases: "decision making", "decision-making", "decision-making process", which all mean the same thing. The same meaning also applies to "university" and "universities". Although they are included in the search, they are shown separately in the visualisation. It would be reasonable in the analysis and interpretation of the results obtained to group or standardize the keywords used in publications.

5. Summary

The study finds 2619 publications (with a total of 16,885 keywords) in the Web of Science database, and 2886 publications in the Scopus (with 19,886 keywords) in English-language publications concerning strategies and higher education institutions in the author keywords. The sum of publications from both analyzed databases was 4,152 (comparative analysis showed a duplication of 1353 items). Based on the analysis, it is possible to indicate an interest in the topics as "sustainability", "instructional strategies", "innovation", "4-adolescence".

Deepening the analysis to publications that also included the issue of decision-making resulted gives 57 documents found in Scopus and 24 in Web of Science, mostly after 2000 year. All publications searched in Web of Science are included in the publications meeting the criteria set in Scopus. Therefore, 57 publications were analyzed. 81% of publications addressing the topics of decision-making, strategy and higher education institutions at the same time, were published after 2012. By September 23 in 2023, 9 items on this topic had already been registered in the publication databases. The results confirm the increasing interest in the topics taken up. Earlier publications have also included such keywords as "innovation", "sustainabililty", "information systems", "knowledge management". In recent publications, the most common keywords are: "decision support system", "strategic management", "strategic decision-making", "strategic decisions", "game theory". Thus, it can be pointed out that these keywords indicate the current areas of research interest for scientists.

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PROGRAM GOVERNANCE: OVERVIEW OF PROGRAM MANAGEMENT STANDARDS

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Purpose: This article aims to conduct a thorough analysis of program governance, considered from multiple perspectives. Despite the extensive literature in the field of program management, there is a clear knowledge gap in understanding program governance and the effectiveness of various tools for its assessment, which limits the understanding of their practical usefulness.
Design/methodology/approach: The article is cross-sectional, based on a literature review and desk research technique.
Findings: The cross-sectional approach and literature review employed in this study have enabled a comprehensive understanding of program governance. Furthermore, the analysis of program governance assessment models has revealed a methodological shortfall in developing a complete approach that would provide comprehensive recommendations for improving governance processes.
Originality/value: The article discusses both the role and significance of program governance in the program management process, key areas, and models for evaluating program governance.

Keywords: Program governance, program management, program context, assessment models.

Category of the paper: General review

1. Introduction

In the face of increasing complexity and rapid changes in the global business environment, program management takes on crucial significance (Yan et al., 2019) as a tool enabling organizations to achieve strategic goals and maintain competitiveness (Hu et al., 2015). Program management encompasses actions taken to coordinate the organization, direct, and implement a set of projects that collectively lead to the attainment of strategically significant benefits (Trzeciak, 2023b).

For most organizations, a program constitutes a significant undertaking (Stretton, 2020), involving substantial financial investments and significant change. Furthermore, the organization's strategy and policies that underlie the program are both influenced by and influence the internal and external environment (Stellingwerf, Zandhuis, 2013). Moreover, a program often confirms or questions strategic analyses and the resulting conclusions. To achieve this, a program must be enduring yet flexible to meet strategic requirements (Ritson et al., 2012). Hence, there is a need to maintain close alignment with the dynamic organization's strategy, both at the program level (Martinsuo, Hoverfält, 2018) and its component projects (Rijke et al., 2014). Secondly, a program should establish a functioning environment that is both robust and sufficiently adaptable to deal with frequent, sometimes radical changes in its boundaries (Trzeciak, 2023a). Therefore, it is essential to ensure an effective flow of feedback from programs to those responsible for the strategy (Turkulainen et al., 2015). This enables them to refine future strategies based on facts and data gathered from programs.

Such a developed system is defined in the literature as program governance, encompassing a set of principles, processes, and structures aimed at directing and controlling programs. This governance framework plays an invaluable role in ensuring that program initiatives are executed efficiently and in alignment with stakeholder expectations (Khatib et al., 2023; Zhai et al., 2017). Furthermore, in the face of the ever-evolving business environment, program governance becomes a key mechanism enabling organizations to adapt to changes and capitalize on new opportunities (Derakhshan et al., 2020). The essence of program governance lies in creating a structure that facilitates effective management of complex initiatives that go beyond traditional project boundaries. By integrating principles, processes, and structures, program governance ensures that all program elements are coordinated and aligned with the organization's overall strategy (Müller, 2009; Müller et al., 2014; Pellegrinelli, 2011).

The article focuses on exploring various aspects of program governance, including the analysis of its areas and assessment models.

2. Methodology

This article aims to conduct an in-depth analysis of program governance, viewed from multiple perspectives. Initially, it focuses on clearly explaining the definition of program governance, which is crucial for understanding its significance in a broader context. Next, it explores the various components of governance that are essential for effective program management. Special attention is given to governance assessment methods, presenting a variety of tools and techniques that enable the identification of strengths and weaknesses in program management. Consequently, the article demonstrates how the application of these tools can systematically improve management processes and increase the efficiency of programs.

It also emphasizes the importance of continuous assessment and adjustment of management strategies to meet the dynamically changing requirements and challenges in the field of program management.

However, despite the extensive literature in the field of program management, there is a clear knowledge gap in the integration of theory and practice (Martinsuo, Hoverfält, 2018). Most research focuses on the theoretical aspects of management, often overlooking the practical implications and real challenges associated with implementing these concepts in dynamic business environments (Dźwigoł, Trzeciak, 2023; Trzeciak, 2022). Additionally, there is a lack of research on the effectiveness of various tools for assessing program governance (El Khatib et al., 2022; Flankova et al., 2023; Derakhshan et al., 2020), which limits the understanding of their practical utility. This article aims to fill this gap, allowing for a better understanding of how theory can be applied in practice and what the real effects of using different tools in program management are.

In pursuing this goal, the author formulates a series of significant research questions. The first concerns the definition of program governance and its place in the structure of corporate governance (RQ1). The next question focuses on identifying the key areas of program governance necessary for effective management (RQ2). The final question examines the various tools for assessing program governance, which can be used for analysis and improvement of management processes (RQ3). By effectively addressing these multi-faceted issues, the article aims to create a comprehensive picture that enables readers to gain a deeper understanding of both the theoretical and practical aspects of program governance, its impact on management effectiveness, and the possibilities for its assessment and refinement.

Utilizing a deductive approach, this article is based on a cross-sectional methodology, in line with the model presented by Zangirolami-Raimundo et al. (2018). The foundation of the research is a thorough analysis of literature and desk research, following the methods described by Wahid et al. (2023) and Guerin et al. (2018). These research techniques provide a solid foundation for exploring and analyzing an extensive knowledge base on program governance in project management. This approach not only allows for a deeper understanding of existing concepts and theories but also for the identification of research gaps and new perspectives. Focusing on a variety of sources and a wide range of literature significantly contributes to developing a comprehensive and profound understanding of the discussed topic, which is key to creating new, innovative concepts in the field of program management. Consequently, the article becomes not just a compendium of existing knowledge but also a platform for further research and discussion.

3. How is program governance defined, and what role does it play in the context of corporate governance?

Understanding program governance and its role in the context of corporate governance first requires examining what program management means in practice. A program, in the context of management, is a collection of related projects and activities (Shao, Müller, 2011) that are coordinated to achieve specific benefits (Fernandes, O'Sullivan, 2021) and strategic goals (Miterev et al., 2020), which exceed the capabilities of a single project or generate benefits greater than those arising from the capabilities of individual projects (Trzeciak, 2023a). Key to the effectiveness and success of such a program is the environment in which it operates, encompassing both internal and external aspects.

The ISO 21500 standard, offering a framework for project management, emphasizes the importance of understanding the project environment both in its internal and external context (Stellingwerf, Zandhuis, 2013). These environmental elements, identified and analyzed by the project team, are essential for effective planning, execution, and monitoring of the project. Similarly, program management standards such as Managing Successful Programmes (MSP, 2020) and the Standard for Program Management (SPM) published by the Project Management Institute (PMI, 2017), also emphasize the importance of understanding the program context in shaping program governance. Additionally, the IPMA PEB (Project Excellence Baseline) standard, whose fundamental premise is the harmonization of the actions of project and program leaders and teams with the principles and policies defined within the governance, also highlights the importance of the project context (Figure 1). This concept underscores the importance of aligning project strategies and actions with broader organizational goals and principles, which significantly contributes to the success and effectiveness of program management.

In this context, program governance is defined as a systematic approach to managing programs, which includes principles, policies, procedures, and structures responsible for ensuring that programs are managed effectively and in alignment with the organization's goals. Broadly, program governance ensures that decisions regarding the program are made transparently, taking into account the interests of all parties, and that resources are utilized effectively to achieve strategic objectives.

Analyzing the definitions proposed by program management standards such as MSP (Managing Successful Programmes) and SPM (Standard for Program Management), similar elements can be observed. MSP defines program governance as a collection of functions, duties, processes, and procedures that determine the way a program is initiated, managed, and controlled (MSP, 2020). This definition emphasizes the importance of a well-organized management system, which is key to the effective conduct of programs and the achievement of set goals.

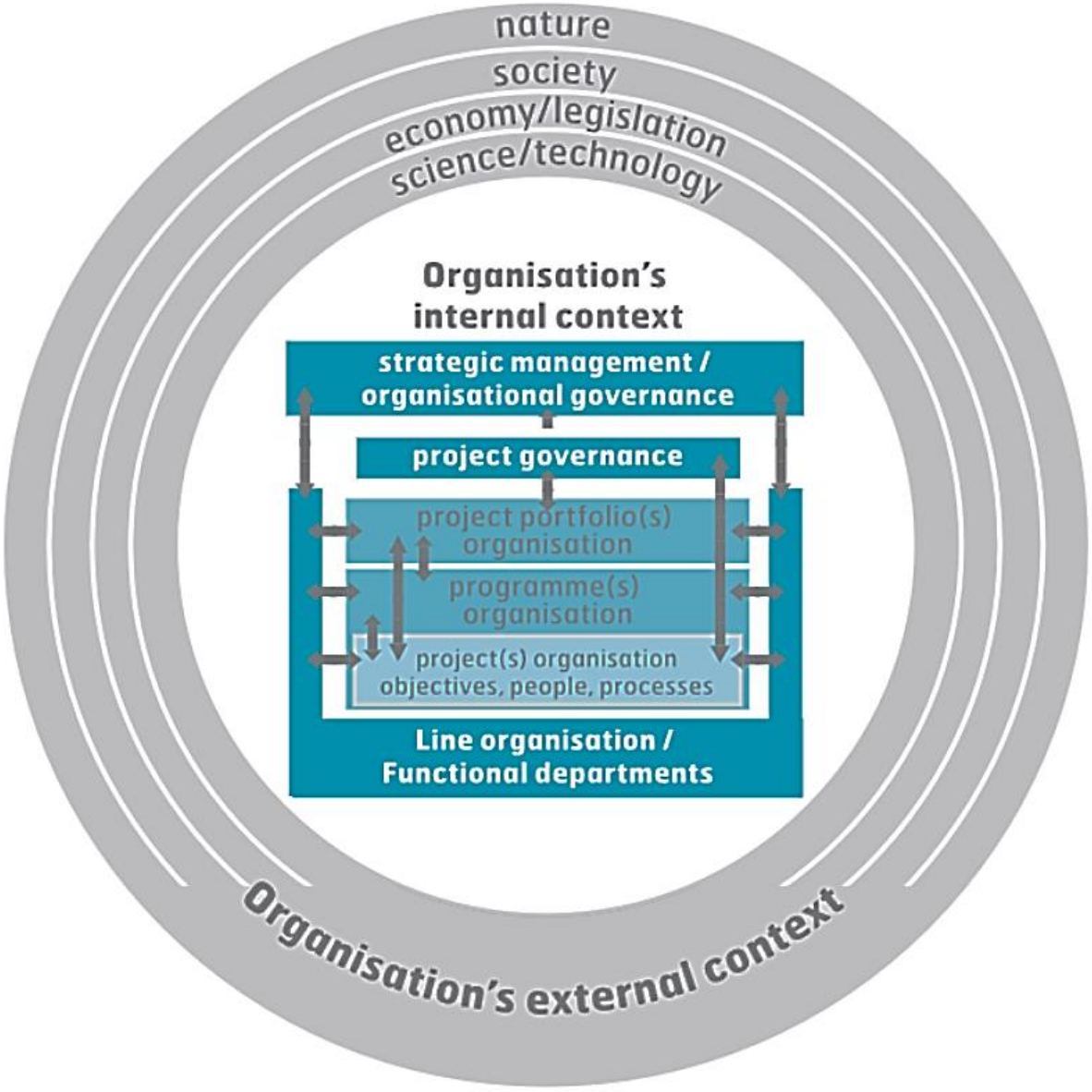

Figure 1. External and internal context of the project.

Source: IPMA, 2016, p. 36.

Conversely, PMI in its approach to program governance, as described in the Standard for Program Management, defines it as the process of developing, communicating, implementing, monitoring, and evaluating policies, procedures, organizational structures, and practices associated with a given program (SPM, 2017). This perspective indicates the dynamic nature of program governance, encompassing not only the establishment of structures and principles but also their continuous evaluation and adjustment to changing conditions and requirements.

In both definitions, emphasis is placed on a systemic approach to program management, which includes both structural and procedural aspects. The importance of establishing appropriate management frameworks and their effective communication and implementation in practice is emphasized. Both MSP and SPM highlight the need to consider the interests of various parties and ensure transparency in decision-making, which is crucial for the success of programs and for building trust within the organization and with its stakeholders.

In the context of corporate governance, program governance plays a key role (Khatib et al., 2023), as it is the mechanism through which organizations can ensure that their program initiatives are aligned with their overall strategy and direction of action (Derakhshan et al., 2020). This is particularly important in the current times, as organizations face the challenges of a dynamic business environment and growing stakeholder expectations (Martinsuo, 2023; Trzeciak, 2015). Effective program governance not only ensures the achievement of specific program goals but also strengthens the overall management structure (Khan, 2014), accountability, and transparency within the organization (Miterev et al., 2016), which is crucial for maintaining stakeholder trust and long-term corporate stability.

The dynamic nature of program governance, as evident from the project management literature, is a key element in the effective management and adaptation of programs to changing conditions (Derakhshan et al., 2020). In the perspective of evolutionary governance theory (Beunen et al., 2015), governance structures are not seen as static, but as continuously changing and adapting to new challenges. This perspective emphasizes that program governance must be flexible to effectively respond to the dynamics of internal relationships and the external environment (Qiu et al., 2019). Such flexibility allows for achieving higher capabilities and increasing efficiency within the program (Adami, Verschoore, 2018; Müller et al., 2014; Crawford et al., 2008; Zhai et al., 2017). Moreover, Derakhshan et al. (2020) also highlight that the configurations, dependencies, and mechanisms of governance undergo changes during the development of the program. This means that the management approach, decision-making, and stakeholder relationships are subject to variability in response to the nonlinear and complex dynamics of the context (Li et al., 2018). Van Assche et al. (2013) emphasize that as a program evolves, it is necessary to continuously direct and control the governance mechanism, balance goals, and define rights and responsibilities, allowing for effective adaptation to changing conditions.

In summary, program governance is a key element in the effective management of programs, ensuring that activities are conducted efficiently and in alignment with the organization's goals. It is based on a systematic approach that includes principles, policies, procedures, and structures (Müller, 2009), which support transparent decision-making (Müller et al., 2014), consideration of the interests of all parties, and effective resource utilization (Pellegrinelli, 2011). This approach has a direct impact on achieving strategic goals and strengthens the management structure, accountability, and transparency within the organization. Additionally, the theory of evolutionary governance emphasizes that program governance structures must be flexible and adaptive to effectively respond to changing internal and external conditions, which is essential in the face of a dynamic business environment (Derakhshan et al., 2020). In this way, program governance not only supports the realization of individual projects within the program but also contributes to the long-term stability and success of the entire organization.

4. Key areas of program governance

In the context of program management, the effectiveness of program governance is a key factor determining success, both short-term and long-term. The structure of program governance plays a fundamental role in defining and implementing management mechanisms essential for achieving the program's objectives.

In the SPM (Standard for Program Management) standard, program management activities are conducted in all phases of the program life cycle and require organizations to establish and enforce policies that include the following aspects (SPM, 2016, p. 22):

1. Common procedures for all projects within the program.
2. Proper controls to ensure consistent application of procedures.
3. Approach to developing and documenting program assumptions and decisions.
4. Approach to managing changes in the program.
5. Quantifiable measures for assessing the success of individual projects and the program.
6. Common practices for recording risks, issues, benefit measurements, and lessons learned.

Policies developed by the program office, in collaboration with the steering committee and project team, provide a framework for all program activities (SPM, 2017).

On the other hand, the MSP (Managing Successful Programmes) standard defines program governance as a framework of authority and responsibility applied by investing organizations to ensure effective management and value creation. Within these structures, the program requires the implementation of controls that ensure transparency and trust that activities will proceed as expected. These controls include policies, processes, tools, and behaviors. In MSP, program governance encompasses seven key frameworks designed to provide a comprehensive and coherent approach to program management, as reflected in Table 1.

Table 1.
Governance themes in the MSP standard

MSP themes	Explanation
Organization	The area of the program organization to ensure effective leadership, financing, supervision, and decision-making, including clarity on roles and their responsibilities and delegating the boundaries of authority.
Design	Area ensuring clarity of the final state and understanding of benefits and risks.
Justification	Area ensuring the justification of capital and resource investment by balancing financial capabilities and achievability with desired stakeholder value benefits.
Structure	Area defining the way projects and other activities are carried out, ensuring the best pace of delivery to enable the organization to transition to the future state and achieve benefits.
Knowledge	Area defining ways of acquiring, managing, and utilizing knowledge and information for drawing conclusions and building a culture and practice of continuous improvement.
Assurance	Area providing transparency and assurance to the sponsoring group that the program will achieve its goals, focusing on the most risky aspects of the program.
Decisions	Area defining how decisions are made at various points in the program lifecycle, whether they relate to problem-solving, risk response, or any other choice requiring a considered and managed approach.

Source: Own study based on: Axelos Global Best Practice. (2020). MSP – Managing Successful Programmes. London: TSO, The Stationery Office.

Aside from the mentioned standards, there are also numerous studies on effective program management. For instance, a study on the role of the Program Management Office (PgMO) identifies five key areas of program governance that are crucial for its success (Trzeciak, 2023b):

- Maintaining program governance,
- Program implementation,
- Program planning and budgeting,
- Processes directly related to engaging program stakeholders and building and maintaining relationships,
- Managing requirements and knowledge resulting from program implementation.

However, Li et al. (2018) suggests that as governance structures evolve, the distinction between upper-tier governance levels and their subordinate departments becomes less clear. Evolutionary governance theory proposes that these governance structures consist of a dynamic interplay among various elements, including actors, institutions, knowledge, and power. These components are constantly changing and influencing each other in an interconnected manner, as explained by Beunen et al. (2015).

Furthermore, the analysis of literature regarding factors supporting effective program management identified 5 areas including strategic alignment, process approach, organization and communication, knowledge, as well as monitoring and control (Table 2).

Table 2.
Areas of program governance in the light of literature research

Areas of program governance	Specification of factors supporting program implementation	Authors
Strategic alignment	Strategic program management	(Miterev et al., 2020; Pollack et al., 2013; Zhou et al., 2022)
	Concurrency of the program's goals with the organization's strategy	(Duryan, Smyth, 2019; Pellegrinelli et al., 2015; Laine et al., 2016; Al-Zwainy Al-Marsomi, 2023)
	Clear identification and planning of benefits, including their categorization and prioritization	(Miterev et al., 2020; Fernandes, O'Sullivan, 2021)
	Program planning	(Rijke et al., 2014; Pellegrinelli et al., 2015; Latip et al., 2023; Al-Zwainy, Al-Marsomi, 2023)
Process approach	Selection of program implementation method	(Pollack et al., 2013; Shi et al., 2014; Zhou et al., 2022)
	Program Management Office	(Rijke et al., 2014; Latip et al., 2023)
	Management processes and decision making	(Rijke et al., 2014; Pellegrinelli et al., 2015)
	Integration mechanisms	(Vuorinen, Martinsuo, 2018; Pellegrinelli et al., 2015)
	Adaptive delivery of benefits	(Pollack et al., 2013; Fernandes, O'Sullivan, 2021)

Cont. table 2.

Organization and communication	Vertical and horizontal communication	(Duryan, Smyth, 2019; Fernandes, O'Sullivan, 2021)
	Requirements for stakeholder interest and cooperation in the program	(Duryan, Smyth, 2019; Miterev et al., 2020; Laine et al., 2016; Fernandes, O'Sullivan, 2021; Latip et al., 2023)
	Competencies of the program management team	(Pollack et al., 2013; Zhou et al., 2022)
	Autonomy and decision making	(Vuorinen, Martinsuo, 2018; Fernandes, O'Sullivan, 2021)
Knowledge	Knowledge management	(Duryan, Smyth, 2019; Miterev et al., 2020; Amelia et al. 2022)
	Development and Maintenance of Competencies	(Miterev et al., 2020; Pellegrinelli et al., 2015)
	Decision Support Systems	(Pellegrinelli et al., 2015; Fernandes, O'Sullivan, 2021)
	Culture of Knowledge Sharing	(Duryan, Smyth, 2019; Amelia et al., 2022)
Monitoring and control	Program performance	(Fernandes, O'Sullivan, 2021; Al-Zwainy, Al-Marsomi, 2023)
	Mechanisms for Tracking and Evaluating Progress	(Shi et al., 2014; Fernandes, O'Sullivan, 2021)
	Reporting and Communication	(Shi et al., 2014; Laine et al., 2016)
	Quality Control and Compliance	(Pellegrinelli et al., 2015; Amelia et al. 2022)

Source: Own work.

In summary, program management requires an effective governance structure, which is a key factor in success both in the short and long term. Program management standards like SPM and MSP offer frameworks covering a wide range of aspects, from organization to design, justification, structure, knowledge, quality assurance, and decision-making processes. Moreover, literature research not only confirms the frameworks included in the standards but also extends them with new areas related to strategic alignment and process approach.

5. Selected models enabling the assessment of program governance

There are several models that support organizations in assessing and monitoring program governance. Among them is the IPMA Project Excellence Baseline (IPMA PEB), which focuses on project excellence and evaluating a program as a complex project. This model considers areas such as "People and Goals," "Processes and Resources," and "Project Outcomes." Another model is P3M3 – the Portfolio, Programme and Project Management Maturity Model, which assesses the maturity of portfolio, program, and project management in an organization. The last well-known model is the Health Check within the MSP® standard, providing tools and frameworks for assessing and improving program management.

The IPMA PEB allows organizations to assess the extent to which their projects meet high standards of project and program management. This model focuses not only on project outcomes but also on processes, strategy, leadership, and stakeholder management (IPMA,

2016). It enables organizations to get a comprehensive view of project and program management and identify areas for improvement (Lee, et al., 2021). Moreover, using IPMA PEB can bring several benefits. Firstly, it helps identify strengths and weaknesses in projects, allowing organizations to focus on further improving their management practices. Secondly, IPMA PEB provides a framework and a uniform language for assessment, facilitating project comparison within or between organizations. Thirdly, it can serve as a developmental tool, enabling organizations to prioritize corrective actions to enhance the quality of program management.

In the context of program assessment using the IPMA PEB model, there are three approaches (IPMA, 2016):

1. Assessment of overall program management - This approach provides overall feedback on the evaluation of the program, without assessing individual projects within it. Results are evaluated only from the perspective of the program's overall business justification.
2. Assessment of a selected project within the program - According to the model, such a project should be evaluated similarly to an independent project. However, auditors are advised to precisely define the scope of the assessment first.
3. Assessment of the entire program, including subprograms and individual projects - This approach outlines three additional assessment possibilities:
    - Assessment of the entire program - Here, the program is evaluated as a complex project without breaking it down into individual elements.
    - Assessment of the overall level of program management combined with individual assessments of all projects - This approach combines the two previously described methods.
    - Assessment of the overall level of program management combined with individual assessments of a selected sample of projects - In this approach, the program assessment is conducted similarly to the previous mode but only applies to a selected group of projects.

The IPMA PEB model is a useful tool for assessing project success (Osmakov et al., 2019), but it faces criticism in program evaluation. Firstly, a program manages benefits based on outcomes from constituent projects. Program success assessment must consider whether specific benefits were achieved and contributed to the organization's strategic goals. The IPMA PEB model does not account for this, focusing only on outcomes from individual projects (Ding et al., 2022). Secondly, it mainly focuses on project excellence but does not consider specific organizational contexts affecting program management aspects. "IPMA PEB is based on the concept of individual and organizational competencies in project management (IPMA ICB and IPMA OCB), but it focuses solely on how all factors combine in a specific project, allowing for the measurement of its excellence" (IPMA, 2016). In summary, the IPMA PEB model treats a program as a mega-project, requiring the evaluation to consider benefit management, program specifics, and organizational context in assessing success.

P3M3 (Portfolio, Programme and Project Management Maturity Model) is a model for assessing the maturity of portfolio, program, and project management in organizations. It is a comprehensive model developed by the British Office of Government Commerce (OGC). The purpose of P3M3 is to provide a framework of reference that can be used to determine an organization's capabilities in managing projects, programs, and portfolios (Juchniewicz, 2009). P3M3 was first developed in 2006, and the latest version was released in 2021 (AXCELOS, 2021).

The assessment of the maturity level has two possible modes and is based on 7 perspectives, which cover aspects such as: organizational governance, implementation control, benefit management, risk, stakeholders, finances, and resources. The first mode is self-assessment, which allows an organization to assess its maturity level in a short time. This is dedicated to small and medium-sized organizations that do not need to obtain an official project maturity certificate.

The second mode is the official method of maturity assessment, conducted by Accredited Consultants from Accredited Advisory Organizations. Furthermore, the maturity assessment of an organization can be conducted in any of the three areas: project management, program management, and portfolio management, provided certain requirements are met. If an organization decides to assess the maturity of program management, it must also evaluate project management. Similarly, if an organization wants to assess the maturity of portfolio management, it must conduct an assessment of both program and project management.

Although the P3M3 model provides organizations with guidelines and recommendations for improving the management of portfolios, programs, and projects (Bartolome, 2022), there are certain limitations that need to be considered. Within the P3M3 assessment, there is a category of "general attributes" that is evaluated in all three sub-models. However, there is controversy in both popular and academic discourse about whether these general attributes are the same in the context of program and portfolio management, which have different characteristics (Young et al., 2014; Afrazeh, Hajiyakhchali, 2017). There is evidence suggesting that maturity in these areas requires different skills than in project management (Miterev et al., 2016; Farid, 2021). For example, skills such as prioritization, decision-making, and balancing, which are key in program management, are not assessed by P3M3. Furthermore, organizational learning, strategic alignment, and support from top management are important factors that should be considered when examining an organization's capabilities but are not fully included in the P3M3 model (Young, et al., 2014).

The health check is a process of evaluating and diagnosing programs based on the principles and processes contained in the MSP standard. It aims to identify areas for improvement, assess the effectiveness of program management, and determine corrective actions to achieve better results (TSO, 2014).

The health check within MSP not only provides organizations with an objective assessment of their programs but also offers a range of benefits and opportunities for improvement. Firstly, the health check enables the identification of areas for improvement and the recognition of problems and challenges that the organization may face in program management (TSO, 2014). Additionally, the health check allows organizations to leverage industry best practices and expert knowledge through analysis, which is in line with the MSP methodology.

The health check, despite its numerous advantages, can also have some drawbacks. Firstly, it only refers to the MSP standard, which limits its universality. Secondly, it may be prone to subjective opinions and interpretations of the assessors, due to the lack of metrics that are available, for example, in the IPMA PEB model. There is a risk that the assessment results may be biased towards subjective preferences and not adequately reflect the actual state of the program. Thirdly, the health check does not include an assessment of competencies, focusing only on 7 governance themes and the course of transformation.

6. Conclusion

This article focuses on the significance of program governance from multiple perspectives, starting with a clear definition of program governance, through identifying its key components, to a detailed analysis of governance evaluation models. This comprehensive analysis aimed to deepen the understanding of governance in the context of program management and its impact on management effectiveness.

The contribution of the article to program management theory lies in three aspects. First, it provides a more comprehensive understanding of program governance. Second, based on the analysis of literature, it identifies key areas of program governance both in terms of international standards and research conducted independently by various authors. Third, the analysis conducted indicated the need to develop a comprehensive model, a tool that allows for the assessment of program governance. Considering this, the development and testing of new tools and governance assessment models are recommended, which may better reflect dynamic business environments.

The article's contribution to the practice of program management is manifested through the analysis of practical applications of various methods for assessing program governance. It emphasizes how these tools help in identifying weaknesses in management, contributing to the optimization of processes and enhancing the effectiveness of programs, especially in changing business conditions. The article points out the practical benefits of effective governance assessment, facilitating decision-making and adjusting management strategies.

The main research limitations stem from the adopted methodological approach. The article is based on a literature review and descriptive research analysis, which may not capture the full spectrum of practical experiences and realities of program management in dynamic business environments. Consequently, it is recommended to expand the research to include empirical case studies, which can provide practical examples of applying program governance theory.

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MOTHERHOOD AS A FACTOR DIFFERENTIATING WOMEN'S CAREERS

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Purpose: The aim of this study is to demonstrate the differences in the professional careers of women with and without children.
Design/methodology/approach: The quantitative study was conducted using the survey method (CAWI) using an online questionnaire on a sample of 517 women. The survey included single- and multiple-choice and open-ended questions. The study lasted 9 months (February-October 2022) and included professionally active women working in medium-sized or large enterprises in south-eastern Poland.
Findings: The obtained results indicate emerging significant differences between the surveyed women with children and women without children, in the context of professional career, preferences and activities undertaken for professional development. Professional career covers various spheres of life, including family, which means that motherhood has a significant impact on women's professional development. The higher education and age of women with children suggest the dominance of a conventional or dual career path. The age differences between the groups coincide with the trend of younger women giving up motherhood. Childless women are more likely to work in prestigious industries, while mothers value performing a prestigious profession. The average earnings of mothers are lower than those without children, but mothers are more likely to earn top wages. Childless women value continuous learning in their careers more. Women with children show a higher level of career satisfaction, which may reflect the modern approach to combining motherhood with professional work.
Research limitations/implications: The research has limitations and the results cannot be generalized to the entire population. They only focus on certain aspects related to motherhood and women's careers, which could be expanded in future research. It is also suggested to study the differences between Polish regions and a longer analysis of the development of women's careers in various phases of professional life, especially those related to motherhood.
Originality/value: Due to the very diverse approach to the topic of motherhood and careers, there are few studies relating to the differences in women's careers resulting from motherhood, and even fewer studies in this area are based in selected regions of Poland. Therefore, it seems justified to take up the topic of motherhood discussed in the article as a factor differentiating women's careers.

Keywords: career, women's career, maternity, motherhood, work-life balance.

Category of the paper: Research paper.

1. Introduction

Modern society is an arena of dynamic changes, where women play an increasingly important role not only in the family sphere, but also in the labor market. However, even in the era of social progress and equal rights, motherhood still appears to be one of the most important experiences that influence women's professional lives. This topic is becoming the subject of increasing interest among researchers due to its potential impact on women's professional careers. Research covers the topic of combining motherhood and career (Collins, 2019) in a very broad scope. Many studies discuss the topic of academic careers. The latest studies focus on, among others, the impact of motherhood on a scientific career (Gallardo, 2021), prejudices against women - mothers in science (Staniscuaski et al., 2023; Thébaud, Taylor, 2021). There are also studies combining the topics of academic careers, motherhood and the COVID-19 pandemic (Bowyer et al., 2022; CohenMiller, Izekenova, 2022; Minello et al., 2021; Staniscuaski et al., 2021) or publications talking about gender diversity towards parenting among early career scientists (Bonache et al., 2022). The authors' research also concerns motherhood and professional careers in other areas, e.g. sports (Tekavc et al., 2020), medicine (Hoffman et al., 2020) or management (Moczydłowska, 2023). Among the more general approach to the discussed topic, which does not link motherhood and career with a specific area, one can point to research on overcoming prejudices related to motherhood in the workplace (Arena Jr et al., 2023), differences in remuneration due to motherhood (Cukrowska-Torzewska, Matysiak, 2020), entrepreneurial behavior of mothers and their professional careers (Kodagoda, Samaratunge, 2023), women's professional careers in modern organizations (Christoph, Krause, 2019), patterns of women's professional careers towards combining family and professional roles (Duda, 2019), dilemmas of young mothers between family and professional work (Czajka, 2021) or women's value systems and their attitudes towards motherhood (Lachowska et al., 2017). Given such a diverse approach to the topic of motherhood and professional careers, there is little However, there are studies relating to differences in women's careers resulting from motherhood, and even fewer studies in this area are based in selected regions of Poland. Therefore, it seems justified to take up the topic of motherhood discussed in the article as a factor differentiating women's professional careers. The aim of this study is to demonstrate the differences in the professional careers of women with and without children. Given this goal, a research question was formulated regarding the differences between the professional careers of women with children and women without children.

Career is an individual process that changes over time. It encompasses the sequence of experiences, roles, and positions that an individual undertakes during his or her life (Sears, 1982). Contemporary career definitions place greater emphasis on an individual's individual experiences, aspirations, and goals (Guan et al., 2020). Career is viewed as a subjective

construct, dependent on personal preferences, values and aspirations. A professional career is not limited to working in one organization. It also includes other areas of life such as family, society and personal development (Hall, Chandler, 2018). Career is a complex process in which an individual integrates various areas of life, striving for a balance between professional and private life. An important feature of a career is also the need to adapt the individual to the changing conditions of the labor market and organization. A professional career requires constant learning, developing skills and adapting to new requirements (Lyons, Kuron, 2014). People who manage their careers effectively are able to achieve success and sustainability in a dynamic work environment. A professional career has both a subjective aspect, related to individual aspirations, expectations and satisfaction, and an objective aspect, related to observable achievements, progress and changes in the profession. It is important to consider both an individual's subjective experience and objective indicators of career success. Career is shaped by the organizational and social context in which an individual operates. The organizational system, organizational structure, opportunities for advancement and professional development, as well as social, economic and cultural variables influence the development of individuals' careers. Today's perspectives on careers also place greater emphasis on personal fulfillment and professional satisfaction (Guan et al., 2018). Career does not only have the dimension of hierarchical promotion, but also involves achieving the professional and personal goals of an individual.

Super (1976) noticed that professional experiences accumulated by individuals in real life influence the development of their refined patterns of professional identity. These patterns include aspects of professional maturity, such as the ability to plan, take responsibility, and accept multidimensionality in professional life and beyond. Super (1976) identified several career patterns for women that are strongly related to their individual characteristics:

- stable career as a housewife - means that a woman focuses mainly on the role of a housewife before taking up work or almost immediately after taking up work. Professional work is of secondary importance, and the main ambitions and commitment are focused on the family area;
- conventional career - involves taking up work immediately after completing education and continuing it until marriage;
- stable job career - concerns women who focus mainly on work, treating it as a role to be fulfilled;
- dual career - characterized by women who achieve professional success, but starting a family means they have to find a balance between professional work and home responsibilities;
- intermittent career - means a situation in which family circumstances force a woman to interrupt satisfactory work, sometimes without having to abandon it;

- unstable career - similar to the male pattern, includes breaks in professional work, usually related to periods of financial difficulties;
- career of repeated attempts - similar to the male role model, but the reasons for frequent job changes usually result from family needs (Herr, Cramer, 2005).

Motherhood, despite the enormous joy and satisfaction it brings, brings with it a number of challenges, especially in the context of a professional career. Women often have to choose between being a mother and developing their career path. This dilemma, although present for years, remains relevant and still influences the life decisions of many women. Structural inequalities and gender stereotypes may make it difficult for women to achieve a balance between the roles of mother and employee (Meeussen, Van Laar, 2018). Women are often expected to be the primary caregivers of children, and parenting in a professional context is most often equated with motherhood, and not to the same extent with fatherhood. It is therefore important to promote equal parental responsibilities and change cultural norms regarding gender roles. Supporting equality in the division of household responsibilities and childcare can contribute to a greater balance between the roles of mother and employee and enable women to develop their professional careers equally as men (Young, 2018). Secondly, insufficiently flexible work policies and support for parents may constitute an obstacle for women in continuing their professional careers (Mikołajczyk, Stankowska, 2021). Many workplaces do not offer sufficiently flexible working time, remote work or childcare options, which makes it difficult for women to reconcile parental responsibilities with professional demands (Hess, Pollmann-Schult, 2020). Moreover, women often experience parental discrimination, which makes it difficult to return to work after maternity leave, or they experience it already at the level of recruitment or selection, where plans to start a family turn out to be a disqualifying criterion. Nevertheless, more and more organizations realize the need to support working parents, including women, by introducing childcare programs and equal opportunities for professional development. This gives hope that in the future women will have better opportunities to combine career and parenthood.

Research conducted at Oxford University (Kahn et al., 2014) shows that childless women aged 25 are better educated, more often employed, and also have higher earnings and work in professions with higher prestige than women. who had previously become mothers. For women aged 20–30–40, a relationship was confirmed - the more children, the lower activity on the labor market, the lower salary and the lower professional prestige. The birth of each additional child means a woman's salary decreases by 3-6%. Women without children earn on average 1/3 more than women with three children and are almost twice as likely to perform more prestigious jobs. This regularity is also visible in Poland. Research provides evidence that mothers earn less on average both compared to men and childless women of similar age, in similar positions and with the same competences (Moczydłowska, 2023). These disproportions are particularly visible in prestigious, highly paid professions. Interestingly, men who become fathers not only do not earn less, but can also expect

the so-called paternity bonus. However, a study conducted as part of the FAMWELL project shows that the number of women who consciously give up motherhood increases from generation to generation. Among those born between 1945 and 1955, the percentage of women who never gave birth to a child was 8%, while among those born in 1970 this figure was 17%. The percentage of women who do not have and will no longer have children is much higher in Poland than in other Central and Eastern European countries (Matysiak et al., 2021).

2. Methods

In order to collect empirical data, quantitative research was carried out using the survey method and the CAWI technique. This study used an online survey questionnaire, created using the Google Forms platform, which used single- and multiple-choice questions and an open-ended question format. Some of the questions used a five-point Likert scale, consisting of the answers: "definitely not", "rather not", "difficult to say", "probably yes", "definitely yes". The survey consisted of questions about professional career and personal details. The study was conducted over 9 months (February 2022 - October 2022) in the form of disseminating an appropriate link to an online survey on the Google Forms platform. First of all, the organization and women working in them were addressed to which the author had direct access. Then, using the "snowball" effect, women participating in the study were asked to further share the survey in other organizations, thus inviting additional respondents to participate. At the same time, the author popularized the study through e-mails containing an invitation to participate in the study, sent to organizations that met the assumed sample selection criteria. The organizations were selected on the basis of rankings of medium and large enterprises prepared by portals such as: https://nowiny24.pl/ (Golden Hundred Companies, 2021), https://www.obserwatorium.malopolska.pl/ (500 List), https://www.forbes.pl/ (Forbes Diamonds, 2021).

The research sample consisted of professionally active women (n = 517), currently working in medium-sized or large enterprises, living in two voivodeships: Lesser Poland and Podkarpackie. The choice of voivodeships was dictated by their economic diversity, socio-cultural conditions and economic differences. The Podkarpackie and Lesser Poland voivodeships are located in the southern part of Poland, which is characterized by a diversified economic structure and level of development. Moreover, the choice of the Podkarpackie and Lesser Poland voivodeships was also due to the small amount of previous research on women's professional careers in these regions.

After collecting the empirical material, the data were subjected to statistical analysis, which included descriptive characteristics and tests of intergroup comparisons - the variables analyzed in the study were two types of data: quantitative and categorical. Quantitative variables were

understood as all answers provided by respondents on a five-point Likert scale, and their characteristics included, among others: arithmetic mean, standard deviation, median, first and third quartile values, and minimum and maximum values. After making comparisons, those results that turned out to be statistically significant were selected for presentation and discussion.

3. Results

Among the surveyed women, over 32% of respondents declared having children (n = 169). Women with children were on average 41 years old. They were more likely than those without children to have higher education of the second degree (60.9% vs. 51.4%) and third degree (10.7% vs. 4.9%) and more often lived in the Podkarpackie Voivodeship (59.8% vs. 40.2%). They also more often earned the highest amounts (above PLN 10,500 per month) (8.3% vs. 3.2%), held positions at the highest levels in the management staff (9.7% vs. 0.3%) and performed executive work of a mental nature (53.2% vs. 43.4%). Women with children most often worked in public administration and national defense (26.6%), education (18.9%), and health care and social assistance (13%).

Women who did not have children were on average 33 years old. They earned amounts up to PLN 4500 per month more often than those with children (59.2% vs. 43.7%). Childless respondents more often held low-level managerial positions (7.2% vs. 5.2%), were independent workers or specialists (25.8% vs. 19.5%) and also worked in mixed executive positions (15 % vs. 8.4%) and physical nature (8.2% vs. 3.9%). Most often (12.1%) they worked in financial and insurance, education and other service organizations. Women without children were much more likely to have worked in their current job position (34.5% vs. 6.5%) and in their current organization (30.5% vs. 6.5%) for less than one year and more often in the same position (48% vs. 39.6%) and in the current organization (47.4% vs. 32.5%) for one to five years than women with children.

All women took actions aimed at developing their professional careers, but depending on the fact that they had children, these actions differed in terms of frequency. Women with children more often took part in courses on developing hard skills (63.9% vs. 44.5%), took up postgraduate studies (35.5% vs. 19.8%) and trained independently of work in the organization (45 % vs. 32.8) and as part of work in the organization (63.9% vs. 46.6%). Women without children were more likely to focus on learning foreign languages (44.3% vs. 20.7%), networking (4.6% vs. 0.6), taking up studies (83.6% vs. 59.8%) and they focused on self-education (27.3% vs. 14.8%).

Women without children more often declared that a professional career was definitely important to them (41.5% vs. 28.4%), while women with children were less determined (the answer was "rather yes") (56.8% vs. 42.5%). However, these women showed a higher level of career satisfaction than those who did not have children (mean 3.46 vs. 3.26).

In the next step, the respondents were asked how important the indicated aspects of their professional career were to them. For women with children, leadership, having power, the ability to delegate tasks to others (average 3.26 vs. 3.04) and performing a profession perceived by society as prestigious (average 3.63 vs. 3.29) were more important. For women without children, the more important aspects were continuous learning and improving the level of their competences (average 4.35 vs. 4.17), as well as high remuneration and achieving a high financial position (average 4.13 vs. 3.86).

Then, they were asked to determine the degree of satisfaction with the presented aspects in relation to their own professional career. Women with children were more often satisfied with such aspects of their career as: continuous learning and improving the level of their competences (average 3.83 vs. 3.6); establishing valuable professional connections (average 3.71 vs. 3.47); receiving distinctions, awards, decorations (average 3.9 vs. 2.86); leadership, having power, the ability to delegate tasks to others (average 3.11 vs. 2.83), realizing one's own ambitions, dreams and professional plans (average 3.5 vs. 3.21); specialization in a given field (average 3.64 vs. 3.37); performing a profession perceived by society as prestigious (average 3.37 vs. 2.93); high salary and achieving a high financial position (average 3.09 vs. 2.77).

In terms of activities related to shaping their own professional career, women with children more often indicated that their professional career is based on the activities of the organization in which they work (average 3.62 vs. 3.41), their professional career development plan was shaped by the influence of close people (family, friends) (average 2.83 vs. 2.61) and that acquaintances, networks and relationships helped them shape their careers (average 2.6 vs. 2.35).

Women with children more often indicated that among the competences and personal resources in the context of shaping their own professional career, the following were more important for them than for women without children: professional experience (average 4.24 vs. 3.8), life experience (average 4.14 vs. 3.75), mobility (e.g. readiness for business trips; temporary change of place of residence) (average 3.43 vs. 3.17), level of education (average 4.14 vs. 3.69), as well as predispositions to performing a given profession (average 4.24 vs. 4.02).

4. Discussion

According to the findings of researchers dealing with career (Hall, Chandler, 2018), who claim that it covers, apart from professional work, also other spheres of life, including: such as family, it can be concluded that motherhood plays an important role in shaping a professional career.

The higher level of education of women with children and the higher average value of their age may indicate the dominant type of women's conventional or dual-track professional career in the study group, as described by Super (1976). The differences in the average age of women with and without children coincide with research conducted as part of the FAMWELL project, which reported an increasing level of resignation from motherhood among increasingly younger women (Matysiak et al., 2021).

Childless women most often worked, among others: in financial and insurance activities, which may be considered more prestigious than public administration, where women with children most often worked, and this is consistent with research conducted by Oxford University (Kahn et al., 2014), which showed that women those without children are more likely to have more prestigious jobs. Therefore, it seems interesting that, in relation to the degree of importance of various aspects of a professional career, performing a prestigious profession was more important for women with children.

Research (Moczydłowska, 2023) also showed that mothers earn less on average compared to childless women, which partially coincides with the results obtained. In most cases, women without children earned amounts of up to PLN 4,500 per month more often than those with children. This is also reflected in the degree of importance of various aspects of professional career, where childless respondents valued high remuneration and achieving a high financial position more. However, the highest wages above PLN 10,500 per month were more often earned by mothers.

As Lyons and Kuron (2014) point out, a professional career requires constant learning, developing skills and adapting to new requirements. Even though women in both groups studied take actions aimed at implementing this aspect, the childless respondents valued continuous learning more in relation to the degree of importance of various aspects of their professional career.

Today's approach to professional career also places greater emphasis on personal fulfillment and professional satisfaction (Guan et al., 2018). In this respect, women with children showed a higher level of career satisfaction than those who did not have children, which may indicate that the idea of combining motherhood with professional work is part of the modern concept of a professional career (Hall, Chandler, 2018).

5. Summary

The study indicates emerging significant differences between the surveyed women with children and those without children, in the context of professional career, preferences and activities undertaken for professional development. Women with children had an average age of 41 years. It is worth noting that this group more often had secondary and third level higher education, which suggests that mothers are more likely to invest in educational development. Additionally, a much larger percentage of women with children held positions at the highest levels, which indicates individuals with a strong position in the professional sphere. In terms of geographical location, women with children more often lived in the Podkarpackie Voivodeship. This is an interesting observation, which may be related to differences in access to resources, social support or the structure of jobs in a given region. Women with children were more likely to earn the highest monthly amounts, which may be due to their higher level of education and management positions. On the other hand, childless respondents more often earned amounts up to PLN 4500, which may result from a different priority in terms of professional life. In the area of career development activities, women with children were more likely to participate in courses developing hard skills, undertake postgraduate studies and train independently of work in the organization. However, childless women were more likely to focus on learning foreign languages, networking and taking up studies. This may suggest that mothers invest more in specific skills, while childless women emphasize the development of more universal competencies. In relation to the degree of importance of various aspects of a professional career, leadership, having power and performing a prestigious profession were crucial for women with children. However, childless respondents valued continuous learning, high salary and achieving a high financial position more. In the context of career satisfaction, women with children showed higher levels of satisfaction with various aspects of their career path. What was important for them was continuous learning, establishing valuable contacts, receiving awards, leadership and specialization in a given field. Career-shaping activities also differed between the two groups. Mothers more often indicated that their career is based on the activities of the organization, the influence of close people, as well as the importance of acquaintances and networks of contacts. In the area of competences and personal resources important for a professional career, women with children attached more importance to professional and life experience, mobility, level of education and predispositions to perform a given profession.

The research conducted is not free from limitations. First of all, it should be noted that the results obtained can only be used to demonstrate differences in the studied group and there are no grounds for generalizing them. The examined aspects do not exhaust the subject of motherhood and professional career, but constitute only a fragment of it, which can be treated as an introduction to the full research. However, this limitation indicates a possible direction for future research that could focus on a deeper understanding of the impact of having children

on women's career development. It could also be interesting to examine the differences in other regions of Poland and compare the results obtained or conduct research on the entire country. The study could also be extended with a longer analysis of women's career development to see what changes occur in different phases of professional life, especially in the context of having children.

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INTERNATIONAL SUPPLY CHAINS IN PHARMACEUTICAL INDUSTRY AFTER SARS-CoV-2

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Purpose: The paper presents the issues related to international supply chain in the pharmaceutical industry.
Design/methodology/approach: The study used world-bank reports from Statista portal and the own research.
Findings: The international supply chain is a sequence of events, a process of moving goods with a goal of meeting the demand for certain products. The simplest chain can be defined by three components: supplier, enterprise, recipient. Due to the coronavirus pandemic, the supply chain has been interrupted and disrupted, as shown by the example of a company from the pharmaceutical industry. Components are sourced from suppliers around the world, and thus that the company and its production cycle do not has been disturbed, schedule timely deliveries. Unfortunately, due to the outbreak of the coronavirus pandemic, timeliness has been disrupted, which means that companies relying on one supplier had to acquire new ones in order to be able to implement production plans and meet deadlines from orders. On the example of a company from the pharmaceutical industry, one can come to the conclusion that through the pandemic in the logistics chain, the following were most affected: fluidity of deliveries, compliance of notifications, disturbances in production planning, execution of orders in accordance with the schedule. The article is theoretical and overview in nature. It uses content analysis and identifies specific analytical categories such as supply chains in pharmaceutical industry and trends in the international trade. The research methodology uses the literature analysis and critique method, as well as the document research and case study method.
Originality/value: The publication presents the results of research conducted on the basis the Statista portal.

Keywords: supply chains in pharmaceutical industry, SARS-CoV-2, international trade, global value chains.

Category of the paper: Research paper.

1. Introduction

The supply chain is a network of suppliers, producers, wholesalers and retailers performing the functions of supply, production, storage and distribution.

The supply chain consists of a network of factories and contractors who supply raw materials and components then convert them into semi-finished products and components then produce the final product from them and enable their consumption by the final consumer. Transport and storage are key elements of the supply chain. All literature definitions point to three basic characteristics of the supply chain:

- Subject structure, i.e. clearly distinguished entities participating in the supply chain,
- The subject of flow, understood as products, materials, goods processed and transferred through subsequent links in the supply chain,
- Objectives, functional scope and areas of cooperation of participating entities

Enterprises in any supply chain must make decisions, alone or together, in five areas: production, wrestling, location, transport and information. The sum of these decisions defines the scope of possibilities and efficiency of the supply chain.

2. International Supply Chains

Transformations taking place in the global economy have significantly contributed to increasing the level of commitment of individual countries in global value chains. Logistics is of a global nature because it is associated with international trade, often of a global range, which is characterized by concentration of turnover, geographical dispersion of highly competitive supply and sales markets. The basic directions of global logistics are achieving operational excellence, cost leadership and a high level of customer service, especially in the field of supply (distribution) logistics and distribution. In the global economy, the supply chain is transformed into an international, integrated network of coordinated dependencies and logistics activities implemented by external and internal partner companies within the framework of global logistics systems. Such a global chain provides companies with the highest achievable availability of goods, increased productivity and improved service quality at an optimal level of costs, acquisition and maintenance of inventory, transport, storage, distribution and the amount of working capital. The most important trends in the functioning of global supply chains - continuation to reduce costs - the need for a better understanding of cost sources and the location of their origins. Expansion of supply bases - optimization of human resources - improvement of business expansion methods. By analyzing the supply chain internationally, it can be defined as a network of related and dependent organizations that operate on the basis

of mutual cooperation, jointly controlling, directing and improving material and information flows from suppliers to final recipients, with some of these organizations being outside the borders of the country where the final recipients of the good (customers) live. There must therefore be a crossing of the state border in the supply chain.

Management of the global supply network should focus more on improving management and distribution efficiency by improving efficiency and effectiveness, rather than supply chain management.

3. Supply chain management

For the first time, the term "supply chain management" appeared in the literature in 1982 and was initially associated primarily with the reduction of inventories within the enterprise and the companies cooperating with them. The creators of this concept are considered R. Oliver and M. Webber, who wrote about the supply chain in the context of the role that the top management of international companies should play in recognizing conflicts, the goals of various functional areas of the organization that cause an uncoordinated flow of products, information and financial resources (Christopher, 2021).

One of the first definitions of supply chain management in the logistics context (Witkowski, 2003) was the formulation that it was planning, coordinating and controlling the flow of materials, parts and finished products from suppliers to recipients, which include two separate flow streams (materials and information). An example of logistic interpretation is also the supply chain model disseminated by the Supply Chain Council (SCC) existing since 1996. The association, similarly to the APICS organization for MRP II class systems, has developed a reference model in relation to the function of software tasks for supply chain management. The reference model developed by SCC containing the principles and elements used in the creation and computerization of supply chains is called SCOR (Supply Chain Operations Reference). The SCOR model regulates operations related to planning, purchasing, manufacturing and supplying products in the supply chain.

Management of integrated supply chains began to develop dynamically only in the early 1980s. However, it should not be forgotten that the source of the theoretical and methodological foundations of the management idea discussed were the results of research on distribution channels, cooperation of production enterprises or system integration, published at least twenty years earlier. Researchers in supply chain management even refer to the achievements of the late 1950s and early 1960s. This is especially true for Forrester's publication, which, by examining flows between suppliers and customers, pointed to the problems of excess inventory at suppliers as a result of a gradual increase in information distortions about small

changes in demand as they moved away from the market, which was popularized under the meaningful name of the "bull effect".

The latest methods of supply chain management developed in the years 2005-2013 were preceded by the reconstruction of the subject scope of research on the supply chain. Experience to date has been limited to transport, inventory management and optimization of logistics networks, and demand analysis. The new approach is that supply chain management should be combined with financial, marketing or information management to ask the question of how and why. The modern supply chain influences the competitiveness of the transnational corporation. There were even theses that integrating all functions of strategic management with logistics can be described by 53 other scientific disciplines such as sociology, philosophy, political sciences and psychology besides economics.

Supply chain management aims to provide the highest value to the customer at the lowest cost for the entire chain and consists in managing relations with: suppliers, recipients, and clients.

Each organization that is on the path of material flows in the supply chain alters their characteristics and increases their value. Controlling the flow of goods and related information is an essential task of supply chain management. This management is synonymous with planning, controlling and controlling the flow of goods through all phases of creating value added to goods from the place of obtaining raw materials, through production to the final buyer.

All this aims to offer these goods to buyers at the right place and time, in the right quantity and quality, and at pre-determined costs. Thus, effective supply chain management often translates into a reduction in operating costs and an increase in the level of customer service. The most frequently formulated goals of supply chain management in terms of logistics are: minimization of the total costs of product and information flow while maintaining the level of quality of delivery service required by customers; ensuring the shortest possible lead time and the highest possible reliability, frequency and flexibility of deliveries at the assumed level of flow costs; optimization of inventory levels in the supply chain scale along with flexible adaptation to the preferences in handling delivery of individual market segments, the key elements to manage the supply chain are: locating production plants and warehouses, transport activities, storage and handling, shaping and inventory control, collection, processing and transfer of information accompanying the physical flow of the product, cooperation with marketing in the area of customer service, and packaging and residue management.

In addition to the interpretation of supply chain management from a logistics point of view, more and more authors emphasize integration features and the need for space-time synchronization of demand flow management with the physical flow of product supply. The views of the authors emphasizing the integrative aspects of sustainable cooperation of enterprises for which the supply chain and supply chain management are broader concepts than the logistics chain and their management is distinguished by:

- Process orientation, which means treating activities and flows implemented in supply chains as processes;
- Recognizing the significant opportunities for cooperation of chain links in research and development, logistics, production, marketing and financial processes;
- Striving to optimize the value added to the products and services offered, and as a consequence increase the value of the supply chain itself;
- The need to integrate and coordinate the three streams, which are material, information and financial flows.

Since the mid-nineties of the twentieth century, the dominant view is that cooperation in supply chains begins already at the stage of product creation and development. On the other hand, the next of the basic processes that should be managed on a chain scale include demand planning and order fulfillment. An even broader scope of cooperation in supply chain management results from the analysis of the relationship between the product and relationships in the supply chains. Under both these variants, R. Cooper and R. Slagmulder distinguished between the stages of creation and implementation.

Analysis of the relationship between product design and production and network design allows you to determine areas of supply chain management which are: product and network configuration, product design, formation of production networks, optimization of processes in the supply chain.

Operational management, closely linked to strategic, concerns techniques and technologies supporting strategic decision-making, and new solutions in this area include: RFID as a new way to identify goods in the supply chain; a team of techniques for using voice, e.g. pick by voice, to issue orders regarding the relocation of inventory; EU directive called WEEE (Waste Electronical and Electronic Equipment) for the implementation of sustainable supply chains for environmental protection for recycling.

These methods can be introduced and implemented subject to the use of information technology, which at the same time helps to make the necessary decisions but also provides a lot of necessary information needed to manage the supply chain.

4. International supply chains in the pharmaceutical sectors after SARS-CoV-2

The international supply chain of the pharmaceutical industry was running very smoothly until the COVID-19 pandemic. However, the pandemic period revealed two disturbing phenomena. Firstly, the high dependence of the supply chain on air transport. Secondly, the crisis revealed a very strong dependence of the pharmaceutical industry on India and China, which account for 60 to 80 percent of the production of active substances. Radical shift in drug

production to be tackled by the European Commission in the coming weeks. However, international observers of the sector point to difficulties in recreating national factories of active substances. Therefore, more than a return to active substance production in Europe, there is now more talk about diversification of supply sources as a more viable and less expensive solution.

The United States was the largest domestic pharmaceutical market in 2022, accounting for more than 42 percent of total pharmaceutical spending worldwide. China is the second largest market with a market share of around eight percent (although it only includes the hospital market). The global pharmaceutical market was valued at approximately $1.48 trillion in 2022. Pharmaceutical sales in the United States generated approximately $630 billion in 2022, more than $500 billion more than any other country.

Differences between countries result, among other things, from the prices of prescription drugs. In the United States, the prices of branded drugs increased significantly between 2011 and 2019. In 2021, the United States had the highest per capita pharmaceutical spending in the world at an average of US$1,310. Branded drugs benefit from patent protection and the lack of competition means that both manufacturers and pharmacies can charge what is acceptable to the market.

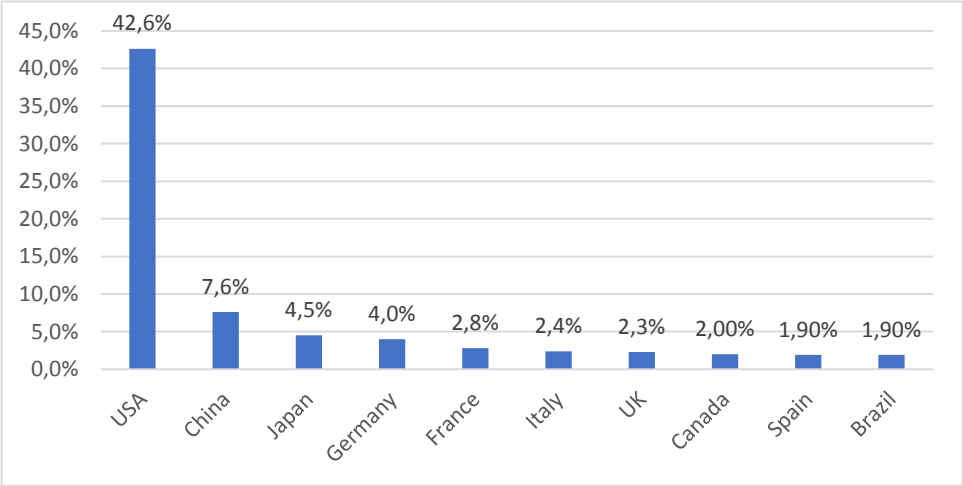

Figure 1. Market share of leading 10 national pharmaceutical markets worldwide in 2022.

The global pharmaceutical sector has an oligopolistic structure also at the level of enterprises. It is dominated by strong global companies. In 2019, 42% of the value of the pharmaceutical market was among the 16 largest global enterprises in the world. They are: Roche (Switzerland/Germany), Novartis (Switzerland), Pfizer (US), Merc & Co (US), Bristol-Myers Squibb (US), Johnson & Johnson (US), Sanofi (France), AbbVie (US), GlaxoSmithKline (UK), Takeda (Japan), AstraZeneca (UK), Amgen (US), Gilead Science (USA), Boehringer Ingelheim AG & Co KG (Germany), Bayer Pharma (Germany), Eli Lilly (USA).

5. Supply chains in the pharmaceutical industry

The analytical part of our paper is presented on the basis of one of enterprises supply chain disruption caused global pandemic since December 2019. The plant produces medicines and is located in several countries around the world. At work we will analyze the data on the acceptance of deliveries in one of the Polish branches companies. The Polish branch has 2 warehouses, and the components necessary for production supplies from over 150 different suppliers from around the world. From companies vans: 48 are located in Poland, 8 in Asia, and over 80 in Europe. European suppliers are stationed in countries such as: Germany, Great Britain, Slovakia, Italy. Italy – with the largest share among European suppliers. Imported goods from Poland and Europe are transported by trucks – land transport accounts for 97%. Sea transport is only 3%, it is Asian supplier. Deliveries are made on the basis of previously placed orders, adapted to a strictly defined production plan. In warehouses safety stock is maintained.

In this section, a comparison of the number of deliveries in 2019 will be presented and the first half of 2020. All deliveries arriving at the site are registered. This means that all goods are delivered to the warehouse in a planned manner, which facilitates not only unloading, but also the work of all departments companies. Below we present the differences in the compliance of the actual arrival of a delivery vehicle to the plant with the time of entry, based on last year 2019 and 2020, in which the structure of work was disturbed due to the prevailing pandemic.

Table 1.
Deliveries in 2019

2019	**2019**
Month	**Amount of deliveries**
Januar	383
Febrauar	500
March	525
April	568
Mai	576
Juni	600
July	492
August	520
September	594
October	568
November	596
December	515

Table 2.
Deliveries in 2020

2020	**2020**
Month	**Amount of deliveries**
Januar	206
Febrauar	260
March	65
April	61
Mai	89
Juni	230
July	392
August	420
September	494
October	540
November	550
December	501

Analyzing the number of deliveries accepted in 2019 and 2020, we can observe a dramatic decrease in the number of cars arriving at the plant. In 2019, except for two months in which the number of working days was lower. However, even in months parking, this number was not as low as in 2020, where from the first month we can observe a decrease in accepted deliveries. These are the lowest values recorded in the company's history. The worst period is in March, April and May, i.e. months where the economic situation was most disturbed. This resulted in stoppages of production lines or delays in their delivery. The situation began to return to normal in June 2020.

6. Summary

As shown in the presented example, interrupted supply chains can affect the operation of a pharmaceutical company in many ways. The largest areas of negative impact of the pandemic are:

- Liquidity of deliveries - in 2020, the number of accepted deliveries decreased compared to the same period of the previous year. It has it direct connection with the forced stoppage of production at suppliers and failure to deliver according to schedule.
- Disruption of production planning - untimely deliveries result in shortages component in stock, which translates into the inability to implement a specific production plan. The production planning department is forced to adjust plans based on the current availability of materials in warehouses. This is due to the increased inventory of the stock.
- Fulfillment of orders as planned - sudden changes in the production plan led to some orders not being fulfilled.

It can be said that as a result of the pandemic, global supply chains have been severely strained. This can be seen in the examples mentioned above, though pharmaceutical companies use alternative solutions whenever possible dealing with the economic crisis.

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ORGANIZATION AND MANAGEMENT SERIES NO. 186

SUSTAINABLE CONSUMPTION AND ENERGY EFFICIENCY

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Purpose: The paper presents the issues related to the sustainable consumption and energy efficiency.
Design/methodology/approach: The study used world-bank reports from the University of Oxford publication Our World in Data and own research.
Findings: The main purpose of the article is to increase consumer awareness and demand for energy needs. It is worth emphasizing the important role played by sustainable energy expenditure in this area. They are an important element of sustainable consumption, because the way society uses energy has a significant impact on the environment, health and energy resources. Sustainable energy expenditure is a way of using energy that allows you to achieve a balance between the demand for energy and its consumption. Selected measures of energy efficiency show that economic development does not have to be equated with an increase in the consumption of energy resources.
Originality/value: The publication presents the results of research conducted on the basis the University of Oxford publication Our World in Data.

Keywords: sustainable consumption, energy efficiency, solar energy.

Category of the paper: Research paper.

1. Introduction

The Sustainable consumption is consumption that takes into account the impact on the environment and society. This means that consumers make purchasing choices that are more environmentally and socially friendly. In accordance with the idea of sustainable consumption, the priority is to meet the needs and increase the quality of life for everyone on a local and global scale, while respecting human and labor rights, taking into account the possibility of meeting the needs of future generations and preserving and restoring natural (natural) capital for them (Kurzak, 2016). Sustainable consumption aims to reduce the negative impact on the natural environment and society by reducing the amount of waste, energy and water consumption and choosing products that are consistent with social values. The effects of human

impact on the environment from consumption can be of two types: direct and indirect. Direct pressures include: emissions to air from the combustion of fuels in private cars or the burning of coal, gas and oil for heating purposes (heating the house, heating water, cooking) in households. Indirect pressure, on the other hand, is related to the consumption of goods and services whose production has an impact on the environment. This pressure is the most difficult to estimate due to the fact that the production of each good is associated with various impacts on people and the environment in the production phase (Jaros, 2014). In July 2008, the European Commission proposed a package of actions and proposals on sustainable consumption and sustainable industrial policy (COM(2008)0397).

2. Consumption and energy expenditure

The main objective of such activities was to increase consumer awareness and demand for sustainable goods and production technologies, promote innovation in EU industry and regulate international issues. It is worth emphasizing the important role played by sustainable energy expenditure in this area. They are an important element of sustainable consumption because the way society consumes energy has a significant impact on the environment, health and energy resources. Sustainable energy expenditure is a way of using energy that allows you to achieve a balance between the demand for energy and its consumption. This means that consumers make purchasing choices and use energy in a more environmentally friendly way, which also affects the "quality of life and social well-being", as the authors point out (Barwińska, Małajowicz, Knapkova, Szczotka, 2023). Energy expenditure is closely related to energy efficiency. It is difficult to give a universal definition of energy efficiency. After analyzing the existing literature on the subject, it can be assumed that it is the ratio of the obtained results, services, goods or energy to the energy input. Efficient use of energy aims to reduce the amount of energy needed to deliver products and services (Doms, Dunne, 1995). Definitions such as "resource efficiency, energy consumption reduction, energy services per unit, use of energy resources" are available. Energy efficiency therefore focuses on minimizing energy losses and waste through the optimal use of available resources and minimizing losses in the processes of energy transformation and supply. According to the directive of the European Parliament from 2012, energy efficiency is "one of the most important elements to ensure the sustainable use of energy resources". In other words, it is a series of activities aimed at reducing energy consumption in the economy.

3. Energetic efficiency

There are several energy efficiency measures that are used to assess and compare the energy performance of systems, equipment, buildings or sectors, as shown in table 1. It is worth noting that energy efficiency measures may vary depending on the sector, context and purpose of the assessment. It is also important to consider all aspects of energy consumption, such as fossil fuel consumption, electricity consumption and greenhouse gas emissions, in order to obtain a comprehensive energy efficiency assessment. The selected measures of energy efficiency show that economic development does not have to be equated with an increase in the consumption of energy resources (Gulczyński, 2009).

A certain dissonance between economic growth and energy consumption is permanent due to both the energy-saving direction of technology development and pro-innovation policy, as the authors note (Malko, 2012). From October 1, 2016, the Act of May 20, 2016 on energy efficiency (Journal of Laws of 2021, item 2166) has been in force, which introduces changes to the regulations that are beneficial both for the development of the economy and for every citizen. The purpose of the regulation is that anyone who meets certain requirements (energy efficiency audit for a specific investment) will receive a benefit in the form of property rights resulting from energy efficiency certificates (commonly referred to as white certificates). White certificates are issued by the President of the Energy Regulatory Office. The most popular investments for which white certificates are awarded include: thermal modernization, insulation, replacement of industrial equipment, replacement of lighting and energy recovery from industrial processes.

Table 1.
Energy efficiency measures

Indicator Characteristics	**Indicator Characteristics**
Energy Efficiency Ratio (EER) or Coefficient of Performance (COP)	These metrics are applied to HVAC (heating, ventilation, air conditioning) systems and help measure the ratio of energy delivered (e.g. cooling or heating) to energy consumed. The higher the EER or COP, the more energy efficient the system (lower operating costs).
Energy Consumption Index, ECI	They are used to measure energy consumption for a specific area, sector or device. They can be expressed as a ratio of energy used to other measures such as building area, industrial production or units of time.
Building Energy Efficiency Index (BEEI)	It is used to assess the energy efficiency of buildings. It measures the ratio of a building's total energy use to another parameter, such as floor space or energy intensity.
Energy Utilization Index (EUI)	It is used to compare the energy consumption of different buildings or sectors. It expresses the total energy consumption in relation to a unit of measurement, such as a square meter of building area or a unit of production.
Index of energy efficiency of industrial processes	Energy efficiency measures may include indicators such as the Energy Intensity of Production, which measures the ratio of energy used to a unit of GDP.

Source: own elaboration (https://www.ure.gov.pl/pl/efektywnosc-kogenerac/efektywnosc-energetyczn, https://www.iea.org/data-and-statistics/data-product/energy-efficiency-indicators).

In 2018, under the "Horizon 2030" directive, the goal was to reduce energy consumption by 32.5 percent. by 2030. In absolute terms, energy consumption is expected to be a maximum of 1,128 million tonnes of oil equivalent for primary energy and 846 million tonnes for final energy, measured on the basis of 2007 forecasts. It was also assumed that the average annual energy consumption would decrease by 4.4%. on Member States by requiring them to develop a 10-year national plan on how to meet the energy efficiency target. In order to maintain energy efficiency, the assumptions of the European Green Deal are implemented. According to its provisions, the European Union should achieve climate neutrality by 2050. Initially, by 2030, greenhouse gas emissions are to be reduced by at least 55%. compared to the data from 1990. The share of energy generated from RES is to be 40%. all energy producers, and emissions from delivery vehicles are to be reduced by 50%. This goal primarily means increasing the production of energy from renewable energy sources, which include: solar energy, wind energy, hydro energy, geothermal energy, biomass energy, including solid energy (e.g. wood, plants), liquid energy (biofuel), gas energy (biogas) (Barwińska, Małajowicz, Knapkova, Szczotka, 2023). The list of individual energy producers is presented in table 2. It shows that solar power plants operate with the highest efficiency for 24.9 percent of the time. time during the year, and wind farms by 35.4 percent. Geothermal power plants operate around the clock, which is a significant advantage over other unconventional sources such as solar, wind or water power plants. However, the ranking is won by obtaining energy from nuclear sources, as much as 92.5%.

Table 2.
Energy efficiency of individual energy sources

A type of energy	**%**
Nuclear energy	**92,5%**
Geothermal energy	74,3%
Gas	56,6%
Water energy	41,5%
Coal	40,2%
Wind	35.4%
Solar energy	24,9%

Source: own elaboration: (https://www.energy.gov/ne/articles/nuclear-power-most-reliable-energy-source-and-its-not-even-close)

However, the review of the literature shows that the importance of renewable energy, in particular energy obtained from photovoltaic sources and wind energy, is increasing. The development of the photovoltaic market in the EU-27 countries is very dynamic and its share in the energy market is increasing year by year (the increase compared to 2019 reached 18.8 GW). The chart below shows the annual production of electricity from the sun in the world, measured in terawatt hours. In 2022, it was approximately 1200 TWh. Thanks to its practical technology, solar energy is popular and more and more households decide to cover their roofs with photovoltaic panels, becoming prosumers. The prosumer concept aims to decentralize electricity production, allowing individuals and small businesses to participate in energy production and reducing dependence on traditional suppliers.

However, the review of the literature shows that the importance of renewable energy, in particular energy obtained from photovoltaic sources and wind energy, is increasing (Barwińska, Małajowicz, Knapkova, Szczotka, 2023). The development of the photovoltaic market in the EU-27 countries is very dynamic (Izdebski, Kosiorek, 2023) and its share in the energy market is increasing year by year (the increase compared to 2019 reached 18.8 GW).

The chart below shows the annual production of electricity from the sun in the world, measured in terawatt hours. In 2022, it was approximately 1200 TWh. Thanks to its practical technology, solar energy is popular and more and more households decide to cover their roofs with photovoltaic panels, becoming prosumers. The prosumer concept aims to decentralize electricity production, allowing individuals and small businesses to participate in energy production and reducing dependence on traditional suppliers.

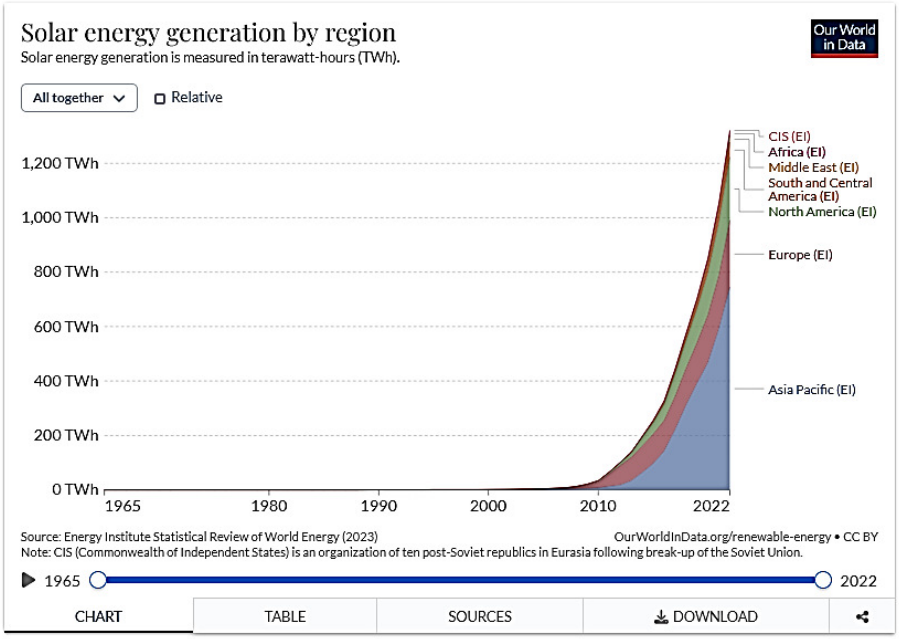

Figure 1. Solar energy production in the world.

According to the latest data provided by the Central Statistical Office (GUS), households in Poland had a significant share in the national energy consumption, not counting the consumption of engine fuels. In 2021, this indicator was 20.2 percent. Households consumed on average 24.6 GJ of energy per capita. For comparison, the European average was 24.5 GJ/capita. As much as 65.1 percent. of energy used by households was used for space heating. It is worth noting, however, that its share decreased by 3.7 percentage points. compared to 2012. Heat from the network (52.2%) and solid fuels (32.8%) were most often used for space heating - mostly hard coal and firewood. In addition to heating rooms, they were also used to heat water (22.5%) and cook meals (1.7%). Natural gas was used in 56.5 percent. households, but 30.8 percent recipients used it only for cooking meals, and only 14.6 percent. for residential heating only. In dwellings equipped with their own central heating boilers, the most common were double-function boilers (26.3%), which were also used to prepare hot water. Single-function boilers were less popular (15.1%), and fireplaces were even less common

(2.4%). Solar collectors were used by 1 in 38 households, and heat pumps by only 1 in 132 households. Electricity was used mainly for lighting and powering household appliances and electronics. The use of electricity for heating purposes was small (5.5%), e.g. due to high prices and the existence of cheaper substitutes. The heating network was most often used to obtain hot water (41.1% of households). Boilers or electric thermal baths also had a significant share (19.5%). Increasing energy efficiency in a household can contribute to reducing energy consumption, lowering energy bills and limiting the negative impact on the environment. Actions that households can take on their own to increase energy efficiency include: the use of thermal insulation, the use of energy-saving lighting, temperature control, the use of devices with a high energy efficiency class (e.g. marked A++ or A+++), which consume less energy, turning off unused devices, optimal use of natural light, economical use of water, reducing electricity consumption and others. Poland is not widely recognized as a country with high energy efficiency. There are some challenges that Poland has to face in the context of energy efficiency. For example, in Poland there are still many older buildings that have low energy efficiency and need modernisation. The district heating sector is also a challenge as many plants still use coal as their main fuel, which has a negative impact on the environment. Poland is still one of the largest emitters of greenhouse gases in the European Union. However, in recent years, Poland has been making efforts to improve energy efficiency and reduce emissions. Programs and initiatives are being implemented, such as co-financing programs for thermal modernization of buildings, support for renewable energy sources and energy efficiency programs in industry. Poland has also committed itself to meeting the European Union's climate and energy goals, which requires greater emphasis on energy efficiency.

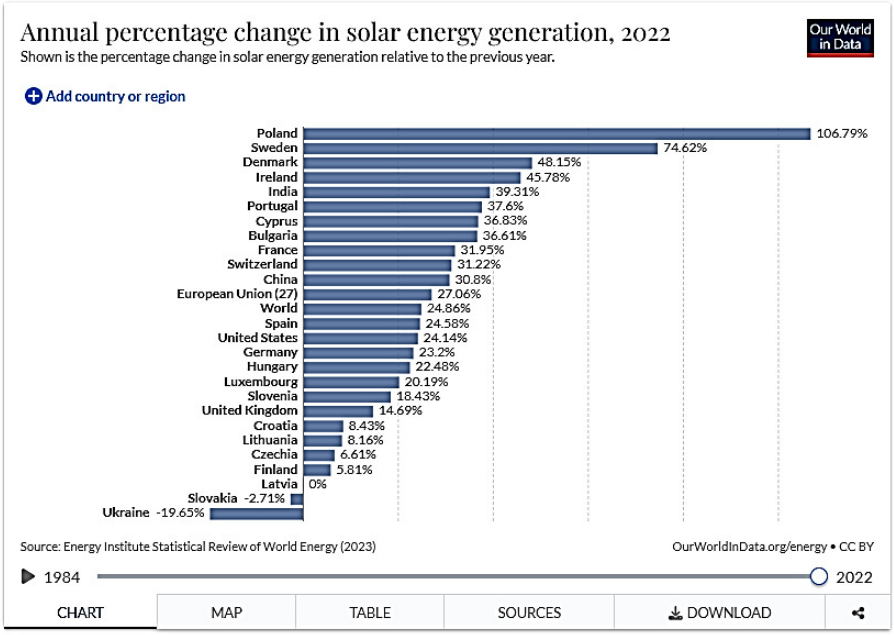

Figure 2. Annual percentage change in solar energy generation, 2022.

The chart above shows that in 2022 Poland recorded the largest jump in the use of solar energy. This is positive news, and at the same time a surprise that most photovoltaic analysts did not expect. The driving force for photovoltaics in Poland turned out to be the micro-installation segment, which enjoyed a favorable system of accounting for energy produced and collected from the grid. In the context of energy efficiency, energy security is also an important issue, which aims to ensure the energy stability of the country in uncertain times or in the event of unforeseen situations that have a negative impact on the flow of energy and a sudden increase in its price. The country should have enough energy to meet current and future energy needs. Easily available and cheap energy for society has an impact on the development of the economy, which needs to constantly produce more and more goods. Interruptions in energy supply pose a threat to human health, expose entrepreneurs and individuals to financial losses, and may contribute to destabilization. Energy security can be achieved e.g. thanks to the diversification of energy sources. In March 2022, after the start of Russia's invasion of Ukraine, for fear of Russia using fossil fuels as a weapon, for example by interrupting their supplies, changes were proposed under the "REPowerEU" program in the field of energy security and energy storage rules. An obligation was imposed to fill gas storage facilities to at least 80 percent until November 1 of the same year, and in subsequent years the limit was increased to 90 percent. On May 18, 2022, under the same program, the European Commission proposed a number of changes in energy efficiency, taking into account the Russian invasion of Ukraine. One of the most important of these is the European Union's independence from Russian fossil fuel supplies by diversifying supplies and saving energy and accelerating the clean energy transition.

4. Summary

With the growing emphasis on energy security and diversification of supplies, but also addressing climate change, it is crucial to develop a strategy for the transition from non-renewable energy sources to renewable ones. It is important that those in power increase subsidies for alternative energy sources, in particular photovoltaics, and introduce programs aimed at increasing public awareness of energy saving. Governments can use financial incentives for people using renewable energy sources, such as tax credits, to encourage them to use these sources.

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RESEARCH ON THE DEVELOPMENT OF DIGITAL SIGNAGE SYSTEMS AND THE FACTORS THAT INFLUENCE THE EFFECTIVENESS OF THE MESSAGE

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Purpose: This paper aims to research of the methods of communication in the public sphere, which will provide a better understanding of the reasons and development of digital signage systems. This will allow to understand where digital signage systems came from and improve the effectiveness of communication.
Design/methodology/approach: The objectives have achieved through a review of the literature and focus on the growth of digital signage systems. The factors influencing the effectiveness of the message were also analyzed.
Findings: In the course of the work was analysis digital signage systems development which are the basic type of systems used for communication in the public sphere. Moreover, presented factors influencing the effectiveness of the message will contribute to development tailored digital signage system.
Research limitations/implications: Worthy of investigation in future research would be the impact of individual digital signage solutions on audiences as well as users.
Practical implications: This research is great starting point for researchers who want to learn more about digital signage systems. This research can also be useful for software development enterprises during the process of developing a digital signage system.
Social implications: This research can contribute to people's understanding of the reality around them and, more specifically, the systems that present them various content. It will also help make the messages more effective.
Originality/value: This article is valuable for researchers studying digital signage systems, especially their development, as well as for the digital signage industry. The research can be a great starting point for future research on these systems, and can help make the message more effective. Despite frequent use of digital signage systems in everyday life, there are rarely addressed topic in the scientific sphere. What makes taking up this topic innovative and very important for future development of digital signage systems as well as effective communication in the public sphere.

Keywords: digital signage systems, communication in the public sphere, communication tools, effective communication, mass communication.

Category of the paper: Research paper, General review.

1. Introduction

Through the ability to communicate, people began to build communities, which in turn supported technological development and the growth of civilization. Over time, new ways of communicating appeared, more complex, allowing information to be transmitted over longer distances. The more our technology developed, the faster new solutions to the problem of data transmission appeared.

Nowadays, a lot of technology, equipment, various types of software assist us in communicating content to others. In order to make the message more attractive, easier to receive and thus make a better impression on the recipient, multimedia content is used. The message is not just text, but often the evocation of appropriate emotions or actions in the recipient.

This message can be an advertisement for a product or place, important information to be conveyed, such as, a cancelled meeting, train or bus schedules, college or school hours, an emergency, or information about a sudden event that requires the response of those close to you, such as a fire or the need to evacuate. It can also be information about current events, holidays, etc. Often multimedia content is a supplement to various events such as fairs, lectures, concerts, meetings. Then they perform the function of complementing the full experience of the event. Videos with computer animation and stage lights enhance the reception of music at concerts, as well as the presentation of a new product at a trade fair. Infographics and charts support the message of content presenters at lectures and company meetings.

All this information is conveyed to people in different ways. During demonstrations using monitors, TVs, projectors, you can also take care of the right atmosphere using other devices such as blowers, smoke generators, etc. It all depends on what kind of impression we want to create, what kind of information to convey, whether it is to be during an event and what the nature of the event will be.

2. Flow of information through digitization

There is a lot going on around us these days. The need for information flow between people is huge and greater than ever before. The ability to transmit information to a specific group of people in a specific location is also of great importance. Throughout history, the way information is transmitted has changed. From gestures, speech, through the appearance of various types of writings. In order to achieve certain goals, for example, to make the message secret or to make it transmitted over a greater distance it was changed into another form, for example, Caesar code, Morse code. With the development of civilization and the construction of new devices and technologies, as well as the development of education,

the transmission of information was increasingly improved. Technology began to allow the expansion of the audience to a large extent when devices such as radio, television and finally the Internet were created (ZPE – MEiN, 2021).

Over the past 20 years, the Internet has become an indispensable part of our lives. It's hard for us to imagine a day where we don't read a new blog post, a new article on our favorite website, browse social media, chat with friends using instant messaging, or listen to a new episode of an interesting podcast. The multitude of content and forms is overwhelming, and everything is at our fingertips.

The Internet allows one person sending a message to reach many recipients regardless of geographic location. It has allowed an easy way to communicate and to read the message at the moment it suits us. However-that said, we have no control over how quickly the message will be presented to the recipient and whether it will be the right time. We do not, also, know for sure if the person in the location will check the messages provided for them or if they will have an application that will notify them.

3. The course of the communication process and the effectiveness of information transfer

In order for the communication process to take place, there must be such elements as the recipient, the sender and the message that passes through a given communication channel. The information, that is, the thought we want to convey, is encoded into a message, e.g. in the form of text, graphics, video. This message is passed through the communication channel, accompanied by so-called noise that interferes with the message reaching the recipient. Once the message reaches the recipient, it still needs to be decoded correctly, i.e., well understood by the recipient. An important fact is that the communication process can be two-way or one-way (Ober, 2013).

Whether the message will be read correctly by the recipient is influenced by a number of factors that generate the previously mentioned noise, perhaps outside noise, an underexposed room or such things as the recipient being tired and distracted. In order for a message to be received by the recipients according to our intentions, it must also have the right context. The stories to which the sender refers should be familiar to the recipient so that he or she can understand the message well. The influence of the other person's perception or the way the message is presented also has a huge impact on its reception, as does the cultural background (Sypniewska, 2015). Context can also be the time and place in which the message is received. If it is received too late or too early, the message read by the recipient may not be understood or received as we would like. Therefore, it is important to properly synchronize the display of the message to the recipient at the right time and in the right order.

Nowadays, a lot of technology, equipment, various types of software assist us in communicating content to others. To make the message more attractive, easier to receive, and thus make a better impression on the recipient, multimedia content is used. There are many factors that affect the effectiveness of the message (Walędziak, 2014):

- **Brevity** - Using more words does not increase the effectiveness of the message, and a long message can tire the recipient and reduce their focus on the content. Sometimes one clear argument can be better than many.
- **Suggestiveness** - It is important that we are convinced of the value of our message, if we want it to intrigue others. To make the message more suggestive we use various techniques such as communicating benefits, emphasizing uniqueness. The best example of messages using these techniques are advertisements, where we always hear that the advertised product is always the "the most": "the best", "the highest quality", or "the cheapest". It happens that these messages miss the truth, but the intensity and certainty with which the creators of the advertisements present their products makes recipients grasp the hook. Although the things just described are important, the most important element of an evocative message is to define the purpose of the message, we must clearly determine what action our message is intended to encourage.
- **Consistency** - Even the best message, can prove unreliable to the recipient. People by nature are distrustful and inquisitive, if something sounds too good they begin to analyze it and look for hooks. All it takes is one inconsistent sentence, for them to delete the entire message. Here we see the advantages of brevity, it is better to use fewer arguments than to reach for ones that may prove incomprehensible.
- **Understanding** - Another key to effective communication is the ability to empathize with the recipient. When building a message, pay attention to: views, education and mindset of the potential audience. This allows you to be constructed so that it contains content of interest to its addressees. Empathy also helps to create direct relations and makes communication more personal and therefore also more effective.
- **Context** - There are factors that the creator of the message did not anticipate and even factors that are beyond his control:
  - Place and time - the willingness to transmit a message does not mean that others are ready to receive it.
  - Events preceding or following the message.
  - The recipient's experience.
  - Messages accompanying a given message.
  - Mood of the recipient.

- **Credibility** - It depends on various factors, such as:
  - Sender - if the sender is a credible, sincere, knowledgeable person relevant knowledge then his statements will be more credible than those coming from a person who has failed our trust, or is a layman in a given subject.
  - Introduction - our statement is more credible if we start it with a brief analysis of the situation before sharing our insights. In this way we show that we understand the problem and our solution is well thought out.
  - We should be careful about our relationship with our audience, their trust is difficult to gain, and even one slip-up can affect the credibility of subsequent messages.
- **Concreteness** - A message containing concrete examples and figures is better received than when it refers to hypothetical events. Using figures from a reliable source is always a strong argument. It is also a good idea to use statements that clarify goals, they carry a commitment that we are more likely to believe.
- **Massiveness** - The more often we hear a piece of information, the more likely we are to accept the statement as true. This is one of the reason why long-term and repetitive advertising campaigns are more successful than short-term and one-time campaigns. Additionally, if we hear a given statement from multiple independent sources, it is us more credible than one announced from a single source.
- **Originality** - Unfortunately, even the best message can eventually get boring. That's why it's important to change the way you present information from time to time. In order to attract the attention of the recipient, it is necessary to be inventive, unconventional approach. For example, sometimes it's enough to change the label of a product to stimulate our curiosity and ultimately get us to purchase.
- **Completeness** - It is important to give the recipient a complete set of information, answers to his additional questions. When doubts arise on his side, and he does not receive answers to them we may not convince him of our product. Everyone needs a different range of information to make a decision. Some act spontaneously, needing little to make a decision. Others require a complete set of information before they make up their minds otherwise they may later regret a hastily made decision.
- **Political correctness** - It is very easy to offend or upset someone, something that was supposed to be material for an expressive and interesting message can turn out to be a cause for attacks and boycotts. Therefore, it is important to be able to empathize with the recipient and try to anticipate how the message might be received.

In order to make communication more effective, more and more new viewpoints on this issue have been created. One of them is visual communication, which, according to the Encyclopedia of Management, can be defined as communication through images, the transmission of information in visual form between the sender and the receiver by means of media (Gieracka, 2020). The visual form in this case can take various forms, they can be images,

videos, animations, photos, infographics, illustrations (Kawka, 2015). In this way it is much easier to attract people's attention, especially when our message is to reach many recipients.

4. Evolution from signage to digital signage

Mass communication is a rather specific type of communication that differs from typical interpersonal communication. Appropriate ways of such communication using signs have been developed. Further evolution and technological development led to the creation of systems that allow centralized management of the transmitted content.

4.1. Mass communication

Communication to a wide audience has not always been as easily accessible as it is now. Classifying communication by the reach of its participants, it turns out that the highest level is mass communication. But in order for it to be possible, appropriate means of communication were needed. Mass communication became widespread with the development of mass media. It began as early as the mid-15th century, when the first printed book was written. About 200 years later, the press was established and other mass media were developed, i.e. cinema, radio, television, until the second half of the 20th century saw the emergence of new media, i.e. the Internet, cable and satellite networks, etc. (Dobek-Ostrowska, 2007).

An example of reaching a wider audience is the printing and hanging of posters. The first posters in the world were created as early as the first half of the 19th century, but the main development took place in the 1980s and 1990s. Posters cover a variety of topics and are made using different methods. According to the dictionary of the scientific publishing house PWN, a poster is defined as "an artistic genre of graphic design that fulfills the functions of information, advertising, propaganda and political agitation" (PWN, 2003, p. 317).

4.2. Signage

Another interesting example of informing a wide audience is the creation of signs and symbols to convey important information. This process is called signage. On chemicals there are signs describing the substances inside, while a road sign system informs and warns drivers about various traffic incidents, indicates the correct route, etc. Thanks to the fact that the symbols are simple, clear, and school education has content on the subject in the core curriculum, the signs are clear and understandable to most people. Information is conveyed to many people at the right time when they need it, for example, signs indicating the direction leading to a particular city at an intersection.

4.3. Electronic signage

Advertising signs were also created to encourage people to visit a place, for example. With the passage of time and the development of technology, signs in electronic form - electronic signage, were invented. These signs were usually luminous to make them more visible and attractive, and were made up of electronic parts, e.g. using light bulbs, or even using fluorescence.

There were many positive aspects of using electronics for signage, the signs became more visible, one could say that they were more interactive than traditional ones. The downsides of such a solution were certainly the need to provide electricity, the higher cost of purchase and the cost of operation, such as replacing the bulb.

4.4. Digital signage

With the improvement of electronics and the emergence of more technologies, the digital age has arrived. Digital circuits, calculators, telephones, portable music players, digital cameras, computers, tablets, LED monitors, LED TVs, etc. were created.

The next evolution bore fruit in the form of Digital Signage. The definition of Digital Signage is best encapsulated in the document "Digital Out of Home - A Primer-Section 1 - Introduction", written in cooperation with companies dealing with these issues. “Digital signage is a network of digital displays that is centrally manageable and addressable for targeted information, entertainment, merchandising and advertising” (Abrons et al., 2019, p. 3). In simple terms, it is any digital screen that is not in a private location. It could be a video screen in front of a supermarket, screens displaying menus at fast-food restaurants above the cash registers, screens displaying train or bus schedules at a bus stop, screens presenting content at a university or school, or even screens or projectors displaying animations during a concert.

The evolution process from signage to digital signage is shown in Figure 1.

Figure 1. The evolution process from signage to digital signage.

Source: Own study/Photos taken from pixabay.com

4.5. Digital technologies outside the home

When digital information visualization technologies, such as TV in the home, began to be used outside the home retreat, they also began to be referred to as Digital out of Home (DOOH). DOOH belongs to Digital Signage, but it is a more specific division of Digital Signage, as it refers to screens outside the home that display advertising content and whose content can be changed remotely using digital technology (Abrons et al., 2019).

4.6. Capabilities of digital signage systems

Digital signage offers a great deal of advantages over its predecessors. There is the ability to quickly change content remotely, which helps save time and costs. It is possible to tailor the content displayed to the location and personalize the content, and it is also possible to conduct interest surveys using additional devices, such as using Microsoft's Kinect motion sensor to make the content change according to the data coming from the device, or connecting to sensors in the ceiling that will create a map showing how customers move around the store (Abrons, 2019). Digital signage systems consist of hardware and software components. The upfront costs of building a system can be high because of the hardware and software needed, but what you get in return is a lot of capabilities and a long life. The right software, the so-called Content Management System, or CMS for short, usually allows us to have many options for scheduling and managing the content we display, and some even allow us to directly create content from any location, even from home, without having to hire professionally trained staff to do so. The simplest example is the ability to quickly change the prices displayed in a restaurant, rather than having to print new ones and replace them, or change the breakfast menu to lunch evenly at 10:30 am. A good example is also the ability to quickly change the time of a train's arrival at a station, or to inform everyone in a building about a fire or bomb alarm and the need to evacuate quickly.

5. Discussion

During the research, it was noted that the development of digital signage systems is very interesting. These systems were developed with the rise of digitization in response to the need to communicate messages to a wide audience. Through an in-depth study of the subject, it was found that digital signage systems originated from signage. Signage allowed for easy and fast mass communication, and digital signage type systems have greatly facilitated the management of information transmission and displayed content using the latest technologies. In practice, carrying out this study allows us to understand the reality around us, to better shape the future by making more informed decisions about the design of digital signage systems, as well as to communicate information more effectively.

Through the research, it can be noted that it is not only the content of the message itself that affects the effectiveness of the message. External factors such as the noise surrounding an addressee or the context should also be taken into account. By context we can also mean the place and time of transmission of the message to an addressee. It can be concluded that when creating digital signage systems, the location of the screens is important, as well as the time at which the content is displayed.

6. Conclusions

In summary, the ability to communicate to a wider audience has come a long way. Nowadays it is widely used, but this required technological development, as well as proper education. Mass communication is used for a variety of purposes, whether to convey information, entertainment or, as is already being used extensively, for marketing. In addition, not only text or sound alone began to be transmitted, but many types of media at one time. Multimedia is widely used during mass communication, and with further development, information systems began to emerge to support the mass communication process and allow much more than before.

Nowadays, in order to be able to easily manage the information message and presentation of multimedia content, a suitable information system of the digital signage type is needed.

When creating messages intended for a wide audience, it is worth considering the factors mentioned that affect the effectiveness of the message. This will allow to increase the effectiveness of message.

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WORK SAFETY AND HEALTH – THE BUSINESS ANALYTICS USAGE IN INDUSTRY 4.0 CONDITIONS

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Purpose: The purpose of this publication is to present the applications of usage of business analytics in work safety and health.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: In the era of Industry 4.0, characterized by automation and smart technologies, the preservation of workforce health and well-being takes center stage. This paper explores the transformative integration of business analytics into work safety and health practices, signaling a paradigm shift in monitoring, managing, and elevating occupational safety standards. The publication underscores the proactive role of business analytics, especially through wearable device-driven physiological monitoring, in safeguarding worker health without compromising productivity. By aligning seamlessly with regulatory compliance, business analytics becomes a linchpin in mitigating legal and financial risks associated with workplace incidents. The synergy between work safety, health, and business analytics presents a transformative approach, empowering organizations to proactively address safety concerns and cultivate safer work environments. While delving into the software applications, the paper highlights the versatility of analytics in predicting incidents, monitoring compliance, and optimizing workloads. Challenges such as data quality, privacy concerns, and integration issues are acknowledged, yet the multitude of advantages showcased, including incident prevention, data-driven decision-making, and cost savings, affirm the transformative potential of business analytics in shaping a safer, more efficient, and healthier future workplace.
Originality/value: Detailed analysis of business analytics in work and safety area.

Keywords: business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; work safety and health.

Category of the paper: literature review.

1. Introduction

In the context of Industry 4.0, where automation and smart technologies are prevalent, the health and well-being of workers remain a priority. Business analytics aids in monitoring the physiological parameters of workers through wearable devices, ensuring that their health is not compromised in the pursuit of increased productivity. This proactive health monitoring not only prevents potential health issues but also contributes to employee satisfaction and retention. Furthermore, the integration of business analytics in work safety aligns with regulatory compliance requirements. By maintaining detailed records and analytics reports, organizations can demonstrate their commitment to safety standards, mitigating legal and financial risks associated with workplace incidents. This proactive approach not only safeguards the workforce but also protects the reputation of the business in an increasingly scrutinized corporate landscape.

The convergence of work safety and health with business analytics in the era of Industry 4.0 signifies a paradigm shift in how organizations approach employee well-being. The data-driven insights provided by business analytics empower businesses to proactively address safety concerns, optimize operations, and create a safer and healthier work environment. As Industry 4.0 continues to evolve, the synergy between work safety and business analytics will be a cornerstone in fostering a culture of safety and well-being within industrial settings (Ghibakholl et al., 2022).

The purpose of this publication is to present the applications of usage of business analytics in work safety and health.

2. The selected aspects of business analytics usage worker safety and health

Work safety and health have always been paramount concerns in industrial settings, with the well-being of employees being a top priority for businesses. In the rapidly evolving landscape of Industry 4.0, the integration of business analytics has emerged as a transformative force, bringing about significant advancements in monitoring, managing, and enhancing occupational safety and health standards.

The adoption of Industry 4.0 technologies, characterized by the interconnectedness of devices and the utilization of data-driven insights, has paved the way for a more comprehensive approach to work safety. Business analytics, in this context, plays a crucial role by leveraging data from various sources within the industrial ecosystem. This includes real-time data from sensors, wearable devices, and other IoT-enabled equipment, providing a holistic view of the work environment (Bakir, Dahlan, 2022).

One of the key advantages of business analytics in the realm of work safety is its ability to proactively identify potential hazards and risks. Through advanced analytics algorithms, patterns and anomalies in data can be detected, allowing organizations to preemptively address safety concerns before they escalate. This predictive capability empowers businesses to implement preventive measures, reducing the likelihood of accidents and injuries. Moreover, business analytics facilitates a data-driven approach to safety decision-making. By analyzing historical incident data, organizations can identify trends and root causes, enabling the development of targeted safety strategies. This insights-driven strategy not only enhances the overall safety culture within the workplace but also contributes to the optimization of resources and operational efficiency (Zeng et al., 2022; Pech, Vrchota, 2022).

Table 1 contains descriptions of how business analytics is used in the case of work safety and health. This table highlights various applications of business analytics in the context of work safety and health, showcasing how data-driven insights can contribute to a safer and healthier work environment.

Table 1.
The usage of business analytics in work safety and health

Application	Description
Incident Prediction	Incident prediction involves the analysis of historical safety data to identify patterns, trends, and contributing factors that may lead to workplace incidents. By leveraging advanced analytics, organizations can proactively identify potential hazards and implement preventive measures. This approach empowers businesses to stay ahead of safety risks and create a safer working environment for employees.
Safety Compliance Monitoring	Safety compliance monitoring utilizes business analytics to track and ensure adherence to safety regulations and standards within the workplace. By systematically analyzing data related to safety protocols and regulatory requirements, organizations can identify areas of non-compliance and take corrective actions promptly. This application of analytics promotes a culture of safety and helps organizations meet regulatory standards, ultimately reducing the risk of accidents and injuries.
Employee Health Monitoring	Employee health monitoring involves the use of analytics to assess and track the well-being of individuals within the workforce. By analyzing health-related data, such as employee wellness program participation, absenteeism patterns, and health insurance claims, organizations can identify potential health risks. This allows for the implementation of targeted wellness programs and interventions to improve overall employee health and safety.
Root Cause Analysis	Root cause analysis with business analytics is a process of investigating the underlying factors contributing to workplace incidents. By analyzing data related to accidents, injuries, or near misses, organizations can identify the root causes and address them systematically. This approach goes beyond addressing symptoms and helps in implementing effective preventive measures to eliminate or reduce the recurrence of safety incidents.
Workload Optimization	Workload optimization involves the use of analytics to analyze work patterns, employee schedules, and task distribution. By understanding how workloads are distributed across teams and individuals, organizations can identify potential stress points and mitigate risks associated with overburdened workforces. This application of analytics contributes to creating a balanced and manageable workload, promoting employee well-being and safety.
Real-time Safety Dashboards	Real-time safety dashboards provide a dynamic and visual representation of key safety metrics and indicators. By leveraging real-time analytics, organizations can monitor safety performance, identify potential hazards, and respond promptly to emerging safety issues. This application enables quick decision-making, enhances situational awareness, and contributes to a proactive safety culture within the workplace.

Cont. table 1.

Training Effectiveness	Training effectiveness analytics assess the impact and efficiency of safety training programs. By analyzing data related to training participation, test scores, and post-training performance, organizations can evaluate the effectiveness of their safety training initiatives. This data-driven approach helps in refining training programs, addressing knowledge gaps, and ensuring that employees are well-prepared to adhere to safety protocols and guidelines.
Predictive Maintenance	Predictive maintenance involves using analytics to predict equipment failures or malfunctions before they occur. In the context of work safety, this application helps organizations anticipate potential risks associated with malfunctioning equipment that may compromise safety. By proactively scheduling maintenance based on predictive analytics, organizations can minimize downtime, reduce the risk of accidents, and ensure the reliability of safety-critical equipment.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

3. Software used in worker safety and health in Industry 4.0 conditions

The integration of business analytics software has significantly transformed the landscape of worker safety and health, offering organizations powerful tools to proactively manage and enhance workplace well-being. These software solutions leverage advanced analytics to collect, process, and interpret vast amounts of data related to various aspects of safety and health within the workforce (Cillo et al., 2022).

Business analytics software enables organizations to predict potential workplace incidents by analyzing historical safety data. Machine learning algorithms identify patterns and trends, providing insights that facilitate the implementation of preventive measures. These tools empower businesses to move beyond reactive approaches, fostering a culture of proactive incident prevention. Compliance monitoring systems use analytics to track adherence to safety regulations and standards. They provide real-time insights into regulatory compliance, automate checks, and generate reports. By ensuring compliance, organizations reduce the risk of accidents and injuries, while also streamlining the reporting process for regulatory authorities (Gajdzik, Wolniak, 2022; Gajdzik et al., 2023).

Analytics software focused on employee health monitors various health-related data, from participation in wellness programs to absenteeism patterns. This comprehensive analysis aids in identifying potential health risks, allowing organizations to implement targeted wellness programs and interventions. By prioritizing employee well-being, businesses can create a healthier and more productive workforce. When incidents occur, business analytics software facilitates root cause analysis by systematically examining data related to accidents or near misses. It helps organizations identify the underlying factors contributing to incidents, enabling them to address root causes and implement effective preventive measures. This data-driven approach enhances the overall safety culture within the workplace (Akundi et al., 2022).

Workload optimization tools leverage analytics to analyze work patterns and employee schedules. By identifying stress points and optimizing workloads, organizations promote employee well-being and reduce the risk of burnout or injuries associated with overburdened workforces. This fosters a balanced and healthy work environment. Real-time safety dashboards provide dynamic visualizations of key safety metrics, allowing organizations to monitor safety performance in real-time. Integrated with alert systems, these dashboards enable quick decision-making and proactive intervention in response to emerging safety issues, minimizing the impact of potential risks (Jonek-Kowalska, Wolniak, 2021).

Table 2 highlighting examples of software and applications used in worker safety and health, along with descriptions of their usage. These key features highlight the capabilities of each software/application in promoting worker safety and health through the utilization of business analytics.

Table 2.
The usage of business analytics software in worker safety and health

Software/Application	Description	Key Features
Incident Prediction Tools	Incident prediction tools use advanced analytics to analyze historical safety data and identify patterns that predict potential workplace incidents. These tools enable proactive safety measures.	- Machine learning algorithms - Data visualization for trends - Early warning systems - Integration with safety protocols and preventive measures
Compliance Monitoring Systems	Compliance monitoring systems utilize analytics to track and ensure adherence to safety regulations and standards. They identify non-compliance areas, enabling timely corrective actions.	- Regulatory tracking and reporting - Automated compliance checks - Audit trail functionality - Notifications for non-compliance issues
Employee Health Analytics	Employee health analytics software assesses and monitors the well-being of employees by analyzing health-related data. It aids in identifying and addressing potential health risks.	- Health data analytics - Employee wellness program tracking - Absenteeism analysis - Integration with wearable devices and health monitoring tools
Root Cause Analysis Software	Root cause analysis software investigates the underlying factors contributing to workplace incidents. It systematically analyzes data to implement effective preventive measures.	- Incident data analysis - Trend identification - Workflow integration - Collaboration features for cross-functional analysis and problem-solving
Workload Optimization Tools	Workload optimization tools use analytics to analyze work patterns and employee schedules, ensuring balanced workloads for enhanced employee well-being and safety.	- Workload analytics - Schedule optimization - Stress point identification - Resource allocation optimization
Real-time Safety Dashboards	Real-time safety dashboards provide dynamic visualizations of key safety metrics. They enable real-time monitoring, quick decision-making, and proactive safety interventions.	- Real-time data visualization - Alert systems for safety issues - Customizable dashboards - Integration with IoT devices and sensors for live data feeds
Training Effectiveness Platforms	Training effectiveness platforms assess the impact of safety training programs. They analyze data to refine training initiatives and ensure employee readiness.	- Training program analytics - Performance assessments - Learning management system integration - Personalized training plans based on data analysis

Cont. table 2.

Predictive Maintenance Software	Predictive maintenance software uses analytics to predict equipment failures. In worker safety, it helps anticipate risks associated with malfunctioning equipment.	- Predictive analytics algorithms - Equipment health monitoring - Maintenance scheduling optimization - Integration with IoT sensors and predictive modeling

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

4. Advantages and problems of business analytics usage in workers safety and health

The integration of business analytics into worker safety and health practices heralds a transformative era, bringing forth a multitude of advantages that significantly enhance organizational safety protocols and employee well-being. Business analytics enables organizations to move beyond reactive safety management by predicting potential incidents. Through the analysis of historical data, predictive analytics identifies patterns and trends, allowing for the implementation of preventive measures before accidents occur. This proactive approach reduces the likelihood of workplace incidents and fosters a safer working environment (Scappini, 2016).

The use of analytics ensures that decisions related to worker safety and health are grounded in data-driven insights. Real-time and historical data analysis provides organizations with a comprehensive understanding of safety risks, enabling informed decision-making. This approach ensures that safety measures are strategically aligned with identified trends, contributing to a more effective and targeted safety strategy. Business analytics facilitates the monitoring of safety compliance, ensuring adherence to regulatory standards. Organizations can automate compliance checks, track regulatory changes, and generate reports efficiently. This not only reduces legal risks but also enhances overall regulatory adherence, ensuring that the workforce operates in accordance with safety standards (Adel., 2022).

Analyzing employee health data allows organizations to identify health risks, track the effectiveness of wellness programs, and implement targeted interventions. This proactive approach promotes a healthier workforce, reduces absenteeism, and enhances overall employee well-being and satisfaction, contributing to a positive workplace culture. In the event of incidents, business analytics expedites the root cause analysis process (Charles et al., 2023). Through data analysis, organizations can identify the underlying factors contributing to accidents, allowing for the implementation of effective corrective actions. This ensures that incidents are thoroughly investigated and addressed, minimizing the likelihood of similar occurrences in the future (Nourani, 2021).

Workload optimization tools leverage analytics to analyze work patterns and schedules, ensuring balanced workloads. By optimizing resource allocation and workload distribution, organizations reduce stress among employees, improve productivity, and minimize risks associated with overburdened workforces (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

Analytics assesses the effectiveness of safety training programs by analyzing participation, test scores, and post-training performance. This ensures that training initiatives are tailored to address specific needs, enhancing employee knowledge and adherence to safety protocols. Predictive maintenance using analytics allows organizations to anticipate equipment failures (Greasley, 2019). This proactive approach minimizes downtime, reduces the risk of accidents related to malfunctioning equipment, and ensures the reliability of safety-critical machinery and systems.

While there is an initial investment in implementing analytics solutions, the long-term benefits include cost savings. Efficient resource allocation, reduced incidents, lower maintenance costs, and improved productivity contribute to overall cost savings for organizations (Nourani, 2021).

Table 3 contains the advantages of using business analytics in worker safety and health within Industry 4.0 conditions, along with descriptions for each advantage. These advantages highlight how business analytics positively impacts worker safety and health by fostering a proactive safety culture, facilitating informed decision-making, and optimizing various aspects of organizational processes.

Table 3.
The advantages of using business analytics in worker safety and health

Advantage	Description
Proactive Incident Prevention	Business analytics enables organizations to proactively identify potential safety risks by analyzing historical data. Predictive analytics helps in forecasting incidents, allowing for the implementation of preventive measures before accidents occur.
Data-Driven Decision-Making	Analytics provides actionable insights based on real-time and historical data, empowering organizations to make informed decisions. Data-driven decision-making ensures that safety measures and interventions are strategically aligned with identified risks and trends.
Improved Compliance and Regulatory Adherence	Analytics facilitates the monitoring of safety compliance, ensuring adherence to regulatory standards. Organizations can automate compliance checks, track regulatory changes, and generate reports, leading to improved regulatory adherence and reduced legal risks.
Enhanced Employee Health and Well-being	By analyzing employee health data, organizations can identify health risks, track wellness program effectiveness, and implement targeted interventions. This promotes a healthier workforce, reduces absenteeism, and enhances overall employee well-being and satisfaction.
Efficient Root Cause Analysis	Business analytics expedites the root cause analysis process following incidents. Through data analysis, organizations can identify the underlying factors contributing to accidents, enabling the implementation of effective corrective actions to prevent future occurrences.

Cont. table 3.

Optimized Workload and Resource Allocation	Workload optimization tools leverage analytics to analyze work patterns and schedules, ensuring balanced workloads. This leads to reduced stress, improved productivity, and minimized risks associated with overburdened workforces through optimal resource allocation.
Real-Time Safety Monitoring	Real-time safety dashboards provide dynamic visualizations of key safety metrics. This enables organizations to monitor safety performance in real-time, respond promptly to emerging safety issues, and implement immediate interventions to mitigate potential risks.
Effective Training Programs	Analytics assesses the effectiveness of safety training programs by analyzing participation, test scores, and post-training performance. This ensures that training initiatives are tailored to address specific needs, enhancing employee knowledge and adherence to safety protocols.
Predictive Maintenance for Equipment Safety	Predictive maintenance using analytics allows organizations to anticipate equipment failures. This proactive approach minimizes downtime, reduces the risk of accidents related to malfunctioning equipment, and ensures the reliability of safety-critical machinery and systems.
Cost Savings and Resource Efficiency	While there is an initial investment in implementing analytics solutions, the long-term benefits include cost savings. Efficient resource allocation, reduced incidents, lower maintenance costs, and improved productivity contribute to overall cost savings for organizations.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Table 4 contains the problems of using business analytics in worker safety and health within Industry 4.0 conditions, along with descriptions for each advantage. These problems highlight the potential hurdles organizations may encounter when implementing business analytics in worker safety and health and underscore the importance of careful planning, ethical considerations, and addressing organizational and technical challenges.

Table 4.
The problems of using business analytics in worker safety and health

Problem	Description
Data Quality and Accuracy	Inaccurate or incomplete data can lead to flawed analytics outcomes. Poor data quality, inconsistencies, or outdated information may compromise the reliability of safety predictions and hinder the effectiveness of preventive measures.
Privacy Concerns	Collecting and analyzing employee data for safety purposes may raise privacy concerns. Balancing the need for safety insights with respecting individual privacy rights is crucial to maintaining trust and compliance with data protection regulations.
Integration Challenges	Integrating business analytics software with existing systems and workflows can be challenging. Incompatibility issues, data silos, or resistance to change within the organization may impede the seamless implementation and utilization of analytics solutions.
Complexity of Analytics Models	The complexity of advanced analytics models can be a barrier for organizations without the necessary expertise. Understanding and interpreting complex algorithms may require specialized skills, posing challenges for smaller or less tech-savvy enterprises.
Lack of Employee Buy-In	Successful implementation of safety analytics relies on employee cooperation and engagement. Resistance to new technologies, skepticism about the benefits of analytics, or a lack of understanding among the workforce can hinder the adoption and effectiveness of safety initiatives.
Overreliance on Historical Data	Relying solely on historical data for predictions may not account for evolving workplace conditions or emerging risks. Business analytics should be complemented with real-time data and continuous monitoring to ensure its relevance and responsiveness to changing circumstances.

Cont. table 4.

Unintended Consequences	Misinterpretation or overreliance on analytics predictions may lead to unintended consequences. Blindly following analytics recommendations without considering the broader context or human factors may result in suboptimal decisions or actions that negatively impact safety.
Cost of Implementation and Maintenance	Implementing and maintaining business analytics solutions can be resource-intensive. The initial investment in technology, training, and ongoing maintenance costs may pose financial challenges, particularly for smaller organizations with limited budgets.
Cultural Resistance and Organizational Dynamics	A cultural shift towards data-driven decision-making may face resistance within traditional organizational cultures. Addressing resistance, fostering a culture of safety, and ensuring effective communication are essential for the successful integration of analytics into safety practices.
Legal and Ethical Considerations	Adhering to legal and ethical standards in the collection and use of employee data is paramount. Organizations must navigate complex legal frameworks, ensuring compliance with regulations such as GDPR or HIPAA, to avoid legal repercussions and maintain ethical practices.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

5. Conclusion

In the dynamic landscape of Industry 4.0, where automation and smart technologies reign supreme, the health and well-being of the workforce persist as paramount concerns. The fusion of business analytics with work safety and health practices marks a paradigm shift, catalyzing significant advancements in monitoring, managing, and enhancing occupational safety standards. This publication aimed to elucidate the applications of business analytics in this context, shedding light on its transformative impact.

Business analytics, particularly in the form of wearable device-driven physiological parameter monitoring, stands as a sentinel against compromising worker health in the pursuit of productivity. This proactive health surveillance not only averts potential issues but also fosters employee satisfaction and retention. The integration of business analytics aligns seamlessly with regulatory compliance, as meticulous records and analytics reports demonstrate a steadfast commitment to safety standards, mitigating legal and financial risks associated with workplace incidents. The synergy of work safety and health with business analytics signifies a pivotal transformation in how organizations approach employee well-being. The data-driven insights from business analytics empower businesses to proactively address safety concerns, optimize operations, and cultivate safer and healthier work environments. As Industry 4.0 continues its evolution, the symbiotic relationship between work safety and business analytics becomes a cornerstone for fostering a culture of safety and well-being in industrial settings.

This publication delved into selected aspects of business analytics usage in worker safety and health, emphasizing the profound impact of Industry 4.0 technologies. The adoption of interconnected devices and data-driven insights ushers in a comprehensive approach to work

safety. Business analytics, leveraging data from diverse sources within the industrial ecosystem, provides a holistic view of the work environment, enabling organizations to make informed decisions. The subsequent focus on software used in worker safety and health showcased how business analytics software serves as a catalyst for transformative change. These tools, equipped with advanced analytics capabilities, predict incidents, monitor compliance, assess employee health, conduct root cause analyses, optimize workloads, and provide real-time safety dashboards. Table 2 detailed various software applications along with their key features, underlining the versatility of business analytics in enhancing worker safety and health.

However, this integration is not without its challenges, as outlined in Table 4. Data quality, privacy concerns, integration challenges, and the complexity of analytics models pose potential hurdles. Ensuring employee buy-in, avoiding overreliance on historical data, and navigating the cost implications are vital considerations. Cultural resistance and legal/ethical considerations further underscore the need for a meticulous and ethical approach to implementation. Yet, the advantages outlined in Table 3 demonstrate that the benefits far outweigh the challenges. Proactive incident prevention, data-driven decision-making, improved compliance, enhanced employee health, and cost savings are among the many advantages. Real-time safety monitoring, effective training programs, and predictive maintenance exemplify how business analytics fosters a culture of safety, efficiency, and well-being.

The integration of business analytics in worker safety and health within Industry 4.0 conditions is transformative. It empowers organizations to prioritize safety, make informed decisions, and create environments that not only comply with regulations but also foster the health and satisfaction of their workforce. The journey towards a safer and healthier workplace is navigable with strategic planning, ethical considerations, and a commitment to overcoming challenges. The future of work safety lies in the symbiotic relationship between human welfare and the insights gleaned from the data-driven world of business analytics.

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MAINTENANCE RESOURCE ALLOCATION – THE BUSINESS ANALYTICS USAGE IN INDUSTRY 4.0 CONDITIONS

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Purpose: The purpose of this publication is to present the applications of usage of business analytics in maintenance resources allocation.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: The integration of business analytics with condition monitoring technologies heralds a transformative shift in maintenance resource allocation. Through the utilization of real-time data from sensors and monitoring devices, organizations can craft dynamic and adaptive maintenance strategies. These strategies, grounded in the current equipment condition, strike a nuanced balance between preventive and corrective actions. Business analytics enriches decision-making by factoring in critical elements such as equipment importance, operational impact, resource availability, and budget constraints. This integration instigates a paradigm shift, fostering proactive, adaptive, and efficient resource allocation, resulting in heightened asset reliability, diminished downtime, and amplified operational performance. The evolving synergy between business analytics and maintenance practices is becoming integral to the future of asset management and industrial operations. The diverse applications of business analytics in maintenance, as outlined in Table 1, underscore its versatility, encompassing predictive maintenance, condition monitoring, asset performance management, work order prioritization, resource optimization, cost-benefit analysis, inventory management, and performance metrics monitoring. Concurrently, the adoption of advanced software solutions in Industry 4.0 conditions, exemplified by IBM Maximo Asset Management, SAP Intelligent Asset Management, and Fiix CMMS, reflects a commitment to efficiency and innovation in maintenance resource allocation. Despite the substantial advantages, addressing challenges outlined in Table 4, including data quality, integration complexities, implementation costs, and skill development, is crucial. These challenges underscore the necessity for a strategic and holistic implementation approach that considers technology, personnel training, and organizational readiness. In essence, the evolution of maintenance resource allocation through business analytics signifies a data-driven revolution poised to optimize current operations and position organizations for sustained success amid rapid technological advancements and the transformations of Industry 4.0.

Originality/value: Detailed analysis of business analytics in the case of maintenance resource allocation.

Keywords: business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; maintenance resource allocation.

Category of the paper: literature review.

1. Introduction

The integration of business analytics with condition monitoring technologies enhances the accuracy of maintenance resource allocation. Sensors and monitoring devices can collect real-time data on the health and performance of assets, feeding this information into analytical models. The result is a dynamic and adaptive maintenance strategy that allocates resources based on the current condition of equipment, optimizing the balance between preventive and corrective maintenance actions. Moreover, business analytics facilitates a more informed decision-making process by considering various factors that influence maintenance resource allocation. These factors may include equipment criticality, the impact of failures on overall operations, resource availability, and budget constraints. By analyzing a comprehensive set of variables, organizations can prioritize maintenance activities and allocate resources in a way that aligns with broader business objectives (Zeng et al., 2022; Pech, Vrchota, 2022).

Integration of business analytics into maintenance resource allocation brings about a paradigm shift in how organizations approach asset management. The ability to harness data-driven insights enables a proactive, adaptive, and efficient allocation of resources, leading to improved asset reliability, reduced downtime, and ultimately, enhanced operational performance. As technology continues to advance, the synergy between business analytics and maintenance practices will likely play an increasingly vital role in shaping the future of asset management and industrial operations (Bakir, Dahlan, 2022).

The purpose of this publication is to present the applications of usage of business analytics in maintenance resource allocation.

2. The selected aspects of business analytics usage in maintenance resource allocation

Maintenance resource allocation is a critical aspect of ensuring the optimal functioning and longevity of equipment, facilities, and infrastructure. It involves strategically assigning resources such as manpower, time, and budget to effectively address maintenance needs and

uphold operational efficiency. By carefully planning resource allocation, organizations can minimize downtime, reduce the risk of equipment failures, and extend the lifespan of assets.

Efficient maintenance resource allocation requires a comprehensive understanding of the maintenance requirements of different assets. This includes routine inspections, preventive maintenance tasks, and the ability to respond promptly to unexpected breakdowns. Prioritizing resources based on the criticality of assets and the potential impact of their failure is essential for maximizing the overall reliability and availability of the systems. In addition to manpower, technology and tools are also integral components of maintenance resource allocation. Investing in advanced diagnostic equipment and predictive maintenance technologies can enhance the effectiveness of resource utilization by enabling proactive identification of potential issues before they escalate. This proactive approach not only reduces the frequency of unplanned downtime but also contributes to cost savings in the long run. Furthermore, a well-structured maintenance resource allocation plan considers factors such as the skill sets of maintenance personnel, training requirements, and the availability of spare parts. Continuous evaluation and adjustment of resource allocation strategies based on performance metrics and feedback are crucial for optimizing the overall maintenance process (Ghibakholl et al., 2022).

Maintenance resource allocation is a strategic practice that involves judiciously assigning human, financial, and technological resources to ensure the reliable and efficient operation of assets. By adopting a proactive and data-driven approach, organizations can minimize disruptions, control costs, and ultimately enhance the overall performance and lifespan of their critical systems (Cillo et al., 2022).

Business analytics has emerged as a powerful tool in the realm of maintenance resource allocation, revolutionizing the way organizations manage and optimize their assets. In the context of maintenance, business analytics involves the use of data-driven insights to inform decision-making processes, enabling more efficient allocation of resources such as manpower, time, and budget (Gajdzik, Wolniak, 2022; Gajdzik et al., 2023). One of the key advantages of leveraging business analytics in maintenance resource allocation is the ability to move from a reactive to a proactive maintenance approach. Through the analysis of historical maintenance data, organizations can identify patterns and trends that highlight potential issues before they escalate into critical failures. This foresight allows for a more strategic deployment of resources, focusing efforts on preventive maintenance tasks that address underlying issues and minimize the risk of unplanned downtime (Akundi et al., 2022).

Predictive analytics, a subset of business analytics, plays a crucial role in enhancing maintenance resource allocation. By utilizing predictive modeling and machine learning algorithms, organizations can forecast equipment failures and determine optimal maintenance schedules. This enables a more precise allocation of resources, ensuring that maintenance activities are performed when needed, rather than on a fixed schedule, leading to cost savings and increased asset reliability (Jonek-Kowalska, Wolniak, 2021).

Furthermore, business analytics provides insights into the performance of maintenance strategies and the effectiveness of resource allocation decisions. Key performance indicators (KPIs) such as mean time between failures (MTBF) and mean time to repair (MTTR) can be monitored and analyzed to assess the impact of maintenance interventions. This data-driven evaluation allows organizations to continuously refine their resource allocation strategies, adapting to changing conditions and improving overall operational efficiency (Scappini, 2016).

Table 1 contains descriptions of how business analytics is used in the case of maintenance resource allocation. This table provides an overview of various applications of business analytics in maintenance resource allocation along with brief descriptions of each application.

Table 1.
The usage of business analytics in maintenance resource allocation

Application	Description
Predictive Maintenance	Utilizes historical data and machine learning algorithms to predict when equipment is likely to fail, optimizing resource allocation by focusing on preventive measures.
Condition Monitoring	Monitors real-time data from equipment sensors to assess their current state, enabling proactive maintenance and efficient allocation of resources to address potential issues before they escalate.
Asset Performance Management (APM)	Analyzes the performance of assets over time, identifying areas for improvement and helping allocate resources to enhance the overall reliability and efficiency of critical assets.
Work Order Prioritization	Uses analytics to prioritize maintenance tasks based on factors such as criticality, cost, and potential impact on operations, ensuring that resources are allocated to the most urgent and impactful activities.
Resource Optimization	Analyzes historical maintenance data to identify patterns and trends, optimizing the allocation of resources by adjusting staffing levels, scheduling maintenance activities, and minimizing downtime.
Cost-Benefit Analysis	Evaluates the cost-effectiveness of different maintenance strategies and resource allocation scenarios, helping organizations make informed decisions about where to allocate resources for maximum impact.
Inventory Management	Applies analytics to track and manage spare parts inventory, minimizing stockouts and excess inventory, thus ensuring that the right resources are available when needed without unnecessary costs.
Performance Metrics Monitoring	Utilizes key performance indicators (KPIs) to monitor the effectiveness of maintenance activities, guiding resource allocation decisions based on the actual impact on equipment reliability and overall business goals.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

3. Software used in maintenance resource allocation in Industry 4.0 conditions

In the context of Industry 4.0, the integration of advanced technologies has revolutionized the landscape of maintenance resource allocation, allowing organizations to enhance efficiency, reduce downtime, and optimize overall operational performance. Several cutting-edge software

solutions play a pivotal role in this domain, leveraging the power of Industry 4.0 technologies to transform traditional maintenance practices (Adel., 2022).

IBM Maximo Asset Management is a leading software solution that embodies the principles of Industry 4.0 for maintenance resource allocation. It integrates seamlessly with IoT devices and employs predictive analytics to forecast equipment failures. This enables proactive maintenance strategies, optimizing the allocation of resources for preventive actions and minimizing disruptions (Nourani, 2021).

SAP Intelligent Asset Management is designed to empower organizations with smart maintenance practices. By harnessing the capabilities of the Industrial Internet of Things (IIoT), it provides real-time insights into asset conditions, allowing for data-driven decision-making in maintenance resource allocation. The software emphasizes a holistic approach to asset management, incorporating predictive and preventive maintenance strategies.

Fiix CMMS is a cloud-based Computerized Maintenance Management System that aligns with Industry 4.0 principles, offering a modern approach to maintenance resource allocation. It leverages data analytics to optimize asset performance, streamline work order processes, and improve overall maintenance efficiency. With its user-friendly interface and customizable features, Fiix CMMS facilitates agile decision-making in dynamic Industry 4.0 environments (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

Table 2 highlighting examples of software and applications used in maintenance resource allocation, along with descriptions of their usage. This table provides an overview of various business analytics software and applications used in maintenance resource allocation, along with descriptions and key features of each.

Table 2.
The usage of business analytics software in maintenance resource allocation

Software/Application	Description	Key Features
IBM Maximo Asset Management	Comprehensive asset management software that utilizes analytics to optimize maintenance resource allocation.	- Predictive maintenance capabilities - Work order management and prioritization - Inventory optimization
SAP Intelligent Asset Management	SAP's solution for intelligent asset management leverages analytics for effective maintenance resource allocation.	- Real-time condition monitoring - Predictive and preventive maintenance - Integration with IoT devices for data collection
Microsoft Dynamics 365 for Field Service	A field service management application with analytics features to enhance maintenance resource allocation.	- Schedule optimization and routing - Asset performance monitoring - Mobile accessibility for field teams
Infor EAM	Infor's Enterprise Asset Management system that incorporates analytics to streamline maintenance resource allocation.	- Reliability-centered maintenance - Asset performance analytics - Integration with IoT and other data sources
Oracle Maintenance Cloud	Oracle's cloud-based maintenance management solution with analytics for efficient resource allocation.	- Condition-based and predictive maintenance - Work order and task management - Asset lifecycle management

Cont. table 2.

Fiix CMMS	Cloud-based Computerized Maintenance Management System (CMMS) that uses analytics for maintenance resource allocation.	- Asset tracking and management - Customizable dashboards and reporting - Integrations with other business systems
Smartenance by Festo	A cloud-based maintenance management solution that incorporates analytics for intelligent resource allocation.	- Condition monitoring and anomaly detection - Automated work order generation - Collaboration features for teams

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

4. Advantages and problems of business analytics usage in maintenance resource allocation

Business analytics plays a crucial role in optimizing maintenance resource allocation, offering a myriad of advantages that contribute to enhanced efficiency, reduced downtime, and improved overall operational performance. Here are several key advantages of leveraging business analytics in maintenance resource allocation:

Business analytics enables organizations to move from reactive to proactive maintenance strategies. By analyzing historical data and employing advanced algorithms, predictive maintenance identifies potential equipment failures before they occur. This foresight allows for timely intervention, reducing unplanned. Through data analysis, business analytics helps organizations allocate maintenance resources more effectively. It considers factors such as equipment criticality, historical performance, and real-time conditions to prioritize tasks. This ensures that resources are directed to the most critical areas, maximizing their impact on overall operational reliability (Nourani, 2021).

Analytics provides insights into asset performance, allowing organizations to identify patterns and trends. This knowledge enables targeted maintenance efforts that address specific issues, leading to improved equipment reliability. Regular analysis helps in fine-tuning maintenance strategies for optimal performance. Business analytics aids in identifying cost-effective maintenance strategies. By analyzing historical maintenance data, organizations can optimize spending, reduce unnecessary expenses, and implement strategies that provide the best return on investment. This cost-conscious approach contributes to overall financial efficiency.

Proactive maintenance, facilitated by business analytics, minimizes unexpected equipment failures and, consequently, reduces downtime. By addressing potential issues before they escalate, organizations can ensure continuous operations, meeting production schedules and enhancing overall business continuity. Business analytics continuously monitors and analyzes asset performance data. This leads to the identification of opportunities for improvement and

optimization. By acting on these insights, organizations can enhance asset performance, maximizing operational efficiency and the overall value derived from their assets.

Business analytics provides actionable insights derived from data analysis. This empowers decision-makers to make informed choices regarding maintenance resource allocation. Data-driven decision-making ensures that strategies align with organizational goals and contribute to long-term success. Optimized maintenance processes, guided by business analytics, reduce manual intervention and streamline workflows. This increased efficiency translates into higher productivity, as maintenance teams can focus on critical tasks, respond to issues promptly, and perform tasks more effectively (Charles et al., 2023).

Business analytics assists in prioritizing maintenance tasks based on criticality, historical performance, and potential operational impact. This ensures that resources are allocated to the most urgent and impactful activities, optimizing the use of available manpower and time. By providing feedback on the effectiveness of maintenance strategies, business analytics facilitates a continuous improvement cycle. Organizations can learn from past performance, refine their approaches, and implement changes that lead to ongoing optimization and excellence in maintenance resource allocation (Greasley, 2019).

Table 3 contains the advantages of using business analytics in maintenance resource allocation within Industry 4.0 conditions, along with descriptions for each advantage. These advantages underscore the transformative impact of business analytics on maintenance resource allocation, contributing to improved efficiency, cost-effectiveness, and overall operational excellence.

Table 3.
The advantages of using business analytics in maintenance resource allocation

Advantage	Description
Predictive Maintenance	Anticipates equipment failures based on data analysis, enabling proactive maintenance and reducing unplanned downtime.
Optimal Resource Allocation	Analyzes historical and real-time data to allocate resources efficiently, ensuring that tasks are prioritized based on criticality.
Improved Equipment Reliability	Identifies patterns and trends in asset performance, allowing for targeted maintenance efforts that enhance overall equipment reliability.
Cost Savings	Enables organizations to optimize maintenance spending by identifying cost-effective strategies and minimizing unnecessary expenses.
Reduced Downtime	Proactively addresses potential issues, minimizing equipment downtime through timely and targeted maintenance interventions.
Enhanced Asset Performance	Utilizes analytics to monitor and improve asset performance, extending the lifespan of equipment and maximizing its operational efficiency.
Data-Driven Decision-Making	Provides actionable insights through data analysis, empowering decision-makers to make informed choices regarding resource allocation.
Increased Productivity	Optimizes maintenance processes, reducing manual intervention and streamlining workflows, leading to increased overall productivity.
Improved Work Order Prioritization	Utilizes data to prioritize maintenance tasks based on criticality and potential impact on operations, ensuring efficient resource utilization.
Enhanced Planning and Scheduling	Facilitates better planning by using historical data, allowing organizations to schedule maintenance activities more effectively and minimize disruptions.
Inventory Optimization	Analyzes spare parts usage and demand patterns, optimizing inventory levels to ensure that the right parts are available without excess stock.

Cont. table 3.

Compliance Management	Helps organizations adhere to regulatory and compliance standards by providing visibility into maintenance activities and documentation.
Continuous Improvement	Facilitates a continuous improvement cycle by providing feedback on the effectiveness of maintenance strategies, leading to ongoing optimization.
Adaptability to Changing Conditions	Allows organizations to adapt quickly to changing conditions by analyzing data and adjusting resource allocation strategies accordingly.
Integration with IoT and Emerging Tech	Integrates with IoT devices and emerging technologies, providing a foundation for advanced maintenance strategies in the era of Industry 4.0.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Table 4 contains the problems of using business analytics in maintenance resource allocation within Industry 4.0 conditions, along with descriptions for each advantage. While the benefits of using business analytics in maintenance resource allocation are significant, addressing these challenges is essential to ensure successful implementation and maximize the value derived from analytics-driven strategies.

Table 4.
The problems of using business analytics in maintenance resource allocation

Problem	Description
Data Quality Issues	Incomplete or inaccurate data can compromise the effectiveness of analytics. Poor data quality may lead to incorrect insights and decisions, impacting the overall maintenance strategy.
Integration Challenges	Integrating analytics tools with existing systems and data sources can be complex. Incompatibility issues may arise, hindering the seamless flow of information for informed decision-making.
Implementation Costs	The initial costs associated with implementing robust analytics solutions, including software, hardware, and training, can be substantial. Organizations may face financial constraints in adopting such systems.
Skill Gaps and Training	Organizations may lack personnel with the necessary skills to effectively use and interpret analytics tools. Training staff to understand and leverage these tools is crucial for success.
Complexity of Analytics Tools	Advanced analytics tools can be complex, requiring a high level of expertise to navigate and interpret. This complexity may pose challenges for non-technical users in the maintenance team.
Resistance to Change	Employees may resist adopting new processes driven by analytics. There might be a cultural shift required within the organization to embrace data-driven decision-making in maintenance.
Lack of Standardization	Inconsistencies in data formats and maintenance processes across different departments or sites can impede the standardization needed for effective analytics.
Scalability Issues	Some analytics solutions may face challenges when scaling up to handle larger datasets or increasing numbers of connected devices, limiting their scalability.
Security and Privacy Concerns	As maintenance data becomes more interconnected, ensuring the security and privacy of sensitive information is critical. Concerns may arise regarding data breaches or unauthorized access.
Overemphasis on Technology	Organizations may focus too much on implementing advanced analytics technology without considering the importance of aligning analytics efforts with strategic business goals.
Lack of Historical Data	For new systems or organizations without sufficient historical data, predictive analytics may be less accurate, limiting the ability to forecast future maintenance needs effectively.
Unforeseen External Factors	External factors such as sudden changes in market conditions, regulations, or technology advancements may impact the relevance and effectiveness of established analytics models.

Cont. table 4.

Limited Understanding of Analytics	Stakeholders may not fully comprehend the insights generated by analytics tools, leading to misinterpretation or underutilization of valuable information.
Difficulty in Measuring ROI	Determining the return on investment (ROI) for analytics initiatives in maintenance can be challenging, making it harder to justify the upfront costs.
Maintenance Process Complexity	Maintenance processes can be intricate, involving various variables. Capturing the full complexity of these processes in analytics models may be challenging, affecting accuracy.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

5. Conclusion

The integration of business analytics with condition monitoring technologies represents a transformative approach to maintenance resource allocation. By harnessing real-time data from sensors and monitoring devices, organizations can create dynamic and adaptive maintenance strategies. These strategies prioritize resource allocation based on the current condition of equipment, striking a balance between preventive and corrective actions. Business analytics further enhances decision-making by considering factors such as equipment criticality, operational impact, resource availability, and budget constraints. The paradigm shift brought about by the integration of business analytics into maintenance resource allocation is evident. This approach enables a proactive, adaptive, and efficient allocation of resources, leading to improved asset reliability, reduced downtime, and enhanced operational performance. As technology continues to advance, the synergy between business analytics and maintenance practices is poised to play a vital role in shaping the future of asset management and industrial operations.

The applications of business analytics in maintenance resource allocation, as highlighted in Table 1, demonstrate its versatility across various facets of maintenance, including predictive maintenance, condition monitoring, asset performance management, work order prioritization, resource optimization, cost-benefit analysis, inventory management, and performance metrics monitoring. Moreover, the integration of advanced software solutions in Industry 4.0 conditions exemplifies the commitment to efficiency and innovation in maintenance resource allocation. Examples such as IBM Maximo Asset Management, SAP Intelligent Asset Management, and Fiix CMMS showcase the power of analytics, IoT integration, and cloud-based solutions in optimizing maintenance processes.

While the advantages of using business analytics in maintenance resource allocation are substantial, it is essential to acknowledge and address challenges. Table 4 outlines potential issues such as data quality, integration complexities, implementation costs, and the need for skill development. These challenges underline the importance of a strategic and holistic

approach to implementation, encompassing technology, personnel training, and organizational readiness.

The evolution of maintenance resource allocation through business analytics signifies a data-driven revolution in the industrial landscape. By leveraging these technologies, organizations can not only optimize their current operations but also position themselves for continued success in an era of rapid technological advancement and Industry 4.0 transformations.

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MONTE CARLO SIMULATION ANALYSIS OF THE PERT METHOD FOR COMPLETE GRAPH WITH ALL ACTIVITIES AS CRITICAL

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Purpose: The main objective of this study is to conduct a time analysis on a complete PERT network in a situation where all activities in the network are critical. This analysis is more exploratory and theoretical in nature, as it assumes a very specific case of a project and the potential implications arising from it.
Design/methodology/approach: The analysis was performed on the full PERT network including 6 events and the resulting number of 15 activities. The numerical procedure was carried out by: determining the number of events and parameters of the project duration, determining the (maximum) number of activities - determining the parameters of the distribution of activity durations using mathematical programming, determining the number of iterations, in each iteration: generating activity durations, determining critical paths, determining time duration of the project and analysis of the results obtained.
Findings: The work draws three main conclusions: the distribution of the project duration differs significantly from the theoretical PERT time, the theoretical activity durations affect the critical importance of activities in the project implementation, the number of events in the critical path affects the project implementation deadline.
Research limitations/implications: The obtained results depend on the adopted methodology, in particular the numerical procedure for generating times: optimistic, modal, pessimistic of activities and generating activity durations from a normal distribution. Further research will focus on these issues.
Originality/value: the main novelty of the work is the analysis using Monte Carlo simulation on the full PERT network, where all activities are critical.

Keywords: Monte Carlo simulation, PERT method, complete graph.

Category of the paper: Research paper.

1. Introduction

The PERT method (The Program Evaluation and Review Technique) (Malcolm et al., 1959; Cook, 1966; Trocki et al., 2003) is a network method of planning and controlling the implementation of the project. It is an extension of the CPM (Critical Path Method) method by

adding uncertainty related to the implementation time of particular activities, and thus the implementation of the entire project (project duration). This method takes into account the risk associated with performing tasks by taking into account three types of time - the shortest possible (optimistic), the most probable (modal) and the potentially longest time (pessimistic). This method assumes that the implementation time of the entire project is the sum of the expected implementation times of critical activities. The expected duration of an activity is calculated from the formula:

$$te = \frac{a+4b+c}{6}, \tag{1}$$

where:
a is the optimistic time,
b is the most probable time,
c is the pessimistic time.

The project implementation time variance is determined as the sum of the variances of activities on the critical path. In turn, the activity duration variance is determined from the formula:

$$var = \frac{(c-a)^2}{36}. \tag{2}$$

Usually, when analyzing the implementation time of a project, it is assumed that the time distribution is consistent with the normal distribution as a special case of the beta distribution - PERT distribution.

In a situation where the project does not consist of activities that can be implemented in parallel, the distribution of project implementation time deviates from the normal distribution.

This is a consequence of the fact that the project implementation time is described by a random variable which is the maximum value of the sum of random variables of the times of individual activities creating the critical path. Analyzes based on classic PERT should therefore be treated as an approximation.

In a general approach, the solution to this problem may be the use of a simulation approach (Van Slyke, 1963; Lu AbouRizk, 2000; Wyrozębski, Wyrozębska, 2013; Walczak, 2014; Karabulut, 2017; Salas-Morera et al., 2018). Moreover, simulation analysis is advisable due to different approaches to estimating task completion times (Udoumoh, Ebong, 2017; Deshmukh, Rajhans, 2018). Therefore, a Monte Carlo simulation approach was used in this work.

In the PERT method, the logical structure of the project is presented by a network (graph) of dependencies. The nodes of the network are events (milestones), while the edges of the network symbolize activities in the project (tasks).

A complete graph (Fully Connected Network) is a network in which every vertex is connected to every other vertex. In terms of the PERT method, this means a project that has the maximum possible number of tasks that make up the entire project. Such a network was adopted in this work because it is a universal project model - any project can be modelled using such a network, because some edges in the graph may symbolize dummy activities.

As can be seen, the main problem (and deviations from the normal project implementation time classically postulated in the PERT method) lies in the potential occurrence of many critical paths (Dodin, 1984; Soroush, 1994). This situation occurs when the project consists of activities, at least one of which can be performed in parallel.

From this point of view, an interesting issue is the analysis of project implementation time when all activities in the network are critical. Such a theoretical project is characterized by "tight in time". Any deviation from the expected completion time of any activity (task) has a potentially significant impact on the project completion date.

Additionally, the properties of the full network and the critical nature of each task may generate interesting implications with respect to task implementation and design.

For example, comparing the critical path including all milestones (events) and the path containing only the first and last event (beginning and end of the project) - in the sense of the PERT method, both paths (like all paths) have the same parameters (expected value and variance). Both of these paths are independent (they do not have common tasks). From the point of view of time analysis, they are identical. The difference is in the number of tasks performed. Comparing the implementation time of these paths leads to a comparison of the implementation time of a project consisting of one task and the implementation of a project when this task is divided into subtasks. Continuing, the research question arises: whether, in accordance with practical recommendations, it is important to divide large tasks into smaller ones.

Taking into account the above considerations, the main goal of the work is time analysis on the full PERT network in a situation where all activities in the network are critical. This analysis is more exploratory and theoretical in nature as it assumes a very specific case of design and the potential implications arising from it. The following research questions were formulated due to the nature of the experiment:

1. Does the distribution of implementation time of the tested project differ significantly from the theoretical PERT time?
2. Do theoretical activity durations influence the critical importance of activities in project implementation (in simulations)?
3. Does the number of events in the critical path affect the project completion date?

1. Methods

1.1. Model

In the analyzed example of the PERT network, 6 events and the resulting number of 15 activities were assumed. The logical structure of the network is shown in Figure 1.

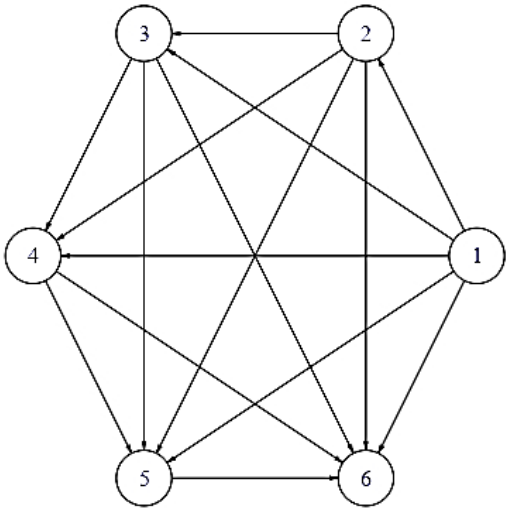

Figure 1. Logical structure of the analyzed network.

Table 1 shows the parameters of the activity time distribution between events (i, j). Where i is the number of the preceding event and j is the number of the event following the action. Expected time to complete the activity (te) and time variance (var). The activity duration parameters were set so that each path was a critical path. The expected duration of the project is 100 (time units), variance 10.

Table 1.
Expected time and variance of the activities duration of the analyzed network

i	j	optimistic	modal	pessimistic	te	var
1	2	13,743	21,052	22,052	20,000	1,918
1	3	32,322	41,336	42,336	40,000	2,785
1	4	50,138	61,772	62,772	60,000	4,434
1	5	68,971	82,006	83,006	80,000	5,471
1	6	84,855	102,829	103,829	100,000	10,000
2	3	16,010	20,598	21,598	20,000	0,867
2	4	32,735	41,253	42,253	40,000	2,516
2	5	51,241	61,551	62,551	60,000	3,553
2	6	66,452	82,509	83,509	80,000	8,082
3	4	14,246	20,951	21,951	20,000	1,649
3	5	32,472	41,305	42,305	40,000	2,686
3	6	47,237	62,353	63,353	60,000	7,215
4	5	15,575	20,685	21,685	20,000	1,037
4	6	28,871	42,026	43,026	40,000	5,566
5	6	10,026	21,795	22,795	20,000	4,529

1.2. Simulation

A single iteration consisted of generating activity durations, determining the duration of the project and critical paths. 100000 iterations were performed.

The obtained results were analyzed. Simulations and calculations were performed in the R environment (R Core Team, 2022).

The numerical procedure was carried out in the following generalized steps:

1. Determining the number of events (6 events assumed), the expected project duration (100 time units assumed) and the project duration variance (10 square time units).
2. Determining the (maximum) number of activities - connections between all events.
3. Determining the parameters of the distribution of activity durations (optimistic, modal, pessimistic) using mathematical programming.
4. Determining the number of iterations (n = 100000).
5. In each iteration: generating activity durations (using normal distribution), determining critical paths, determining the duration of the project.
6. Analysis of the obtained results.

2. Results

The general numerical characteristics of the project implementation time are presented in Table 2.

Table 2.
Basic statistical characteristics of the performed simulation

statistics	values
Mean	104,728
Std.Dev	2,105
Min	96,591
Q1	103,265
Median	104,644
Q3	106,080
Max	114,731
MAD	2,085
IQR	2,815
CV	0,020
Skewness	0,259
SE.Skewness	0,008
Kurtosis	0,142
N.Valid	100000

The analysis of the values presented in Table 2 indicates, first of all, that the main parameters of the project implementation time distribution differ from the theoretical PERT values. The expected implementation time is significantly longer, but the variability measured

by variance is lower. The exact time distribution obtained in the experiment compared to the theoretical PERT is shown in Figure 2.

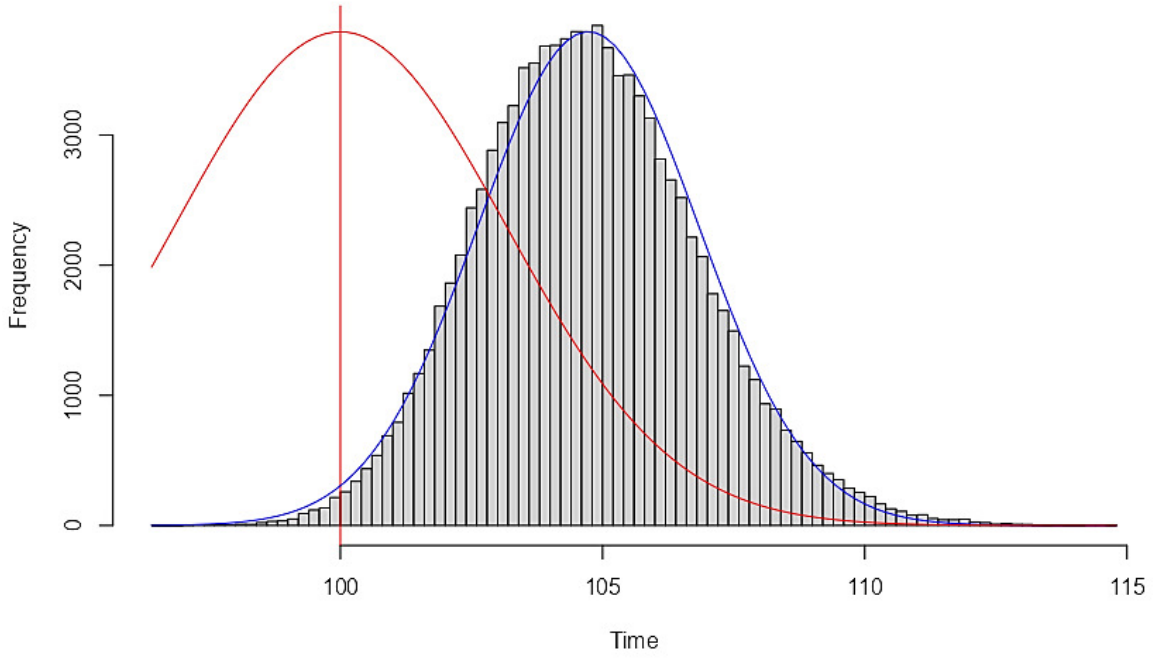

Figure 2. Distribution of project implementation time in the experiment.

The histogram presented in Figure 2 presents the distribution of project implementation time resulting from the conducted experiment. The blue line shows the theoretical distribution of the project implementation assuming normality of distribution and parameters obtained from the simulation N(104.728; 2.105). The red line shows the theoretical time distribution resulting from the PERT method - a normal distribution with an expected value of 100 and variance of 10.

The estimated probability of meeting the PERT expected time (100 time units) is very small and is approximately 0.007. However, the distribution of project implementation time is not consistent with the normal distribution (Jarque-Bera Normality Test, JB = 1205, p-value < 0.001).

The results regarding the frequency of occurrence of individual activities in the simulations are presented in Table 3.

Table 3.
Frequencies of critical activities in the PERT network and the simulations performed

i	j	how many times critical	how many times critical in simulations	te	var
1	2	8	43515	20	1,918
1	3	4	23395	40	2,785
1	4	2	13466	60	4,434
1	5	1	7916	80	5,471
1	6	1	11743	100	10
2	3	4	18308	20	0,867
2	4	2	9605	40	2,516
2	5	1	5412	60	3,553
2	6	1	10190	80	8,082

Cont. table 3.

3	4	4	17415	20	1,649
3	5	2	8969	40	2,686
3	6	2	15319	60	7,215
4	5	4	16703	20	1,037
4	6	4	23783	40	5,566
5	6	8	39000	20	4,529

The value "how many times critical" refers to the share of a given activity in the PERT network and "how many times critical in simulations" refers to the occurrence of a given activity as critical in simulations.

The analysis of the data contained in Table 1 and Table 3 indicates the existence of a relationship between the expected time of performing an activity (te) and the values: "how many times critical" (corr = -0.768, t = -4.324, $p < 0.001$) and "how many times critical in simulations" (corr = -0.591, t = -2.642, p = 0.020). In this situation, the conclusion (alpha = 0.05) that the longer the expected time to complete an activity, the less likely it is that the activity is critical, is justified. This is due to the structure of the activity network and the significant correlation between the expected duration of the activity (te) and the variable "how many times critical" (corr = -0.768, t = -4.324, $p < 0.001$).

The interdependence between "how many times critical" and "how many times critical in simulations" (corr = 0.961, t = 12574, $p < 0.001$) can be considered as a certain disturbance in these relations. Moreover, the PERT network was constructed in such a way that all activities were critical (in terms of expected activity execution times). However, the results of the simulations indicate that it is unlikely that there will be more than one critical path in a specific project implementation. The results regarding the occurrence of specific critical paths are presented in Table 4.

Table 4.
Data and results regarding the critical paths that occur

Path	how many times critical in the simulation	expected time	time variance	number of events
c(1, 2, 3, 4, 5, 6)	2903	100	10	6
c(1, 2, 3, 4, 6)	4460	100	10	5
c(1, 2, 3, 5, 6)	3848	100	10	5
c(1, 2, 3, 6)	7097	100	10	4
c(1, 2, 4, 5, 6)	3892	100	10	5
c(1, 2, 4, 6)	5713	100	10	4
c(1, 2, 5, 6)	5412	100	10	4
c(1, 2, 6)	10190	100	10	3
c(1, 3, 4, 5, 6)	4102	100	10	5
c(1, 3, 4, 6)	5950	100	10	4
c(1, 3, 5, 6)	5121	100	10	4
c(1, 3, 6)	8222	100	10	3
c(1, 4, 5, 6)	5806	100	10	4
c(1, 4, 6)	7660	100	10	3
c(1, 5, 6)	7916	100	10	3
c(1, 6)	11743	100	10	2
SUM	100035			

Out of 100,000 simulations, a maximum of 35 cases had more than one critical path. Therefore, it is unlikely that more than one critical path will occur in the implementation of the project. However, this is strongly dependent on the rounding adopted - the accuracy of time measurement.

Whether a given path is critical depends on the number of events (corr = -0.943, t = -10.569, $p < 0.001$). Generally, the greater the number of events in a path (activities/tasks), the lower the risk that a given path will be critical.

3. Discussion and conclusions

The first question asked: "Does the distribution of implementation time of the studied project differ significantly from the theoretical PERT time?" can be answered positively. Distribution analysis also shows why projects are "always" late (Schonberger, 1981). As the experiment shows, this is especially visible in the case of "tight" projects in which all activities are critical. The expected project completion time (104.728) is significantly different from the theoretical expected PERT time (p-vaue < 0.001). The distribution of project duration determined in the course of the experiment also differs significantly from the normal distribution. Therefore, it can be recommended that in the case of analyzing projects with numerous critical paths, the use of the normal distribution is not justified. The risk of failing to meet the directive deadline will be much higher than that resulting from a normal distribution (for the theoretical parameters of PERT).

The answer to the second question: "Do theoretical activity durations influence the critical importance of activities in project implementation (in simulations)?" is not clear. The experimental results indicate that the answer should be positive, but the structure of the activity network implies the existence of such a relationship. It should be emphasized that the theoretical durations of activities were generated during the experiment in such a way that all paths and activities were critical. It can be seen that there is a strict linear relationship between the modal time of an activity (modal) and the pessimistic time (Pearson's correlation coefficient is 1). These times, in turn, are used to determine the values "te" and "var" from formulas (1) and (2). Taking this into account, the answer to the second question is positive, as shown by the results, but this is a direct result of the assumptions made in the construction of the experiment. Taking into account the results obtained, a recommendation can be made that in the case of "tight" projects, there will always be such a relationship and more attention should be paid to activities whose expected duration is shorter.

The answer to the third question "Does the number of events in the critical path affect the project completion date?" is also positive. In this case, the greater the number of activities, the lower the risk that the path will be critical. A larger number of activities indicates a shorter

expected completion time on average because the expected PERT time for all paths is identical. These results are in some opposition to the conclusions resulting from the answer to the second question. This is a consequence of the fact that activities with shorter implementation times enter a larger number of critical paths. Comparing the path consisting of one activity 1-6 and the path with the largest number of activities 1-2-3-4-5-6, one can notice a large disproportion in the estimated risk. Path 1-6 was critical in 11.7% of cases, while path 1-2-3-4-5-6 was critical in only 2.9% of cases. Since both of these paths are independent, it can be directly observed that the number of activities has an impact on the project implementation time. Referring to the example from the introduction, we can also indirectly conclude that it is justified to divide "large" tasks into smaller subtasks.

To sum up, it can be concluded that in terms of the experiment conducted and the type of activity dependency network examined:

1. the implementation time distribution of the studied project differs significantly from the theoretical PERT time.
2. theoretical activity durations influence the critical importance of activities in project implementation (in simulations).
3. the number of events in the critical path affects the project completion date.

It is worth noting that the proposed Monte Carlo analysis on the full network can be adapted to any part of the project, because some connections (edges) between nodes may be dummy activities. Relatively, it can be adapted to parts of larger projects, in that part of the tasks that are interdependent and "tight" in nature.

Further research will be directed at confirming and verifying the obtained results in terms of various types of distributions of the duration of individual activities and the impact of generating basic parameters of activity durations. Therefore, it is worth emphasizing that the obtained results depend on the adopted methodology, in particular the numerical procedure in point 3 (generating times: optimistic, modal, pessimistic) and point 5 (generating the duration of activities from a normal distribution with parameters calculated on the basis of point 3).

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BUSINESS DEMOGRAPHY IN POLAND: A DSGE APPROACH

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Purpose: This article explores the relationship between macroeconomic factors and business demography in the Poland in years 2012-2023. Recent events, such as the COVID-19 pandemic and the war in Ukraine, have introduced unique challenges to the Polish economy. Understanding these dynamics is essential for informed decision making.
Design/methodology/approach: The objectives of the paper are achieved using the DSGE approach with fixed number of firms. In the given model, the firm creation process is perceived in a procyclical way using the sunk entry cost mechanism.
Findings: Key findings include the impact of negative productivity shocks on new firms, leading to increased costs and reduced investment attractiveness, resulting in a decline in the total number of companies. In addition, increased public consumption drives up production levels, affecting interest rates and new business opportunities. Technological shocks affect prices and inflation, influencing the number of new companies. Tightening monetary policy impacts capital returns and employment levels. This stimulates the emergence of new firms.
Research limitations/implications: Research limitations are strictly related to the limitation of the tool used. Among the limitations of DSGE models are simplifying assumptions (including perfect rationality, representative agents, and complete markets), lack of detail in the financial sector detail, homogeneity between agents, exogeneity of shocks, calibration, and estimation challenges. Despite these limitations, DSGE models have become a cornerstone of modern macroeconomic analysis and policy evaluation.
Social implications: The findings have important policy implications. Policymakers should consider the potential consequences of their decisions on the business environment, especially in terms of labor market regulations, public spending, and monetary policy.
Originality/value: There are no or few research papers concerning business demography in Poland using the DSGE approach.

Keywords: business demography, DSGE, procyclical entry.

Category of the paper: Research paper.

1. Introduction

Dynamic Stochastic General Equilibrium models (DSGE) were created in response to the need to build relatively simple models whose task is to describe the economy. The standard DSGE class model assumes an unlimited number of enterprises operating on the market and at the same time neglects the impact of the process of establishing and liquidating companies on changes in business cycles (Christiano et al., 2018). Meanwhile, empirical research conducted on US data shows four facts. First, the number of active companies is strongly dependent on the phases of the business cycle. Second, the number of newly established companies explains approximately 20% of quarterly changes in the labor market. Third, Jaravel's (2019) research offers proof that the act of entering a market has an impact on how prices are determined. Fourth, firms less than five years old produce about half of the economy's total output (Colciago, Etro, 2010; Davis et al., 2002; Bernard et al., 2010). Therefore, numerous theoretical works have been written to describe these relationships as best as possible (Casares et al., 2020; Obstbaum et al., 2023). The model proposed by Bilbie et al. (2012) enjoys the greatest recognition among researchers who assume the existence of a finite number of companies on the market. This model is characterized by a procyclical number of new enterprises, which is based on the so-called sunk entry costs for new firms, i.e., the assumption that in the first period of the company's existence, the profits of the company are equal to the costs of starting the business. This mechanism can also be understood as meaning that entrepreneurs decide to start a new business when the value of the new company is equal to the costs of its establishment.

Considering the relationship between macroeconomic variables and the dynamics of the creation and liquidation of companies using DSGE class models provides new opportunities to study the relationships between entrepreneurs and the economy. After appropriate scaling of the model parameters to the realities of Poland, it becomes possible to conduct research that will illustrate the impact of factors such as changes in the labor market, public expenditure, technological shocks, changes in the nominal interest rate, or reducing the costs of starting a business on the demography of enterprises in Poland.

2. The model

Dynamic Stochastic General Equilibrium (DSGE) models are a class of macroeconomic models that play a central role in understanding and analyzing the dynamics of modern economies. DSGE models are grounded in microeconomic principles, with agents (such as households, firms, and the government) making decisions based on optimizing behavior. Agents make decisions today based on their expectations of the future, and these decisions,

in turn, affect future outcomes. DSGE models emphasize the importance of general equilibrium, which means that all markets in the economy clear simultaneously. This ensures that supply equals demand in every market, including goods, labor, and financial markets, which is a foundational concept in economic theory. These microeconomic foundations are used to derive the aggregate behavior of the economy.

2.1. Including consumption and prices in the model

Aggregated consumption and price indices

Aggregated consumption C_t depends on the consumption of individual goods $c_{j,t}$, which are indexed using j contained in the set N_t, i.e., the set of goods available at time t. Consumption is expressed using the Dixit-Stiglitz aggregator (1977), which has the CES function form:

$$C_t = \left(\int_0^{N_t} {c_{j,t}}^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}, \tag{1}$$

where the parameter $\theta > 1$ stands for the elasticity of substitution between goods.

Let P_t stands for aggregate price index for goods available on the market at time t, and let $p_{j,t}$ determine the price of good j at time t. The desired property here is that $P_t C_t = \int_0^{N_t} p_{j,t} c_{j,t}\, dj$. Therefore, it can be shown that:

$$P_t = \left(\int_0^{N_t} {p_{j,t}}^{1-\theta} dj \right)^{\frac{1}{1-\theta}}. \tag{2}$$

Defining P_t this way leads to a formula determining the demand of individual households for good j (Gali, 2008):

$$c_{j,t} = {\rho_{j,t}}^{-\theta} \cdot C_t, \tag{3}$$

where:

$$\rho_{j,t} = \frac{p_{j,t}}{P_t} \tag{4}$$

denotes the relative price of the good j at time t (the price of the good divided by the price index).

Types of consumption

The presented model considers the division of aggregate consumption C_t into private consumption $C_{P,t}$ and public consumption $C_{G,t}$. According to empirical research, public consumption is an important component of overall consumer spending in the economy, and its changes significantly affect the behavior of other economic indicators (Blanchard, Perotti, 2002). It is also assumed that the consumer preferences of the public sphere are the same as the consumer preferences of households. Therefore, aggregate consumption in an economy is the sum of private consumption and public consumption:

$$C_t = C_{P,t} + C_{G,t}. \tag{5}$$

Price stickiness

Each company produces only a single good and operates as a monopoly. Therefore, N_t, that is, the number of goods available on the market at time t, is also the number of existing companies. Moreover, the existence of price rigidity is assumed, the dynamics of which is described by the mechanism of Calvo (1983). According to this mechanism, in any period, each existing company can (but does not have to) change the good price of the produced with probability $1 - \Theta$, where $\Theta \in [0,1]$.

Enterprises that can change prices are divided into anticipatory and adaptive enterprises. Anticipatory firms are those that price the good they produce in a way that maximizes discounted profit, while adaptive firms change the price based on past inflation. This value is indexed to the expected price duration, which results in the same (on average) price level for all enterprises operating in the economy.

Let Ξ denote the probability that a firm that can change its price is adaptive. Equation (2) can be transformed into:

$$(\Pi_t)^{1-\theta} = (1-\Theta)(1-\Xi)N_t\left(\frac{p_t^*}{P_{t-1}}\right)^{1-\theta} + (1-\Theta)\Xi\frac{N_t}{N_{t-1}}(\Pi_{t-1})^{\frac{1}{1-\Theta}} + \Theta\frac{N_t}{N_{t-1}}. \tag{6}$$

Formula (6) allows you to determine the optimal price and the equilibrium price level.

2.2. Firms

Production

Companies set a price to make a profit. Let $y_{j,t}$ denote the production volume of good j, and let the aggregate production in the entire economy be denoted as Y_t, then:

$$Y_t = \left(\int_0^{N_t} {y_{j,t}}^{\frac{\theta-1}{\theta}}\, dj\right)^{\frac{\theta}{\theta-1}}. \tag{7}$$

This leads to a relationship between the production volume of good j and aggregate production using the relative price of good j:

$$y_{j,t} = {\rho_{j,t}}^{-\theta} \cdot Y_t. \tag{8}$$

The company's task is to optimally set the price for the produced good using the available physical capital resources $k_{j,t}$, the amount of employment H_t, and labor $l_{j,t}$. In the production process, enterprises use a two-factor Cobb-Douglas production function:

$$y_{j,t} = A\left(k_{j,t}\right)^{\alpha}\left(H_t l_{j,t}\right)^{1-\alpha}, \tag{9}$$

where A stands for the technology, while α is a parameter describing the elasticity of production with respect to factors, with $0 \leq \alpha \leq 1$.

Companies optimize values of production factors in two stages. The first stage is to determine the optimal price of manufactured goods and the quality of production. In the second stage, companies take the wage w_t and the return on capital r_t as data and determine the demand for labor and physical capital that will minimize production costs.

Minimization of costs

Firms minimize costs at time t:

$$\min_{(l_{j,t},k_{j,t})} Cost_t = w_t H_t l_{j,t} + r_t k_{j,t}, \tag{10}$$

with production technology:

$$y_{j,t} = A\left(k_{j,t}\right)^{\alpha}\left(H_t l_{j,t}\right)^{1-\alpha} - \Phi. \tag{11}$$

This leads to the Lagrange function:

$$\min_{(l_{j,t},k_{j,t})} Cost_t = w_t H_t l_{j,t} + r_t k_{j,t} - \lambda_{1,t}\left[A\left(k_{j,t}\right)^{\alpha}\left(H_t l_{j,t}\right)^{1-\alpha} - \Phi - y_{j,t}\right].$$

The first-order conditions for firms are given as:

$$\begin{aligned} &\frac{\partial Cost_t}{\partial k_{j,t}}: && r_t - \lambda_{1,t}\alpha A\left(k_{j,t}\right)^{\alpha-1}\left(H_t l_{j,t}\right)^{1-\alpha} = 0, \\ &\frac{\partial Cost_t}{\partial l_{j,t}}: && w_t H_t - \lambda_{1,t}(1-\alpha)A\left(k_{j,t}\right)^{\alpha}(H_t)^{1-\alpha}\left(l_{j,t}\right)^{-\alpha} = 0. \end{aligned} \tag{12}$$

The Lagrange multiplier is related to technological constraints and is assumed to measure the nominal marginal cost cm_t. Hence the first order conditions have the form:

$$r_t = \alpha cm_t \frac{y_{j,t}}{k_{j,t}}, \tag{13}$$

$$w_t = (1-\alpha) cm_t \frac{y_{j,t}}{H_t l_{j,t}}, \tag{14}$$

and as a result:

$$w_t H_t l_{j,t} + r_t k_{j,t} = cm_t y_{j,t}. \tag{15}$$

Price setting

In the first stage, companies set prices. The optimal price p_t^* is obtained as the quantity that maximizes the weighted, discounted, expected stream of profits:

$$\max_{(p_t^*)} E_t\left\{\sum\nolimits_{k=0}^{\infty}(\Theta\beta)^k\left[\rho_{j,t}y_{j,t+k} - \left(w_{t+k}H_{t+k}l_{j,t+k} + r_{t+k}k_{j,t+k}\right)\right]\right\}, \tag{16}$$

where:

- E_t stands for expected value at time t,
- $(\beta)^k$ is a discount factor,
- $(\Theta)^k$ is the weight corresponding to the probability that the price cannot be changed for k periods,
- $E_t\{\rho_{j,t}y_{j,t+k} - \left(w_{t+k}H_{t+k}l_{j,t+k} + r_{t+k}k_{j,t+k}\right)\}$ is the firm's profit at period $t+k$, expected at time t.

Substituting equations (15), (10), (4) into (16) and assuming that $p_t^* = p_{j,t}$, the following was obtained:

$$p_t^* = \left(\frac{\theta}{\theta-1}\right)\frac{\sum_{k=0}^{\infty}(\Theta\beta)^k\left[Y_{t+k}(P_{t+k})^{\theta}cm_{t+k}\right]}{\sum_{k=0}^{\infty}(\Theta\beta)^k\left[Y_{t+k}(P_{t+k})^{\theta-1}\right]}. \tag{17}$$

In a situation where $\Theta = 0$, i.e., all companies can update their prices from period to period, the formula for marginal costs takes the form: $cm_t = \left(\frac{\theta-1}{\theta}\right)\rho_{j,t}$.

2.3. Number of firms

Contemporary empirical research indicates that the process of winding down a business is much less procyclical than the process of starting a business (Broda, Weinstein, 2010; Lee, Mukoyama, 2007). Therefore, modeling changes in the number of operating enterprises based on the assumption of endogeneity of the liquidation process and exogeneity of the company formation process seems to be justified (Bilbiie et al., 2012). It is assumed that there is general equilibrium in the economy, and therefore, in the long run, the number of new firms balances the loss incurred as a result of liquidation. It is assumed that new firms are established when, in the first period of operation, revenues from operations equal the costs incurred. New companies use only labor resources in the production process:

$$f_{j,t} = AH_t l_{0,j,t}, \tag{18}$$

where:
$f_{j,t}$ is the production volume of the new company j,
H_t describes the employment volume as above,
$l_{0,j,t}$ is the volume of labor used in the production process by the new firm j.

Aggregation of (18) leads to:

$$f_t N_{0,t} = AH_t L_{0,t}, \tag{19}$$

where:
$L_{0,t}$ describes the total amount of work devoted to starting a business in period t,
f_t means the production volume of the new company,
f_t also represents the costs of starting a business.

It is assumed that the amount of investment in new companies corresponds to the costs associated with a single-factor production function:

$$I_{N,t} = w_t H_t L_{0,t}. \tag{20}$$

Therefore, relationship (20) can be rewritten using formula (19) as:

$$I_{N,t} = \frac{f_t}{A} w_t N_{0,t}. \tag{21}$$

The total value of new firms $v_t N_{0,t}$ is equal to the amount of investment in new firms $I_{N,t}$. Therefore, the following occurs:

$$v_t = \frac{f_t}{A} w_t. \tag{22}$$

The number of enterprises evolves according to the principle: $N_t = (1 - \delta_N)N_{t-1} + N_{0,t}$.

2.4. Households

The utility function

The utility function of households depends on consumption and the amount of free time. Public consumption was introduced as in Aschauer (1985) and McGrattan (1994). It is assumed that the utility of consumption of an individual household is a linear combination of private consumption $C_{P,t}$ and public consumption $C_{G,t}$:

$$C_t^P = C_{P,t} + \pi C_{G,t}. \tag{23}$$

The parameter π denotes the constant elasticity of substitution between available types of consumption.

Consumers are guided in their choices by consumption habits. Campbell and Cochrane (1999) pointed out that consumption habits naturally result from human psychological conditions. Considering consumption habits in the study allows for better modeling of the sensitivity of consumption as a result of changes in the level of income, and also allows to increase the resistance of the production level to changes and the negative correlation between rates of return and the future level of production (Boldin et al., 2001). The model assumes that the household utility function depends on the difference between current consumption and that from the previous period (i.e., $C_t^P - \phi C_{t-1}^P$, where ϕ is a constant reflecting the strength of consumption habits, $0 \leq \phi \leq 1$).

The utility function for households also takes free time O_t as an argument. Its functional form is as follows:

$$U_t(C_t^P - \phi C_{t-1}^P, O_t) = \gamma \ln(C_t^P - \phi C_{t-1}^P) + (1-\gamma)\ln(O_t), \tag{24}$$

where $0 \leq \gamma \leq 1$ denotes the weights assigned to consumption and free time. The household must decide how to divide the available time between free time O_t and work time L_t:

$$O_t + L_t = 1 \Rightarrow O_t = 1 - L_t. \tag{25}$$

Households maximize the value stream of expected utility functions. Therefore, what is maximized is the sum of utilities at the current moment and the currently expected future values of the utility function, which are appropriately discounted using the parameter $0 \leq \beta \leq 1$:

$$\mathrm{E_t}\left\{\sum_{t=0}^{\infty} \beta^t U_t(C_t^P - \phi C_{t-1}^P, O_t)\right\}. \tag{26}$$

Budget

The household budget is balanced, income equals expenses. Each household receives remuneration w_t for work L_t depending on the level of employment H_t (less the amount of tax $\tau_{L,t}$), in addition, interest r_t on the physical capital K_t (also taxed $\tau_{K,t}$), it also has a portfolio x_t shares in companies whose value is marked as v_t and which pay dividends from the profits d_t. This money is spent on consumption $C_{P,t}$ (also taxed $\tau_{C,t}$), on capital investments $I_{K,t}$, and reinvests some of the funds in companies, both existing and new ones. By updating their portfolio in the next period, households hope to receive a dividend in the future. The budget constraint for households takes the form:

$$(1+\tau_C)C_{P,t} + I_{K,t} + v_t\left(N_t + N_{0,t}\right)x_{t+1} = (1-\tau_L)w_t H_t L_t + (1-\tau_K)r_t K_t + (v_t + d_t)N_t x_t. \quad (27)$$

Physical capital evolves according to the following principle:

$$K_t = (1-\delta_K)K_{t-1} + I_{K,t}, \quad (28)$$

where $0 < \delta_K < 1$ means the coefficient of depreciation of physical capital, and $I_{K,t}$ means net investment in capital.

Households decide what part of the funds to allocate to capital investments and how much to invest in companies. By investing in companies, households also optimize their portfolio of stocks. The Lagrange problem that households solve comes down to:

$$\max_{\substack{C_{P,t},L_t,\\ K_t,x_{t+1}}} \mathcal{L} = E_t \sum_{t=0}^{\infty} \beta^t \left\{ \begin{matrix} \gamma\, log\left(C_{P,t} + \pi C_{G,t} - \phi\left(C_{P,t-1} + \pi C_{G,t-1}\right)\right) + (1-\gamma)\, log(1-L_t) \\ -\lambda_{2,t}\left[\begin{matrix} (1+\tau_C)C_{P,t} + K_t - K_{t-1} + v_t\left(N_t + N_{0,t}\right)x_{t+1} - \\ -(1-\tau_L)w_t H_t L_t - (1-\tau_K)(r_t - \delta_K)K_{t-1} - (v_t + d_t)N_t x_t \end{matrix}\right] \end{matrix} \right\}.$$

The first-order conditions for households are the following:

$$\frac{\partial \mathcal{L}}{\partial C_{P,t}}: \quad \beta^t \left[\frac{\gamma}{C_t^P - \phi C_{t-1}^P} - \lambda_{2,t}(1+\tau_C)\right] - \beta^{t+1}\left[\frac{\gamma\phi}{C_{t+1}^P - \phi C_t^P}\right] = 0, \quad (29)$$

$$\frac{\partial \mathcal{L}}{\partial L_t}: \quad -(1-\gamma)\frac{1}{1-L_t} + \lambda_{2,t}(1-\tau_L)w_t H_t = 0, \quad (30)$$

$$\frac{\partial \mathcal{L}}{\partial K_t}: \quad \beta^t \lambda_{2,t}[(1-\tau_K)(r_t - \delta_K) + 1] - \beta^{t-1}\lambda_{2,t-1} = 0, \quad (31)$$

$$\frac{\partial \mathcal{L}}{\partial x_{t+1}}: \quad -\beta^t \lambda_{2,t} v_t\left(N_t + N_{0,t}\right) + \beta^{t+1}\lambda_{2,t+1}(v_{t+1} + d_{t+1})N_{t+1} = 0. \quad (32)$$

2.5. Labor market

The total percentage of employees is H_t. Unemployed people who find a job are immediately employed. The fraction of unemployed relative to the total at time t is equal to:

$$u_t = 1 - H_t. \quad (33)$$

Employment occurs as a result of a meeting between the company and the job seeker (Obstbaum et al., 2023). Companies announce s_t vacancies for which they are looking for employees. The number of new jobs depends on the vacancies and the level of unemployment. The linking function describes the contacts established by interested parties leading to the creation of new positions; it has the form:

$$m_t = \Gamma_t {u_t}^{\sigma} {s_t}^{1-\sigma}, \quad (34)$$

It is an increasing function with respect to both arguments and is continuous and homogeneous of degree one. Its basic feature is captured by the inequality $m_t \leq \min[u_t, s_t]$. This corresponds to a situation where at least some job seekers fail to find employment and similarly some vacancies fail to be filled. Due to this, the model allows for unemployment to occur in an economy in equilibrium. Quotient:

$$q_t = \frac{u_t}{s_t}, \tag{35}$$

refers to the number of job seekers per one vacancy. The probability that the company will find an employee to fill the vacant position:

$$q_{1,t} = \frac{m_t}{s_t}. \tag{36}$$

Similarly, the probability that an unemployed person will find a job is:

$$q_{2,t} = \frac{m_t}{u_t}. \tag{37}$$

The average period of employment is $\frac{1}{q_{1,t}}$ and the average time without employment is $\frac{1}{q_{2,t}}$. Furthermore, $\frac{q_{1,t}}{q_{2,t}} = \frac{u_t}{s_t}$, which leads to the conclusion that each additional person looking for a job reduces the chance of finding a job for the unemployed and at the same time increases the chance of the company finding an employee. Similarly, each subsequent vacancy increases the unemployed person's chance of employment and reduces the company's chance of finding an employee.

Exogenous shocks lead to immediate reductions in employment. It is assumed that in period $t-1$ the fraction $\frac{N_t}{N_{t-1}+N_{0,t-1}}$ of companies ceases to exist, moreover, each of the companies that survive until period t dismisses a constant fraction δ_H current employees. Employees who have lost their job start looking for a new job in the next period. Employment results from the need to fill the places left by dismissed employees. The model assumes that people already employed are not looking for work. A company that does not have vacancies is not looking for employees. The equation describing the dynamics of changes in the employment level has the form:

$$H_t = (1-\delta_H)\left(1 - \frac{N_t}{N_{t-1}+N_{0,t-1}}\right)H_{t-1} + m_t.$$

Let λ_t denote the fraction of employees who lose their jobs at period t, then:

$$\lambda_t = \frac{(1-\delta_H)N_t}{N_{t-1}+N_{0,t-1}} + \delta_H, \tag{38}$$

The equation describing changes in the employment level can therefore be written as:

$$H_t = (1-\lambda_t)H_{t-1} + m_t. \tag{39}$$

In equilibrium, the number of people who lose their jobs in each period is equal to the number of people employed during that time. This leads to the relationship:$\lambda_t H_t = q_{2,t}u_t$.

Let J_t and $V_t$denotes, respectively: the discounted value of the filled and unfilled job position at time t. The value of the vacancy is expressed using the following relationship:

$$V_t = -cost_t + (1-\delta_N)\beta\left[q_{1,t+1}J_{t+1} + \left(1-q_{1,t+1}\right)V_{t+1}\right], \tag{40}$$

where $cost_t$ is the cost associated with the process of searching for an employee, $(1-\delta_N)$ is the chance that the company will survive until the next period, β is the discounting factor, $q_{1,t+1}$

is the probability of finding an employee for a vacant job position, $(1-\delta_N)\beta\left[q_{1,t+1}J_{t+1}+\left(1-q_{1,t+1}\right)V_{t+1}\right]$ is the discounted future value of the vacancy.

Similarly, the value of a filled job position is expressed by:

$$J_t = \sigma_{prof} w_t + (1-\delta_N)\beta[(1-\delta_H)J_{t+1} + \delta_H V_{t+1}], \tag{41}$$

where $\sigma_{prof} w_t$ is the difference between the profit brought by the employee and his remuneration, this value in the model depends on the amount of remuneration, $(1-\delta_N)\beta[(1-\delta_H)J_{t+1} + \delta_H V_{t+1}]$ is the discounted future value of the currently filled job position.

Let U_t and W_t denote, respectively: the discounted value of the profits of the unemployed and employed employee at time t. The profits from being unemployed are expressed by the following relationship:

$$U_t = \sigma_{zas} w_t + \beta\left[q_{2,t+1}W_{t+1} + \left(1-q_{2,t+1}\right)U_{t+1}\right], \tag{42}$$

where $\sigma_{zas} w_t$ is the amount of the benefit to which the unemployed person is entitled, $q_{2,t+1}$is the probability of finding a job for the unemployed person in the next period, $\beta\left[q_{2,t+1}W_{t+1} + \left(1-q_{2,t+1}\right)U_{t+1}\right]$ is the future discounted value of profits for the unemployed person.

Similarly, the value of an employed person's profits is expressed by the following relationship:

$$W_t = w_t + \beta[(1-\lambda_{t+1})W_{t+1} + \lambda_{t+1}U_{t+1}], \tag{43}$$

where w_t is the amount of earnings, the remuneration due to the employee, $\lambda_{t+1}$is the fraction of employees who will lose their job at time $t+1$, $\beta[(1-\lambda_{t+1})W_{t+1} + \lambda_{t+1}U_{t+1}]$ is the discounted future value of the employee's earnings.

The firm's net profit from employing an employee is $J_t - V_t$, while the net profit from employment for the employee is $W_t - U_t$. Maximizing the Nash function comes down to determining the amount of remuneration that solves the following.

$$w_t = \arg\max\ (W_t - U_t)^{\sigma_{Nash}}(J_t - V_t)^{1-\sigma_{Nash}}.$$

The value of the σ_{Nash} parameter implies the strength of the employee's bargaining position in relation to the company. The first-order condition that solves the Nash problem takes the form:

$$\sigma_{Nash}(J_t - V_t) = (1-\sigma_{Nash})(W_t - U_t). \tag{44}$$

2.6. Government and central bank

The government's role is reduced to tax collection and income redistribution. The government's consumption preferences are the same as those of households. Moreover, he balances his expenses in each period. The government obtains resources by taxing consumption and income derived from labor and capital. The effective tax rates are denoted by $\tau_{C,t}, \tau_{L,t}$, and $\tau_{K,t}$, respectively. The government budget is as follows:

$$C_{G,t} = \tau_{C,t} C_t + \tau_{L,t} w_t L_t H_t + \tau_{K,t}(r_t - \delta_K) K_t. \quad (45)$$

The central bank's role in the model is to control interest rates. Using available monetary policy instruments, the central bank strives to keep the economy in equilibrium.

The Taylor's rule (1993) relates short-term nominal interest rates to deviations from the equilibrium position for inflation and GDP. The behavior of the central bank in this model is described by the smoothed Taylor rule. According to the rule, the central bank systematically adjusts interest rates in each period, preferring interventions spread over time rather than one-off, strong interventions in the level of interest rates. The linearized equation takes the form:

$$\hat{r}_t = \Psi_0 \hat{r}_{t-1} + (1 - \Psi_0)\left[\Psi_1\left(\hat{\Pi}_t - \overline{\Pi}\right) + \Psi_2\left(\hat{Y}_t - \overline{Y}\right)\right], \quad (46)$$

where $\hat{r}_t$ is the percentage increase in capital return rates r_t, $\hat{Y}_t$ is the percentage increase in GDP Y_t, $\hat{\Pi}_t$ is the percentage increase in inflation Π_t, $\overline{\Pi}$, $\overline{Y}$ are the values of variables achieved when the economy is in equilibrium, Ψ_0, Ψ_1,Ψ_2 are the structural parameters of the model.

2.7. Market clearing

Aggregation leads to:

$$C_t + I_{K,t} + v_t N_{0,t} = w_t H_t L_t + r_t K_t + d_t N_t. \quad (47)$$

Total consumption expenditures, together with capital investments and investments in new firms, is equal to income from labor, capital income, and dividends paid by firms to their shareholders.

3. Empirical analysis

In the next stage of the study, the obtained model was linearized and then a total of five structural shocks were added to it. These shocks have been linked to the costs of starting a business, changes in the level of public spending, changes in production technology, central bank monetary policy, and changes in employment rates. The choice of structural shocks for the model results from the dynamics of events that directly influenced the Polish economy in recent years.

3.1. Data

The model presented includes five structural shocks. Therefore, five macroeconomic variables related to Poland will be used to estimate its parameters. These are: the number of new enterprises registered in the REGON register, Gross Domestic Product, the rate of changes in average employment in the enterprise sector, the price index of consumer goods and services, and the average monthly gross salary. Due to limited access to historical data on selected

variables, the author decided to work with quarterly data, using data from 2012-2023 in the study, which gave a total of 45 observations for each of the variables mentioned.

The model does not consider seasonal fluctuations, and the assumption of a state of general equilibrium results in the need to neutralize any empirically observable trend. Moreover, it should be remembered that after the log-linearization stage, variables interpreted as deviation from the equilibrium state remain in the model. To remove the seasonal component from the data, the author used X-12-ARIMA filtration, a procedure created and widely used, among others, by the US Census Bureau.

3.2. Calibration

The model includes 24 parameters. From this group, 10 parameters are calibrated, and the values obtained for the remaining 14 are the result of Bayesian estimation carried out on real data. The selection of calibrated parameter values involved assigning values that were used by other authors of DSGE models or resulted from the analysis of actual data provided by the Central Statistical Office (Table 1).

Table 1.
Calibrated parameters

Parameter	Value	Comments
β	0.995	Equivalent to a 2% loss of current utility after one year.
δ_N	0.066	The quotient of the number of new and existing non-financial enterprises in Poland from 2015-2023.
δ_H	0.025	Experimentally verified.
τ_C	0.190	Effective VAT rate.
τ_L	0.272	At the personal income tax rate of 18% and tax-deductible costs of 20%.
τ_K	0.190	Tax on capital
$\bar{u}$	0.468	Difference between unity and total employment rate for Poland in 2017.
σ	0.500	Based on literature.
σ_{ZAS}	0.300	Based on literature.
σ_{Nash}	0.500	Based on literature.

Source: Own study based on Baranowski et al. (2013), Torres, (2013); Levis, Polly (2012), Grabek et al. (2010) and Christiano et al. (2005).

3.3. Estimation

The model parameters were obtained using Bayesian estimation. Knowledge about the parameters then comes partly from empirical data and partly from the researcher's subjective assessment. An arbitrarily determined distribution of a parameter is called the a priori distribution. In practice, the parameter estimation process is based on the confrontation of the established a priori distribution with the data. As a result, this leads to a posteriori distribution.

The sample from a posteriori distribution is obtained by using the iterative Metropolis-Hastings algorithm. Five Markov chains were used to estimate marginal distributions using Monte Carlo methods, each of which consisted of one million replications, for which the rejection threshold was set at 25%. Expected values for prior distributions were taken from

other DSGE models (Baranowski et al., 2013; Torres, 2013; Levis, Polly, 2012; Grabek et al., 2010; Christiano et al., 2005).

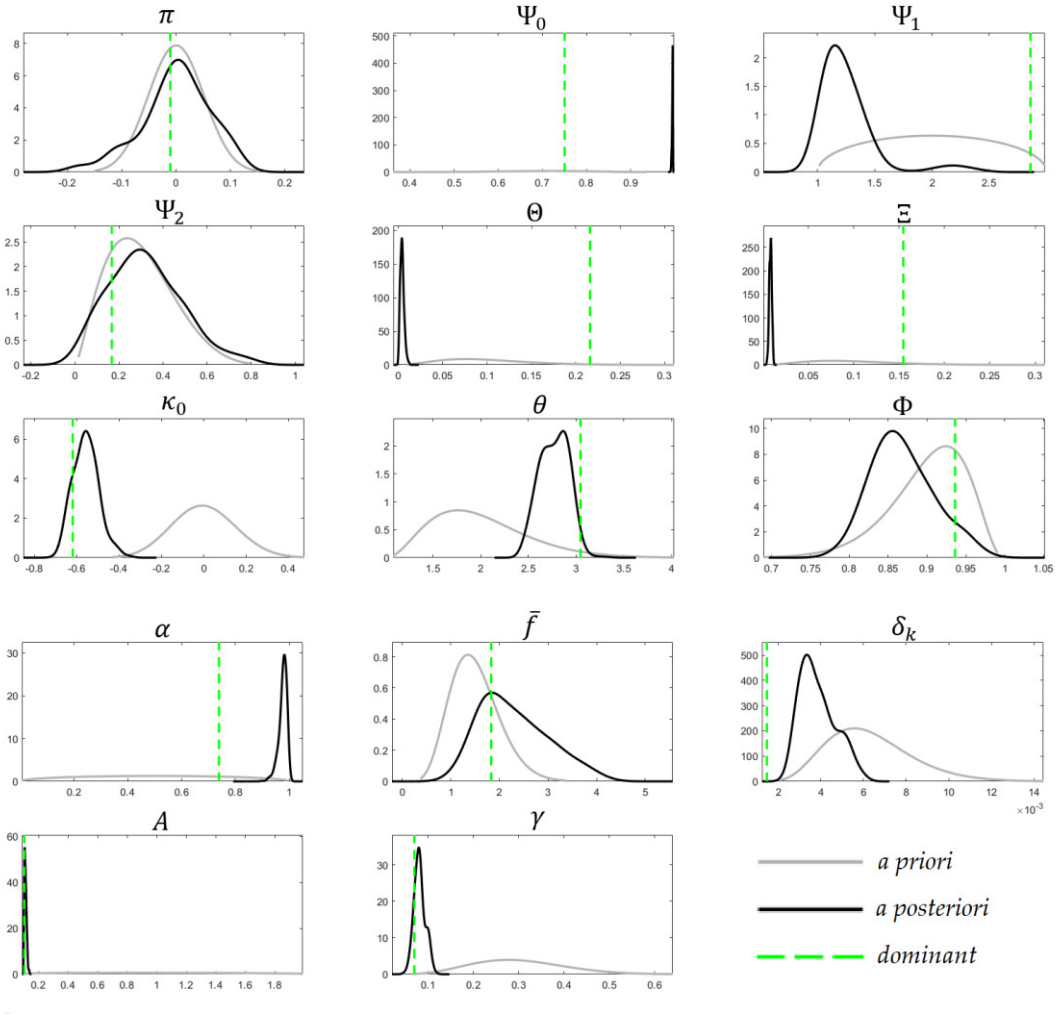


Figure 1. Results of estimating the parameters of the DSGE model using Bayesian techniques.
Source: Own calculations.

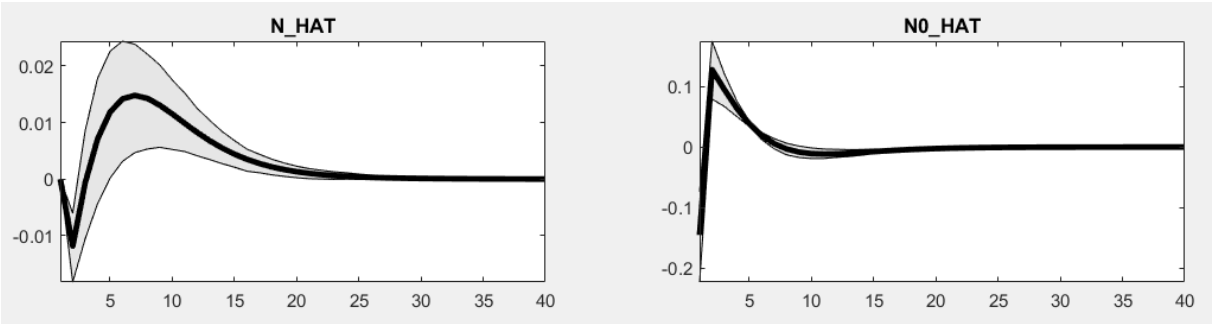
When analyzing the a priori and a posteriori distribution graphs (Figure 1), significant differences are clearly noticeable in all cases except π and Ψ_2. Bayesian estimation in both cases led to a slight change in the expected value of the parameters but did not help reduce the subjectively determined variance of the distributions. In the case of the remaining twelve parameters, the differences concern both the estimated measure of the center and the measure of dispersion, which can be treated as evidence of a good fit of the model to the real data.

4. Results

Impulse response functions (IRF) allow us to answer the question of how the trajectories of deviations from the equilibrium state of model variables develop in response to structural shocks in the model. The assumption of the correct interpretation of the obtained results is that the economy is in a state of equilibrium when the disturbance occurs, and after the disturbance no other disturbances occur. The response of the business population to structural shocks in the model was analyzed. The reactions presented to the impulse concern only new companies and the total number of companies. The window length is 10 years (40 quarters).

4.1. Entry cost

The negative productivity shock regarding new firms increases the costs of doing business. It does not affect the productivity of existing companies, but it reduces the attractiveness of investing in new ones. As a result, the total number of companies is decreasing (Figure 2). A s a result of reduced financing for new companies, consumption increases. Employment levels are falling because fewer new jobs are being created. As a result of the increase in consumption, each new company increases its production level. Since relative prices do not adjust immediately, an increase in production results in an increase in corporate profits. Therefore, this shock generates a negative production gap, which results in the relaxation of the central bank's monetary policy.



Note: The 95% confidence interval is marked in gray.

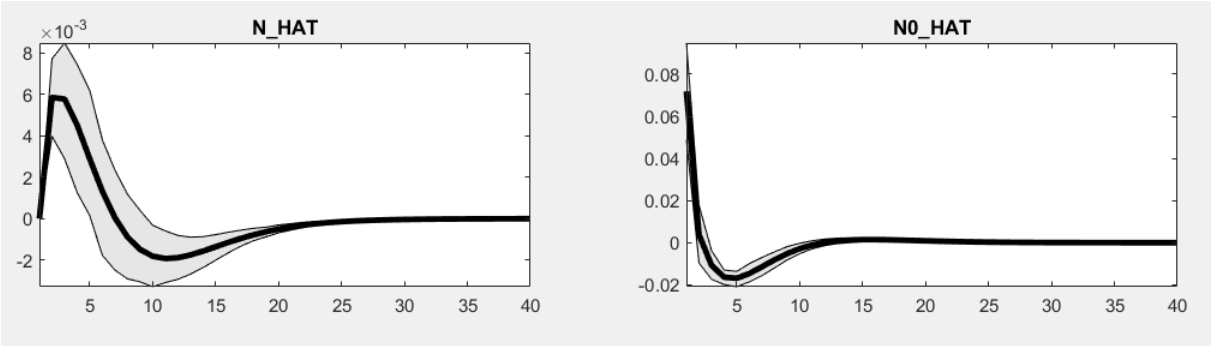
Figure 2. Percentage deviations from steady state for the total number (N) and number of new firms (N0) in response to the increase in entry cost.

Source: Own calculations.

4.2. Public spending

Increasing public consumption reduces the availability of consumer goods for households. As a result, production levels increase. This results in a positive production gap, which in turn affects monetary policy and consequently leads to an increase in interest rates. The level of production of existing companies increases (and, consequently, their profits also increase). This increase is not related to a change in production technology; therefore, the increase in

production occurs as a result of increasing employment and the creation of new companies. The increasing demand for the employment of new employees by existing companies results in a reduction in the availability of work for new companies, which again translates into a reduction in their number over time (Figure 3).



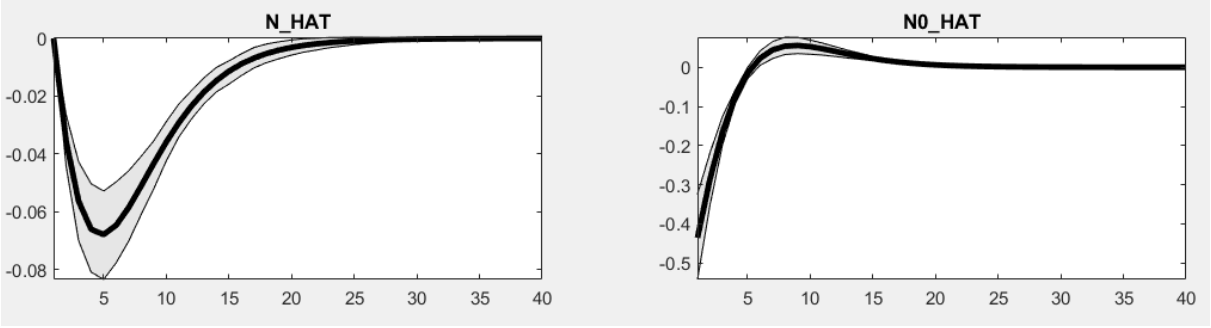
Note: The 95% confidence interval is marked in gray.

Figure 3. Percentage deviations from steady state for the total number (N) and number of new firms (N0) in response to the increase of public spending.

Source: Own calculations.

4.3. Productivity

The increase in productivity resulting from improved production technology will have a direct impact on the price level. As a result, each company will reduce the prices of manufactured goods, which will have a real impact on the level of inflation. The number of companies is determined in advance and, therefore, increasing productivity will increase production. An increase in production combined with a decline in inflation will lead to an increase in the production gap, which will result in a relaxation of monetary policy. An increase in the level of production combined with an increase in the amount of money available will result in an increase in workers' wages. Increasing the level of wages will have a negative impact on the costs of starting a business. This, combined with a decrease in sales prices, will lead to a decrease in the number of new companies (Figure 4).



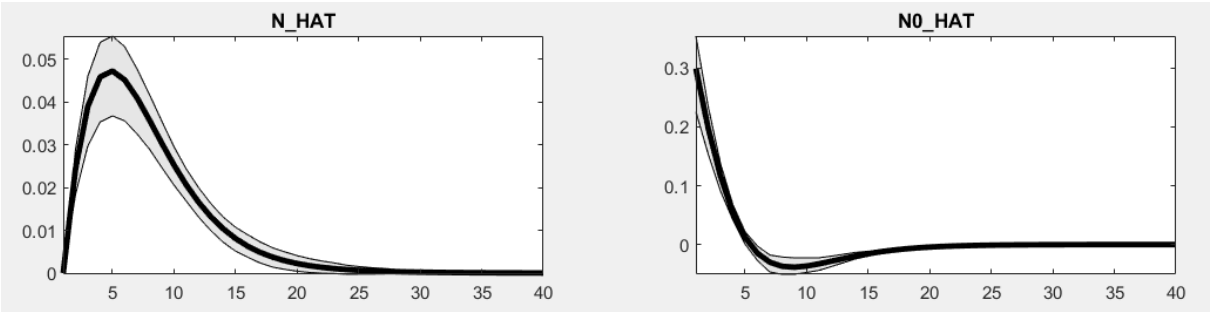
Note: The 95% confidence interval is marked in gray.

Figure 4. Percentage deviations from steady state for the total number (N) and number of new firms (N0) in response to productivity shock.

Source: Own calculations.

4.4. Monetary policy

The tightening of monetary policy causes a decline in the rates of return for capital. This situation leads to increased consumption. As a result, a positive production gap is created. Companies start producing more and therefore have greater profits. New firms are created. To increase production and meet increased consumption, companies increase employment. Increasing employment has a negative impact on the number of new firms over time (Figure 5).



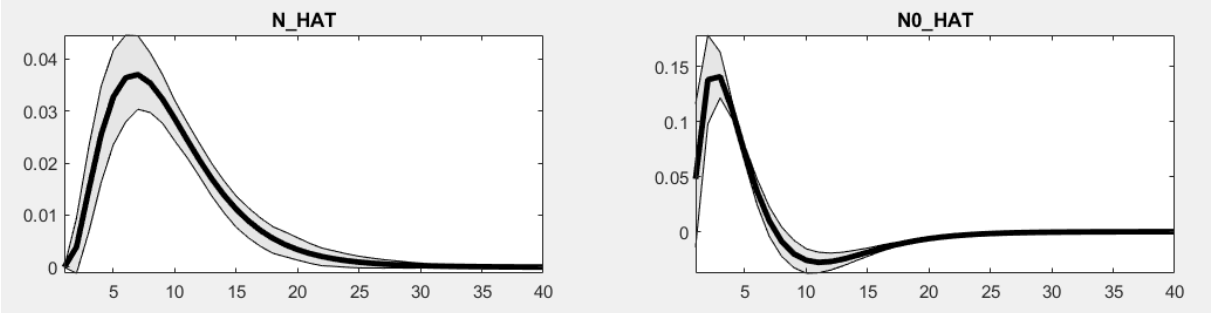
Note: The 95% confidence interval is marked in gray.

Figure 5. Percentage deviations from steady state for the total number (N) and number of new firms (N0) in response to tightening of monetary policy.

Source: Own calculations.

4.5. Employment

The shock associated with reduced employment will negatively impact the level of productivity in the economy. The decline in productivity will have a negative impact on the level of production and, consequently, on the level of consumption. Existing companies will become less productive, and, at the same time, new employees will appear on the labor market. As a result, the costs of starting a new business will decrease. New companies will be established, and the level of production will gradually increase (Figure 6).



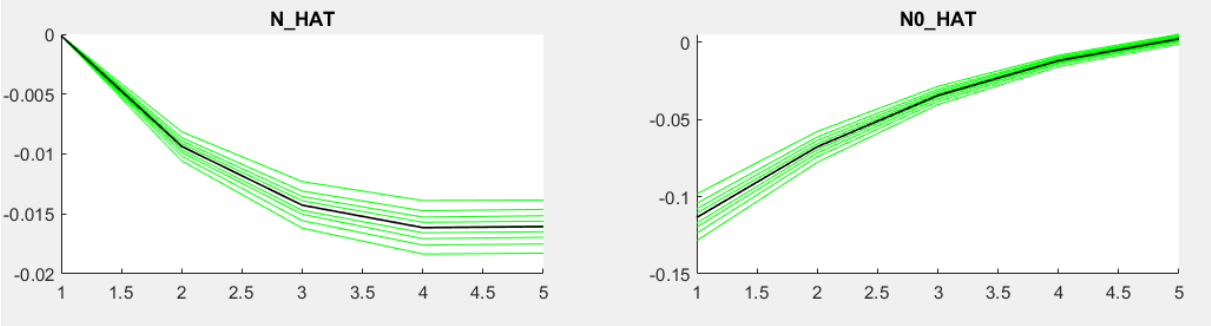
Note: The 95% confidence interval is marked in gray.

Figure 6. Percentage deviations from steady state for the total number (N) and number of new firms (N0) in response to tightening of employment shock.

Source: Own calculations.

4.6. Predictions

It is not easy to estimate the number of companies that operate actively in Poland. REGON statistics 'swell' year by year because they do not consider the division into registered and active entities of the national economy. This was the basic reason for not including this variable in the group of observable variables of the model. However, a good idea of the number of companies can be obtained by observing the number of new entries, and the statistics themselves are reliable. Based on these data, the model presented forecast the total number and the number of new firms in Poland (Figure 7). By analyzing the obtained figures, the number of new companies is currently relatively small. A gradual return to balance is expected in five quarters. In the context of the total number of companies, a decline is expected. This is a natural consequence of the fact that there will be fewer new firms.



Note: The black line indicates the forecast in means for the analyzed variables, obtained using the Kalman filter. Green lines represent deciles of the fitted uncertainty distribution.

Figure 7. Forecasts for percentage deviations from steady state for the total number (N) and number of new firms (N0).

Source: Own calculations.

5. Concluding remarks

In conclusion, the application of DSGE class models to study the relationship between macroeconomic variables and the business demography in Poland offers valuable insights into the complex interactions shaping the business landscape. Several key findings emerge from this analysis:

a) Recent Economic Challenges: Recent events, including the COVID-19 pandemic and the war in Ukraine, have presented unique challenges to the Polish economy. The conclusion of this research is that the Polish economy is sensitive to various shocks, including negative productivity shocks, changes in public consumption, improvements in production technology, changes in monetary policy, and employment fluctuations. These shocks have ripple effects on business creation, growth, and contraction.

b) Monetary Policy's Role: The text highlights the significant influence of monetary policy on business dynamics. Changes in interest rates and monetary policy measures have direct implications for both the number of new firms and the behavior of existing companies.
c) Employment's Impact: Employment levels play a crucial role in shaping the entrepreneurial landscape. Reductions in employment costs can stimulate the establishment of new companies, while increased employment by existing firms can limit opportunities for newcomers.
d) Data Challenges: The analysis acknowledges challenges in accurately estimating the total number of active companies in Poland, emphasizing the use of new entry statistics as a proxy. This underscores the importance of improving data accuracy for more precise economic analysis.
e) Policy Implications: The findings have important policy implications. Policymakers should consider the potential consequences of their decisions on the business environment, especially in terms of labor market regulations, public spending, and monetary policy.
f) Forecasting Business Trends: The presented model forecasts a decline in the total number of companies in Poland, reflecting the current economic conditions. This forecast can guide policymakers and businesses in planning for the future.

In sum, the analysis provides a valuable framework for understanding how macroeconomic variables influence the business demography in Poland. It sheds light on the intricate dynamics at play and offers valuable insights for policymakers and businesses seeking to navigate this evolving landscape.

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NONLINEAR GRANGER CAUSALITY BETWEEN NATURAL GAS AND HEATING OIL PRICES AND SELECTED EXCHANGE RATES

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Purpose: The currently observed uncertainty in financial markets related to changes taking place in the modern world requires investors to look for tools that allow for good forecasting of the price of financial instruments. The detection of causal relationships may contribute to improving the quality of forecasts by reducing the variance of the prediction error. The aim of the research is to detect nonlinear Granger causality in both directions between selected financial instruments and to check whether the identified relationships are stable over time.
Design/methodology/approach: The study of causal relationships between selected financial instruments was carried out using the nonparametric Diks-Panchenko test. This test identifies all types of relationships: linear and nonlinear.
Findings: In the first phase of the study, nonlinear Granger causality was tested using the nonparametric Diks-Panchenko test. Six values of lags and two distance measures were used. It is then shown that the significance of the detected relationships has changed in recent years. For this purpose, two directions of causality and three sub-periods were analyzed.
Research limitations/implications: Due to the short-term character of the detected relationships, they should be taken into consideration primarily by market participants, to create effective investment portfolios and risk-hedging strategies.
Practical implications: Application in making investment decisions on the capital market.
Originality/value: The use of information on causal relationships to improve the quality of forecasts related to the energy and currency markets.

Keywords: nonlinear Granger causality, Diks-Panchenko test, heating fuel market, exchange rates.

Category of the paper: Research paper.

1. Introduction

Due to the exceptional situation on the European and domestic market of heating raw materials that has been ongoing for over a year, a significant increase in the prices of natural gas and heating oil has been observed, which, next to crude oil and coal, are the most important sources of energy in the world. The analysis of these changes is very important because these

energy carriers are of key importance for industry and national economies. They are used, among other things, to produce heat energy, which in Poland is an alternative to high-emission hard coal and lignite. Many countries, including Poland, are largely dependent on the import of these raw materials (Kaliski, 2010). Since their supplies are paid for in foreign currencies, it can be assumed that the prices of natural gas and heating oil are sensitive to changes in exchange rates. Determining the trends in price changes of these raw materials and the factors influencing them is the starting point for forecasts, necessary in long-term business planning.

There are many studies in the literature examining the relationship between crude oil prices and exchange rates (Fratzscher et al., 2014; Wen et al., 2017; Beckmann et al., 2020; Orzeszko, 2021). Among them, we can find works that examined linear Granger causality (Brahmasrene et al., 2014; Sharma, 2017; Adam et al., 2018). However, the obtained results are not so clear on the direction of the causal relationship between crude oil prices and exchange rates. This highlights the need to include nonlinear causality tests in research.

The main goals of the paper are:

- testing two-way non-linear Granger causality between the prices of natural gas and heating oil and selected currency rates, i.e. EUR/USD, PLN/USD,
- and examining whether the identified relationships are stable over time.

The research used time series composed of the closing prices of selected financial assets obtained from the investment portal investing.com. The research period covers the years 2014-2023, narrowed down to three sub-periods in individual analyzes.

The article consists of two main parts: the first is theoretical (the methodology used in the analysis is briefly discussed and references to the literature are given), and the second is the analysis of financial data and its conclusions. The article ends with a summary.

2. Natural gas and heating oil versus exchange rates

Due to its unquestionable advantages, natural gas is often called the fuel of the 21st century. After periods of dominance of coal and crude oil, changes can be observed in the structure of fuel consumption with greater use of gas. It is used not only to produce heat and electricity, but is also widely used in the chemical, heavy and food industries, where it is used, among others, for the production of plastics, detergents and paints.

Another source of energy is heating oil. It is obtained in the process of distillation of crude oil. In the late 1990s, this raw material was advertised as a cheap and ecological fuel. As a result, cooperatives, housing communities and owners of single-family houses began to use this type of heating more and more often. Heating oil differs in its use and quality. It is mainly used as: a means for heating heating installations in industrial furnaces; material for production purposes; fuel for technological purposes.

Currently, natural gas and fuel oil are in high demand around the world. Their popularity has increased as a result of environmental protection requirements and reducing coal consumption. The key role of these raw materials in the global economy implies a discussion on the links between natural gas and fuel oil prices and other macroeconomic and financial factors. Both theoretical and empirical studies have pointed to the sources and potential consequences of these connections (Suleymanli et al., 2020). It was noticed that one of the most important factors influencing the prices of natural gas and heating oil are exchange rates. This is because the prices of these raw materials are quoted and settled in US dollars. When the dollar depreciates against other currencies, the prices of natural gas and heating oil rise, and when the dollar appreciates, the prices of these commodities fall (Figure 1).

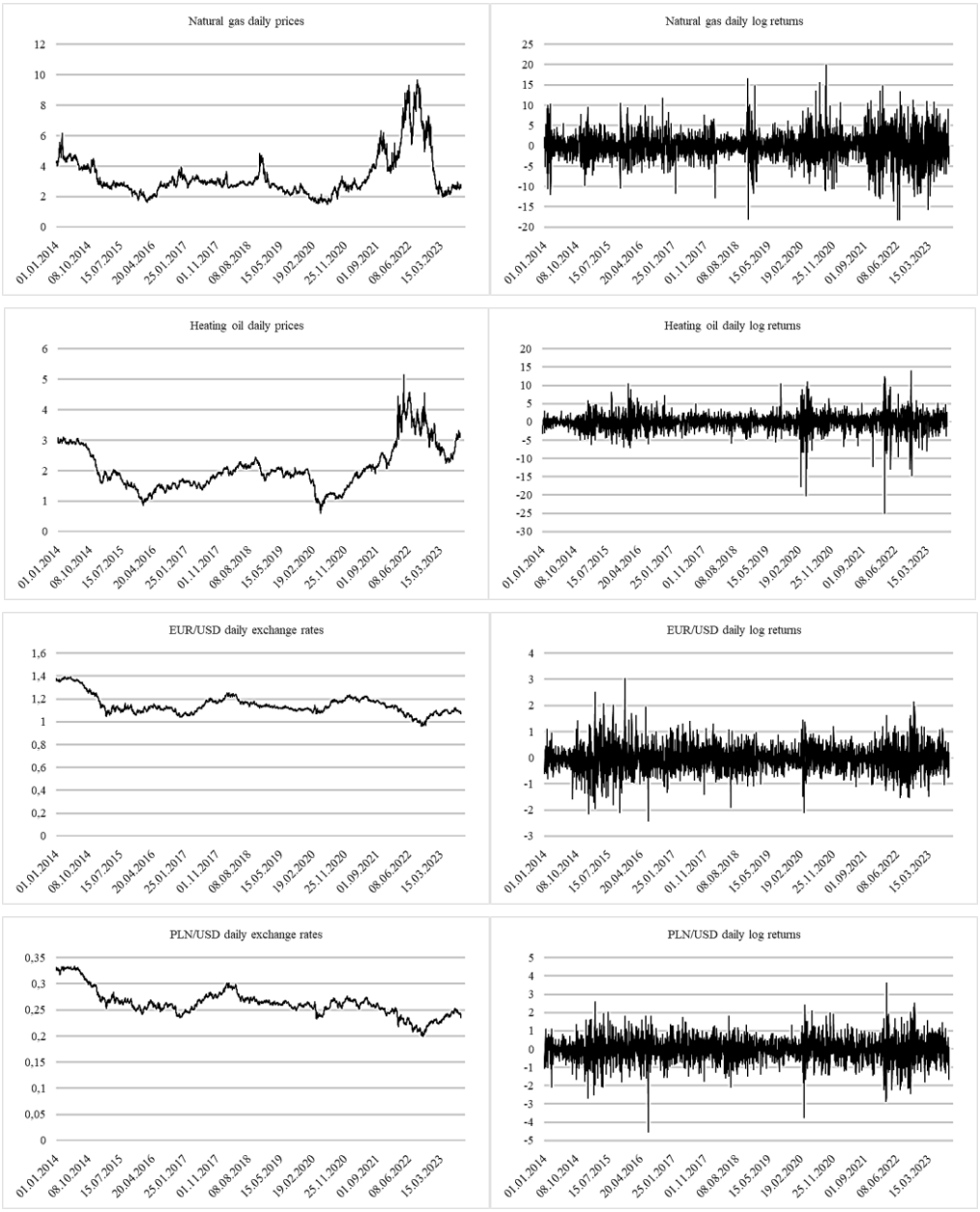

Figure 1. Selected time series from the period 1 January 2014 – 6 September 2023.

Source: own study.

Analyzing the above charts, you can see three sub-periods in which changes in raw material prices change significantly. In the first period, i.e. from the beginning of 2014 to the end of 2016, there was a strong decline in the prices of natural gas and heating oil. Then, the prices of these raw materials stabilized at significantly lower levels in the period from 2017 to 2020. In the recent period (2020-2023), a drastic increase in the prices of energy sources was observed, which may have been caused by the Russian-Ukrainian conflict and related supply restrictions.

3. Nonlinear Granger causality

The definition of causality formulated by Granger (Grenger, 1969) concerns the occurrence of causal relationships between the stationary processes X_t and Y_t in the category of conditional probability distributions. By this definition, X_t is not the cause of Y_t if:

$$F\left(Y_t|\left(X_{t-l_x},\dots,X_{t-1};Y_{t-l_y},\dots,Y_{t-1}\right)\right)=F\left(Y_t|\left(Y_{t-l_y},\dots,Y_{t-1}\right)\right) \tag{1}$$

for any delay $l_x, l_y \geq 1$. In a situation where equation (1) does not hold, then X_t is the cause of Y_t, which in particular makes it possible to use the past values of X_t to predict Y_t.

The study of the occurrence of causal relationships consists in verifying the null hypothesis that X_t is not the cause of Y_t, which by definition is equivalent to condition (1). However, in econometric practice, the verification of the difficult-to-apply condition (1) is replaced by more operational methods (Orzeszko, Osińska, 2007).

Let (X,Y,Z) denote a random vector of the form $(X,Y,Z)=\left(X_{t-l_x}^{t-1},Y_{t-l_y}^{t-1},Y_t\right)$, and f is the probability density function. Diks and Panchenko (2006) proved that the null hypothesis, according to which X_t is not the cause of Y_t, means that the equality is satisfied:

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)}=\frac{f_{X,Y}(x,y)}{f_Y(y)}\frac{f_{Y,Z}(y,z)}{f_Y(y)} \tag{2}$$

They also indicated that the following equality is equivalent to the key formula of Hiemstra and Jones (1994) as the starting point for nonlinear causality analysis:

$$\frac{E[f_{X,Y,Z}(x,y,z)]}{E[f_Y(y)]}=\frac{E[f_{X,Y}(x,y)]}{E[f_Y(y)]}\frac{E[f_{Y,Z}(y,z)]}{E[f_Y(y)]} \tag{3}$$

where

$$E[f_W(w)]=\int f_W^2(s)\,ds \tag{4}$$

is interpreted as a measure of the concentration of the random vector W.

In their study, they showed that in order to study causality, one should not focus on equality (3), but study the following formula:

$$E\left[\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)}-\frac{f_{X,Y}(x,y)}{f_Y(y)}\frac{f_{Y,Z}(y,z)}{f_Y(y)}\right]=0 \tag{5}$$

Thus, the implication of the null hypothesis is as follows.

$$E\left[\left(\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)} - \frac{f_{X,Y}(x,y)}{f_Y(y)}\frac{f_{Y,Z}(y,z)}{f_Y(y)}\right) g(X,Y,Z)\right] = 0 \quad (6)$$

where $g(X,Y,Z)$ is a positive weighting function. Assuming that the null hypothesis is true, this expression is zero because by the formula (5) the value in parentheses is equal to zero. We reject the null hypothesis when the calculated value of the test statistic is too high. For $g(X,Y,Z) = f_Y^2(Y)$ formula (6) takes the form:

$$E\left[f_{X,Y,Z}(x,y,z)f_Y(y) - f_{X,Y}(x,y)f_{Y,Z}(y,z)\right] = 0 \quad (7)$$

Its estimator is based on the indicator function and is expressed by the formula:

$$T_n = \frac{(2\varepsilon)^{-l_x-l_y-1}}{n(n-1)(n-2)}\sum_i\left[\sum_{k,k\neq i}\sum_{j,j\neq i}\left(I_{ik}^{XYZ}I_{ij}^{Y} - I_{ik}^{XY}I_{ij}^{YZ}\right)\right] \quad (8)$$

where *n* is number of observations, *I*(.) is indicator function:

$$I_{i,j}^{W} = I\left(\left\|W_i - W_j\right\| \leq \varepsilon\right) = \begin{cases} 1, \left\|W_i - W_j\right\| \leq \varepsilon \\ 0, \left\|W_i - W_j\right\| > \varepsilon \end{cases} \quad (9)$$

$\|.\|$ denotes norm supremum. In the case of $l_x = l_y = 1$, Diks and Panchenko proved that their test statistics is asymptotically distributed as standard normal and diverges to positive infinity.

It should be noted that the value of the estimator depends on the parameters l_x, l_y, and ε. In practice, lags $l_x = l_y = 1,2,\ldots,l_{max}$, are considered, where l_{max} is a fixed natural number. In the studies presented in the literature, the value of a distance measure ε between 0.5 and 1.5 is recommended for consideration (Orzeszko, 2021).

4. Results of nonlinear Granger causality

Conducting a study of nonlinear causality requires quite a complicated time series analysis. In the study, for each analyzed variable, daily time series covering the period from the beginning of 2014 to September 2023 were prepared. In order to check the stability of causal relationships, the entire period was divided into three separate subperiods. For comparison purposes (i.e., to preserve the same power of the applied test) considered three subperiods of the same length: Period 1 (1/1/2014 - 24/03/2017), Period 2 (27/03/2017 - 16/06/2020) and Period 3 (6/17/2020 – 9/06/2023). All data were transformed to log returns using the formula $r_t = 100\ln(p_t/p_{t-1})$, where p_t is the price at time.

The abbreviations used in the further considerations are presented in Table1.

Table 1.
Full and abbreviated variable names

Full name of the time series	Abbreviate name of the time series
Natural Gas	NG_F
Heating Oil	HO_F
Exchange rate EUR/USD	EUR_USD
Exchange rate PLN/USD	PLN_USD

Source: own study.

The selection of the above series for the study was based on a previous analysis of the factors influencing changes in the prices of natural gas and heating oil.

The basic descriptive statistics for the variables under consideration are presented in Table 2.

Table 2.
Descriptive statistics of the selected returns

Measures/Series	NG_F	HO_F	EUR_USD	PLN_USD
Mean	-0,01977	0,00158	-0,00984	-0,01365
Stan. Dev.	3,52136	2,40539	0,49620	0,65868
Min	-18,06609	-24,75355	-2,41725	-4,54446
Max	19,79844	13,98724	3,02491	3,60479
Skewness	-0,04420	-0,80628	0,08682	-0,23753
Kurtosis	2,91181	11,00023	2,23212	2,52978
Period 1				
Mean	-0,03789	-0,08518	-0,02873	-0,03184
Stan. Dev.	2,94152	2,06216	0,56999	0,67041
Min	-11,93123	-7,07761	-2,41725	-4,54446
Max	11,63348	10,38329	3,02491	2,58253
Skewness	0,14570	0,39532	0,18842	-0,38059
Kurtosis	1,59991	2,14126	2,60221	3,04331
Period 2				
Mean	-0,07659	-0,02809	0,00500	-0,00019
Stan. Dev.	2,85004	2,30059	0,42744	0,57858
Min	-18,05452	-19,99576	-2,06460	-3,69946
Max	16,50638	10,94612	1,42533	2,40376
Skewness	0,00296	-1,20469	-0,11909	-0,35994
Kurtosis	5,22948	14,14649	1,41836	2,68956
Period 3				
Mean	0,05527	0,11813	-0,00580	-0,00893
Stan. Dev.	4,51941	2,79156	0,48005	0,71900
Min	-18,06609	-24,75355	-1,49855	-2,87186
Max	19,79844	13,98724	2,12072	3,60479
Skewness	-0,13356	-1,08777	0,12441	-0,04237
Kurtosis	1,43546	10,95824	1,08647	1,74186

Source: own study.

The averages calculated for all the examined series: were negative in the first period; in the second period they were also negative except for the EUR/USD series; while in the third period they were negative only for the exchange rate series. Other statistics showed noticeable differences between natural gas and heating oil and exchange rates; raw materials proved to be much more volatile than the exchange rates (especially in Period 3). As a consequence, it was characterized by the highest absolute values of the minimum and maximum returns and a very

high standard deviation. Moreover, the distribution of heating oil returns exhibited the strongest skewness (except Period 1) and the highest kurtosis.

In the case of selected series, the following stepwise procedure was used, filtering possible dependencies in conditional variance and linear dependencies. The next steps in the procedure were as follows:

- filtering with the GARCH(1,1) model and calculating standardized residuals,
- elimination of linear dependencies – VAR model,
- normalization of the obtained series,
- calculation of the value of the Dicks-Panchenko statistics,
- comparison with critical values N(0,1) – two-sided distribution.

To calculate the value of the Dicks-Panchenko statistics, six delay values were used: $\boldsymbol{l_x = l_y = 1, 2, \ldots, 6}$ and two distance measures $\boldsymbol{\varepsilon \in \{1, 1.5\}}$ (Syczewska, 2014). We analyzed two directions of causation for the entire period from the beginning of 2014 to September 2023 and three subperiods. The results of these analyzes are presented in Tables 3 – Tables 6. Each cell in the table contains *p*-values of test. Values less than 0.1 are in bold, indicating rejection of the null hypothesis of noncausality.

Table 3.
Diks-Panchenko test results for pairs of natural gas and EUR/USD

NG_F⟶EUR_USD	**Number of lags $l_x = l_y$**					
	1	**2**	**3**	**4**	**5**	**6**
ε	All period					
1.0	0.32074	0.68891	0.50512	0.12477	0.34154	0.16066
1.5	0.18636	0.63932	0.47323	0.48281	0.64240	0.47201
	Period 1					
1.0	0.17635	0.82786	0.67001	0.35353	0.51601	0.39527
1.5	0.11721	0.76047	0.80770	0.45039	0.77012	0.37147
	Period 2					
1.0	0.36392	0.77992	0.59086	0.52952	0.68910	0.47448
1.5	**0.08559**	0.38080	0.38643	0.53580	0.49513	0.44386
	Period 3					
1.0	0.95401	0.91924	0.64272	0.39609	0.55669	0.58468
1.5	0.83107	0.76015	0.59052	0.39623	0.28134	0.59793
EUR_USD⟶NG_F	All period					
1.0	0.13085	0.18564	0.28036	0.46174	0.53639	0.64493
1.5	**0.06910**	**0.04709**	**0.05579**	0.14878	0.25135	0.56059
	Period 1					
1.0	0.24167	0.29264	0.17508	0.58523	0.67735	0.50414
1.5	0.18616	0.14624	**0.06773**	**0.05449**	**0.01902**	**0.06597**
	Period 2					
1.0	0.16578	0.16351	0.64438	0.92755	0.84664	0.67729
1.5	**0.06689**	0.18440	0.33649	0.76735	0.81837	0.84956
	Period 3					
1.0	0.35173	0.35121	0.42027	0.57753	0.51527	0.47818
1.5	0.37681	0.27927	0.41700	0.64498	0.55880	0.66963

Source: own study.

Table 4.
Diks-Panchenko test results for pairs of natural gas and PLN/USD

NG_F⟶PLN_USD	Number of lags $l_x = l_y$					
	1	**2**	**3**	**4**	**5**	**6**
ε	All period					
1.0	0.19789	0.33698	**0.05170**	0.36751	0.48132	0.65203
1.5	0.13904	0.15468	**0.07181**	0.28561	0.24398	0.27923
	Period 1					
1.0	**0.01037**	0.22557	0.24605	0.11335	0.35077	0.55497
1.5	**0.01085**	**0.05559**	**0.07022**	**0.05655**	0.11167	0.10025
	Period 2					
1.0	0.23044	0.56195	0.42960	0.58851	0.27277	0.18800
1.5	**0.06312**	0.15038	0.35198	0.86306	0.69323	0.77558
	Period 3					
1.0	0.96440	0.38858	0.20624	0.43596	0.20523	0.32850
1.5	0.94530	0.66545	0.20817	0.38330	0.13544	0.37779
PLN_USD⟶NG_F	All period					
1.0	0.16784	0.30946	0.49558	0.78330	0.45411	0.64675
1.5	0.16354	**0.07677**	**0.07523**	0.17686	0.10692	0.28472
	Period 1					
1.0	0.39138	0.50116	0.54800	0.71806	0.41391	0.36178
1.5	0.37935	0.30921	0.24455	0.33694	0.09683	0.26606
	Period 2					
1.0	0.25458	0.49223	0.74343	0.95271	0.48533	0.40279
1.5	0.29239	0.40387	0.47628	0.62696	0.59763	0.77133
	Period 3					
1.0	0.17249	**0.08321**	0.21874	0.49651	0.12956	0.54237
1.5	0.23711	**0.05452**	0.14688	0.30013	0.26442	0.32085

Source: own study.

Table 5.
Diks-Panchenko test results for pairs of heating oil and EUR/USD

HO_F⟶EUR_USD	Number of lags $l_x = l_y$					
	1	**2**	**3**	**4**	**5**	**6**
ε	All period					
1.0	0.27041	0.21557	0.17205	0.38937	0.36380	0.30241
1.5	0.32877	0.26063	**0.07010**	0.16792	0.19479	0.14987
	Period 1					
1.0	0.71248	0.41241	0.34908	**0.08300**	0.11356	0.20481
1.5	0.57623	0.32291	0.11955	**0.02174**	**0.04018**	**0.02067**
	Period 2					
1.0	0.35093	0.42575	0.68375	0.88686	0.88539	0.78019
1.5	0.51797	0.47218	0.50150	0.70795	0.75720	0.76172
	Period 3					
1.0	**0.06532**	0.24258	0.26497	0.40632	0.40865	0.15896
1.5	0.10078	0.41118	0.52742	0.71130	0.50553	0.61526
EUR_USD⟶HO_F	All period					
1.0	0.42507	0.20773	0.14055	0.21922	0.31106	0.33107
1.5	0.32500	0.16820	0.17003	0.12291	0.09529	0.13623
	Period 1					
1.0	0.60730	0.27625	0.21686	0.33710	0.29526	0.34515
1.5	0.59989	0.33021	0.59693	0.33466	0.27885	0.19798
	Period 2					
1.0	0.22114	0.52784	0.46358	0.60722	0.11659	0.17559
1.5	0.14411	0.16813	0.21615	0.37993	0.20285	0.45097
	Period 3					
1.0	0.33288	0.35622	0.19685	0.32974	0.53648	0.21861
1.5	0.46169	0.57807	0.37383	0.38028	0.71425	0.62935

Source: own study.

Table 6.
Diks-Panchenko test results for pairs of heating oil and PLN/USD

HO_F⟶PLN_USD	Number of lags $l_x = l_y$					
	1	**2**	**3**	**4**	**5**	**6**
ε	All period					
1.0	0.19632	0.12044	0.09992	0.15776	0.21260	0.27981
1.5	0.29074	0.37335	0.19624	0.09766	0.13133	**0.07116**
	Period 1					
1.0	0.56547	0.29627	0.27399	0.15766	**0.06848**	0.09428
1.5	0.46896	0.33490	0.19128	**0.02867**	0.11967	**0.05716**
	Period 2					
1.0	0.32530	0.24258	0.19194	0.23717	0.14178	0.28707
1.5	0.26865	0.20496	0.25592	0.57387	0.66511	0.44026
	Period 3					
1.0	0.18609	0.63970	0.11025	0.30315	0.26127	**0.08007**
1.5	0.33847	0.88919	0.72387	0.45454	0.43601	0.51269
PLN_USD⟶HO_F	All period					
1.0	0.26625	0.11977	0.12287	0.06630	0.12632	0.25130
1.5	0.16823	**0.08748**	**0.06608**	**0.00609**	**0.01887**	0.11464
	Period 1					
1.0	0.48162	0.50570	**0.07639**	0.19717	0.25892	0.29609
1.5	0.45990	0.32898	**0.05022**	**0.01090**	**0.05966**	0.09787
	Period 2					
1.0	0.43740	0.53787	0.50942	0.86440	0.87605	0.35949
1.5	0.36722	0.44674	0.67668	0.68616	0.58786	0.64779
	Period 3					
1.0	**0.06958**	0.09640	0.16629	0.21550	0.13757	0.44147
1.5	**0.08710**	0.17843	0.27841	0.11739	0.25603	0.61815

Source: own study.

The presented test results indicate the existence of causality between the tested financial instruments. Bidirectional relationships throughout the research period were detected for the following pairs: natural gas and PLN/USD and heating oil and PLN/USD. This is important information from the point of view of market participants investing in the fuel raw materials market or investors conducting currency transactions. Knowledge about this type of relationship may contribute to obtaining better forecasts, both on the energy market and the currency market.

The second aim of the study was to check the stability of the detected causal relationships. In the first period, the hypothesis of lack of causality was rejected for most series. The exceptions were the pairs NG_F ⟶ EUR/USD, PLN/USD ⟶ NG_F and EUR/USD ⟶ HO_F. In the second period, the lack of causal relationships was observed for most pairs, and in the case of the pairs NG_F ⟶ EUR/USD, EUR/USD ⟶ NG_F, NG_F ⟶ PLN/USD, the rejection of the lack of causality was no longer so clear (only a certain value of the delays used in the test procedure led to the rejection null hypothesis). A similar situation was also observed in the third period for pairs: HO_F ⟶ EUR/USD and HO_F ⟶ PLN/USD. However, non-linear causality occurred only in the case of the following pairs: PLN/USD ⟶ NG_F and PLN/USD ⟶ HO_F.

To sum up, it can be stated that the non-linear Granger causality observed throughout the analyzed period does not occur when divided into sub-periods.

5. Summary

Detecting the causality between heating fuels and currency exchange rates are important from the point of view of investors and policy makers since knowledge of the directionality of relationships may help them to take effective decisions from the price signals received from these commodities. Moreover, they may have important implications for market efficiency and predictability.

The study checked bidirectional causal relationships between the prices of two heating raw materials (natural gas and fuel oil) and selected exchange rates (EUR/USD, PLN/USD) in the period from January 2014 to September 2023. For this purpose, the Diks and Panchenko nonlinear causality test was used. In order to analyze the stability of the examined relationships, the period in question was divided into three sub-periods, in which first the prices of natural gas and fuel oil showed a decreasing trend, then the prices stabilized, and in the last period there was a sharp increase in the prices of raw materials. Based on the results obtained, it was established that throughout the entire period under study, most of the analyzed series were linked by causal relationships. The study also revealed significant differences between the considered sub-periods. Relationships that appear in the first period disappear in subsequent sub-periods.

The analysis was performed for daily data, which means that the detected relationships can be considered more short-term. For this reason, they should be taken into account primarily by market participants when creating effective investment portfolios and risk hedging strategies.

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THE IMPORTANCE OF KNOWLEDGE TRANSFER IN THE IMPLEMENTATION OF AN INTEGRATED ERP SYSTEM

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Purpose: Importance of knowledge transfer in the process of implementing an integrated ERP class IT system.
Design/methodology/approach: The chosen research approach involved a case analysis, employing two distinct data collection methods an unstructured interview with a member of the implementation team and observation conducted by the article's author. The rationale behind investigating knowledge transfer in ERP systems implementation projects is well-founded, as it is deemed essential for enhancing the overall efficiency of project management in this domain.
Findings: The research demonstrates a clear correlation between the stages of the knowledge life cycle and those of the project. In the project's preparatory phase, essential organizational knowledge is identified. Subsequently, during the IT solution design phase, there is a transfer of knowledge from employees to consultants, contributing to the development of a cohesive IT solution project. This project is then implemented in the subsequent phase, leveraging organizational knowledge for solution creation, testing, and utilization.
Research limitations/implications: The insights presented in this study pave the way for additional theoretical and practical exploration. The adoption of an integrated ERP class IT system represents a strategic decision with profound implications for business processes, resource utilization, and management efficiency. The ramifications of this decision underscore its pivotal role in shaping the overall trajectory of organizational operations.
Practical implications: The implementation process demands a spectrum of diverse and often specialized knowledge from participants, leading to multidirectional flows of such knowledge. Consequently, there arises a crucial necessity for research into knowledge transfer methodologies within the design environment.
Originality/value: Implementation projects necessitate a range of diverse, often specialized knowledge from participants and entail multidirectional flows of such knowledge. The focal point of these projects is the amalgamation of organizational, management, business, and technological knowledge possessed by all participants, encompassing future users of the integrated system.

Keywords: ERP systems, knowledge transfer, small and medium-sized enterprises.

Category of the paper: Case study.

1. Introduction

Integrated IT system of the ERP class stand as among the most sophisticated and advanced categories of IT system, playing a crucial role in supporting the holistic management of enterprises and institutions. Their deployment significantly impacts the optimization of internal processes and immediate environmental dynamics by providing pre-configured tools. Key features of such systems include (Maditinos, Chatzoudes, Tsairi, 2012; Miłosz, 2012; Issar, Navon, 2016).

1. Functionality - Integrated ERP class IT system are distinguished by their extensive functionality, offering a comprehensive suite of tools and capabilities. These systems are designed to address various organizational needs, streamlining processes and enhancing overall operational efficiency.
2. Integration of Data and Procedures - A hallmark feature is the seamless integration of data and procedures. This integration ensures a cohesive flow of information across different departments and functions within an organization. By breaking down silos and promoting data coherence, these systems contribute to a unified and synchronized operational environment.
3. Functional and Structural Flexibility - Another key attribute is the functional and structural flexibility inherent in ERP class IT system. They are adaptable to evolving organizational requirements, accommodating changes in processes, workflows, and organizational structures. This flexibility is instrumental in ensuring that the system aligns with the dynamic nature of modern businesses.
4. Substantive and Technological Advancement - Substantive and technological advancement is a defining characteristic, encompassing both the depth of knowledge embedded in these systems and the cutting-edge technologies that underpin their architecture. ERP class IT system incorporate the latest advancements in technology to provide organizations with a robust and future-ready IT infrastructure.

In contemporary business landscapes, the implementation and utilization of integrated ERP class IT system serve as the cornerstone for streamlining business management processes, reshaping organizational structures. Enterprises, navigating heightened competition, face escalating demands for quality, speed, and timeliness, particularly in trade and production. Swift responses to customer needs, the ability to offer innovative solutions, and a reduction in project costs become critical avenues for achieving a competitive advantage (Bytniewski, Matouk, Hernes, 2018; Malik, Khan, 2021).

Recognizing the imperative, numerous small and medium-sized enterprises (SMEs) now acknowledge the need for integrated ERP class IT system to effectively support enterprise resource management. A diverse array of systems, primarily designed for SMEs, is readily available in the market (Estébanez, 2021). The implementation of an integrated system is

a strategic decision, with profound effects on business processes, resource utilization, and management efficiency. The success of such implementations hinges on various factors related to both the operational activities of the company and the management approach to the implementation project (Grochowski, 2022).

Executing implementation projects goes beyond acquiring and launching the appropriate IT infrastructure; it involves imparting knowledge that enables the effective utilization of this infrastructure in supporting business processes. Projects demand diverse, often specialized knowledge from participants and involve multidirectional flows of organizational, management, business, and technological knowledge. Participants, including future users of the integrated system, contribute their expertise. Throughout these projects, various implementation and management activities directly contribute to creating and consolidating knowledge in the implementation products, establishing resources that concurrently become the intellectual capital of the entities involved in the projects. (Finnery, Corbett, 2007; Alaskari, Pinedo-Cuenca, Ahmad, 2021; Żółtowski, 2021; Zwierzchowski, 2022). The overarching goal of this article is to underscore the critical importance of knowledge transfer in the process of implementing an integrated ERP class IT system.

2. Knowledge transfer in the process of implementing an integrated system

The implementation of a standard integrated system ranks among the most intricate and challenging IT projects faced by contemporary business organizations. This ambitious endeavor unfolds across a spectrum of key economic processes, implicating substantial organizational resources and concurrently necessitating the adept management of diverse types of knowledge. As the focal point of business operations, these systems permeate various facets of the organizational structure, demanding a sophisticated orchestration of resources and expertise. Scholars and industry experts alike emphasize the critical role of knowledge transfer in ensuring the seamless integration of these systems, prompting discussions on the formulation of specialized procedures to facilitate knowledge transfer specifically tailored to the challenges posed by integrated system implementation (Rodriguez, Molina-Castillo, Svensson, 2020; Rupcic, 2021).

It is imperative to underscore the pivotal role of research dedicated to knowledge transfer in IT projects, with a specific emphasis on ERP implementation projects. The justification for such research lies in its potential to offer profound insights that can enhance the efficiency and effectiveness of project management. The complexities of knowledge transfer within the realm of IT projects, particularly those involving ERP systems, warrant a nuanced understanding that transcends traditional project management paradigms (Lech, 2011). Through empirical studies and theoretical frameworks, this research endeavors to unravel the intricacies of knowledge

transfer, shedding light on the dynamic interplay between technological elements and organizational knowledge. The outcomes of such research endeavors not only contribute to the academic discourse but also provide practical guidance for organizations undertaking the formidable task of implementing integrated systems, offering a roadmap for more efficient knowledge transfer strategies and ensuring project success (Chaudhry, Nawab, Shafi, 2021; Mohd Zamhari, 2020).

The implementation of an ERP system is a multifaceted process that demands meticulous planning, execution, and ongoing monitoring. Among the pivotal factors influencing the success of an ERP implementation, the knowledge transfer curve assumes a critical role (Jayawickrama, Liu, Smith, 2014). The knowledge transfer curve serves as a metric to gauge how effectively users of an ERP system comprehend and utilize the system as the implementation progresses. This curve manifests as a graphical representation, illustrating the trajectory of knowledge transfer and the adoption of the ERP system by users throughout the implementation project's lifespan. Typically, the curve commences at a nascent level and ascends gradually over time as users grow more adept and familiar with the intricacies of the system. The transfer of knowledge curve encompasses several distinct stages, each delineating a phase in the life of an ERP implementation. These stages provide valuable insights into the evolving dynamics of user engagement, offering a roadmap for organizations to navigate the complexities of knowledge transfer and ensure a seamless integration of the ERP system into their operational fabric (De Luca, Cano Rubio, 2019).

1. Pre-Implementation - Before the commencement of the ERP system implementation, the knowledge transfer curve is situated at its lowest point. Users are unfamiliar with the system, and a comprehensive understanding of the benefits and impact of the impending changes may be lacking. During this initial stage, the project team plays a pivotal role by initiating preparatory measures, offering training sessions, and providing support to familiarize users with the upcoming system.
2. Implementation - The implementation stage stands out as the linchpin of an ERP project, witnessing a rapid ascent of the knowledge transfer curve as users actively engage with the new system. Ensuring a smooth transition during this phase requires robust training and support mechanisms. Comprehensive guidance is essential to empower users with the skills necessary for effective utilization of the ERP system.
3. Post-Implementation - Following the implementation stage, the knowledge transfer curve continues its gradual ascent. Users are becoming more proficient in navigating the system and are starting to witness the tangible benefits it brings. Despite this progress, there might still be areas where users require additional training and support to fully capitalize on the system's capabilities.

4. Optimization - The optimization stage marks the zenith of the knowledge transfer curve. Users have attained full proficiency in utilizing the system and have mastered all requisite skills. During this phase, the emphasis shifts from training to the optimization and continuous improvement of the ERP system. Organizations focus on refining processes, identifying efficiencies, and ensuring the system aligns seamlessly with evolving business needs.
5. Maintenance - The maintenance stage stabilizes the knowledge transfer curve at its peak level. Users have achieved a high level of comfort with the system, effectively supporting day-to-day business operations. Maintenance efforts during this stage revolve around ensuring the system's continued functionality, addressing any emerging issues, and implementing necessary updates to sustain peak performance.

A strategic approach involving comprehensive training and sustained support throughout all stages is imperative.

3. The process of implementing an integrated ERP class IT system in production enterprise

Contemporary enterprises recognize the pivotal role of implementing integrated ERP class IT system in effective process management. These solutions have evolved into indispensable tools for enhancing operational efficiency within enterprises. A trade and production company operating in the small and medium-sized enterprises (SMEs) sector has been a presence in the Polish market. Specializing in the wholesale and retail of electronic products, with headquarters in Bydgoszcz, the company serves customers nationwide. Its core objective is to ensure customer satisfaction by providing a comprehensive range of high-quality goods at competitive prices. Since 1999, the company has expanded into manufacturing and, in the last five years, has prioritized the development and modernization of its production plant. Products are available for direct purchase at the company, through sales representatives, at designated points of sale, and online. As the company grew, it encountered challenges unprecedented in its earlier years. The expanding product range and a rising customer base led to difficulties in order processing, resulting in numerous instances of incorrect goods handovers, necessitating corrective documents. The surge in orders, coupled with inefficiencies in warehouse operations, significantly prolonged order fulfillment times. The existing system proved inadequate, particularly in supporting the sales team and lacked features such as automatic price list updates. Faced with these challenges, the company's management decided to implement the Tisoft Work Manager system. The primary criterion for system selection was integration across all company facets and support for the quality assurance system. Initially, the company employed separate IT system for each department sales, accounting, and production leading to internal

inconsistencies. As the company expanded, unforeseen problems emerged, including issues with stock records, incorrect goods handovers, prolonged order processing times, operating in multiple databases, and utilizing outdated database technologies. These challenges hindered decision-making processes and impeded efforts to scale up production. The risk of erroneous data entry into the system escalated. The existing solutions no longer sufficed, making the implementation of an integrated IT system imperative for sustaining market position and fostering company growth.

The focal inquiry guiding this article centers on the management of organizational knowledge throughout various stages of implementing an integrated ERP class IT system. To address this, a comprehensive research methodology incorporating multiple data collection methods was employed. Specifically, the following approaches were utilized:

- unstructured interview - an in-depth, unstructured interview was conducted with a member of the implementation team; the interview, lasting for a duration of 3 hours, was meticulously recorded to capture nuanced insights; the respondent was queried about the methods employed, their effectiveness, and the outcomes at each stage of the knowledge life cycle during the diverse phases of the project,
- observation - the author of the article actively engaged in observational methods to complement the interview data; this involved firsthand observation of the implementation team's activities, interactions, and practices throughout the project; the observational data enriched the overall understanding of knowledge dynamics within the organizational context.

During the unstructured interview, the respondent was prompted to share insights on specific aspects such as the methods used for knowledge transfer, the impacts of these methods, and the overall implementation of knowledge life cycle stages in different project phases. This iterative process involved posing additional questions in response to the respondent's answers, creating a dynamic and insightful dialogue. The culmination of these research efforts resulted in the synthesis of interview responses and observational data, forming a comprehensive narrative that delves into the intricacies of knowledge transfer practices across the various phases of implementing an integrated ERP class IT system.

The interviewee, a member of the complete system implementation team, brought a wealth of knowledge derived from several years of managerial experience. Noteworthy was their analytical thinking ability and proficiency in establishing cause-and-effect relationships, proving instrumental in crafting a business concept that seamlessly integrated organizational knowledge into the ERP system's functionality.

1. In the project preparation phase, occurring at the project management level, the respondent actively participated. This phase culminated in the formal establishment of a project team, signifying the identification of crucial knowledge. Individuals possessing this identified knowledge were appointed to the project team, although the specific method of knowledge identification remained unknown to the respondent.

2. During the business concept stage, the respondent did not need to identify additional knowledge. Knowledge transfer took precedence, facilitated through workshops (both in-person and online) led by a consultant. Participants from various company departments shared their insights, allowing the consultant to integrate organizational knowledge with system knowledge, ultimately shaping a comprehensive business concept.
3. The implementation phase saw the consultant configuring the integrated system in alignment with the detailed business concept. Configuration drew upon integrated knowledge from relevant areas, incorporating insights about the enterprise and the system's functionality. The knowledge transferred in prior phases played a pivotal role in constructing the system.
4. Activities in the preparation phase for launch involved verifying system configuration correctness and end-user training. Test scenario generation required the project team to leverage knowledge about the organization to anticipate diverse business process variations and common errors. Simultaneously, end-users underwent system operation training, representing knowledge transfer from the consultant.
5. During the launch phase, team members and end-users alike applied their knowledge about the organization. The respondent highlighted the anticipation of all conceivable solutions, establishing connections between organizational knowledge and system functionality.

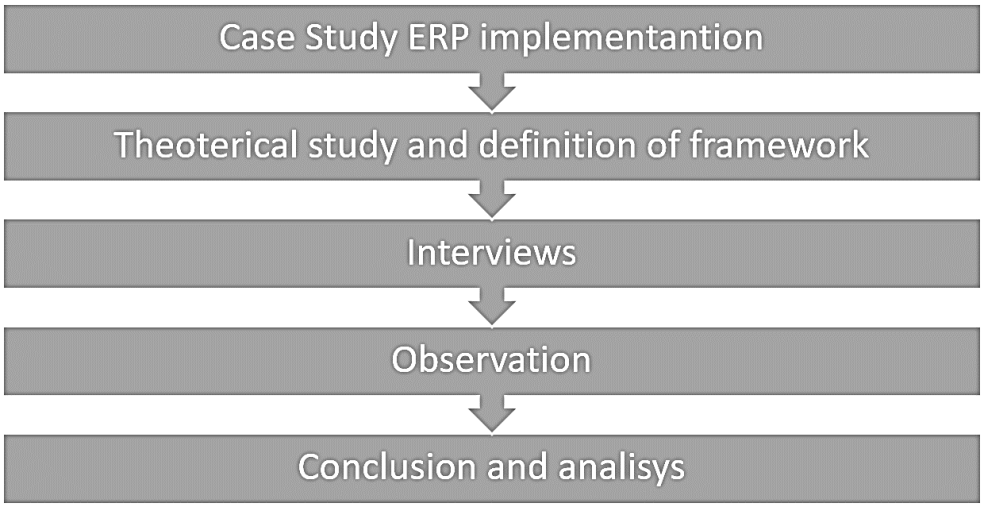

Figure 1. Research process.

This comprehensive account elucidates how knowledge about the organization was managed across distinct phases of the integrated ERP class IT system implementation project, underscoring the pivotal role of knowledge transfer in the successful execution of each stage.

4. Conclusions

The implementation project of an integrated ERP class IT system encompasses critical business processes and demands substantial organizational resources, necessitating the management of various knowledge types. The presented case study highlights the pivotal role of knowledge transfer in the implementation project, emphasizing that effective management of organizational knowledge is a fundamental prerequisite for project success. Accurate incorporation of this knowledge into the system ensures alignment with the organization's economic objectives.

In the realm of IT project success factors, with a primary focus on ERP projects, user involvement is commonly cited. Introducing the dimension of knowledge transfer to the investigation of IT project success elucidates a key outcome of such involvement the proficient management of organizational knowledge for seamless integration into the emerging IT solution.

The study underscores the correlation between knowledge life cycle phases and project phases. In the project preparation phase, essential organizational knowledge is identified. Subsequently, during the IT solution design phase, knowledge about the organization undergoes transfer from employees to consultants responsible for implementation, storage in the form of business concept documents, and integration with system knowledge. This process results in the development of a cohesive IT solution project, implemented in the subsequent project phase. Ultimately, organizational knowledge is leveraged for solution creation, testing, and utilization. The findings emphasize the critical role of knowledge transfer in integrated systems projects, highlighting the imperative need for research into knowledge transfer methodologies within the design environment.

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