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FOREWORD

Presented number of Silesian University of Technology. Scientific Papers. Organization and Management Series. Contemporary management. Presented papers contain result of researches conducted by authors from Poland and Hungary. The number consists of 45 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: business models, production management, Industry 4.0, Industry 5.0, Smart City, logistics, impact of COVID-19 pandemic on management, small and medium enterprises, circular economy, human resource management, economics, industrial management, sustainable development, the usage of ChatGPT in management, financial management, public management, innovations, design thinking, e-commerce, crowdfunding in management.

Radosław Wolniak
Mateusz Trzeciak

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THE SYSTEMATIC REVIEW IN THE FIELD OF MANAGEMENT SCIENCES

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Purpose: A literature review is a thorough summary of the prior research in a topic that has been carried out by other scientists. For a novice researcher, a systematic literature review is the most important and standard step. The scientific discipline determines the methodology for systematic literature reviews.
Design/methodology/approach: A comprehensive overview of the literature relevant to a research issue is provided by a systematic literature review, which also synthesizes earlier work to broaden our understanding of a particular topic. It adheres to the principles of accessibility and bias reduction. Although management research is a growing, complex, and dynamic field, relatively little has been published on how management researchers may employ systematic literature reviews
Findings: This systematic review on a clearly defined subject that uses systematic and explicit processes to identify, select, and critically assess relevant research, and to acquire and analyse data from the research projects that are part of the review.
Practical implications: In order to comprehend the purpose of systematic reviews, we explain one and talk about its rationale. Next, we discuss how conducting systematic literature reviews may enhance management research and correct its shortcomings. We provide a thorough manual to do systematic literature reviews, outlining the steps to follow and providing advice for effective implementation
Originality/value: This review article, focus on the methodology adopted for the literature review in the field of management sciences.

Keywords: Systematic reviews, Methodology, Management sciences.

Category of the paper: Review article.

Introduction

Systematic literature reviews (SLR) are comprehensive, thorough literature syntheses that are centered on well-defined research questions. In order to provide support for practice and policy choices, their objectives are to find and synthesize all academic studies on a given topic, or to uncover research gaps and lessen bias. Most study aims to support a claim in one way or the other. This type of research may provide biased conclusions that distort evidence. The key innovation management challenge is to enable cooperation across disciplines, business operations, divisions, companies, and sectors. In order for innovation to be successful, different players must effectively integrate their expertise. Within innovation management, the idea of boundary objects to accomplish knowledge integration is growing in favor. Despite their increasing importance, there aren't many reviews of the literature on border objects. This review analyses how them systematic literature reviews conduct and how the management sciences items promote knowledge integration via a rigorous analysis. A framework that integrates the study of border objects connects existing contributions to significant theoretical viewpoints on the study of systematic literature reviews on the management science for knowledge integration. Three themes information processing, intellectual abilities, and educational perspective on knowledge integration are identified via a thorough examination of the literature, and relevant articles are located and presented in line with each topic. Three innovation contexts cross-functional collaboration, management, innovation, and phased product development processes are highlighted for potential theoretical approaches. By taking in and examining all available information on a certain aspect, systematic reviews help solve this issue and produce more thorough evaluations of difficult themes and subjects. Systematic reviews are now steadily gaining popularity in the social sciences after first being employed mostly in the health and medical professions. The systematic review technique is becoming mainstreamed in a variety of social science fields, including management and business. Although the movement is expanding, more work has to be done to make this a widespread practice. Systematic reviews vary from conventional literature reviews in a number of ways, but two stand out the most.

The creation of the review question or subject is the first step. Traditional literary evaluations may include wide themes with the intention of integrating the author's understanding into an existing body of knowledge. As a result, there is a propensity to accumulate facts, figures, and research to back up a specific position. A systematic review's subject is a clear research issue that the review itself responds to. Finding all of the evidence in a fair, transparent, and repeatable manner is the aim. The research methodology is the second distinction. Traditional literature reviews often use a search strategy method that is ad hoc and relies on the author's prior knowledge to find research. Rarely are they complete or exhaustive. systematic evaluations make sure the procedure is adequately recorded and replicable, and that efforts are made to discover all published and unpublished material on the study subject.

Creswell (1994, pp. 20, 21) define literature review: The application of literature in a research study accomplishes a number of goals, including: (a) giving the reader the results of further research that is strongly related to the topic being discussed (Fraenkel, Wallen, 1990); (b) By filling in the gaps and expanding preceding research, it links a study to the wider, ongoing conversation about a particular topic in the literature (Marshall, Rossman, 1989); (c) It provides a framework for judging the study's importance (Ridley, 2008, p. 2) describes literature review**.** In a well-written literature review, all the main themes and underlying sub - topics identified within the broader research subject are outlined. These themes and subtopics usually include the methods or findings of the prior investigation. A review of the literature also gives readers background information and explanations about the goals and methods of the first investigation that were published in a publication. To put it another way, you identify the theories and earlier research that have influenced the choice of research topic and the method you are choosing to use in the literature review.

Practically every research effort calls for a literature evaluation. It provides the foundation for advancing knowledge, promoting the creation of theories, filling gaps in existing research, and identifying new research possibilities (Webster, Watson, 2002)**.** A literature review, according to Hatak and Frank (2014), is a "knowledge map" that evaluates and synthesizes earlier material. Because literature reviews are so common, there are currently multiple extensive tools available that walk authors through the procedures required to perform a literature review. Transparency in data collection and synthesis leads in increased objectivity and reproducibility, which is one of an SLR's main advantages (Tranfield et al., 2003).

When we talk about traditional literature reviews, we often mean studies that lack organization, rigor, and transparency and that are more subjective in their methods for collecting and interpreting data. Systematic reviews are also nothing new. Nearly all review papers were referred to be systematic reviews for the first time around the turn of the 20th century (Petticrew, Roberts, 2006).

Fisch and Block illustrates the six recommendations that are essential for every literature review:

1. Indicate the purpose of the subject and the research question.
2. Methodically locate the relevant literature.
3. Select the ideal ratio of width to depth.
4. Focus on ideas instead than studies.
5. Come to intelligent conclusions.
6. Stick to a logical article structure.

Qualitative studies and quantitative studies

All research investigations may be divided into one of two main categories: qualitative studies and quantitative studies. The two types of investigations are qualitative and quantitative. People who seek to understand more about the relationships which occur in a particular social situation often do qualitative research. For instance, a person wishing to investigate the role of team leaders in their society, their interactions with others using a qualitative method would be the most effective way to learn about people's attitudes of their roles in the community. Some of the most typical methods of conducting Interviews, participant observation, and observation are all types of qualitative research. The greatest way to grasp qualitative research is as an effort to comprehend the actual how a social environment runs, how certain group of people interact, and how social world go about their daily lives, jobs, interactions, and feelings in that environment.

The second way researchers often use a quantitative analysis to determine whether or if there is a statistical link between the variables, as well as how significant or frequent that association is present. For instance, if one wishes to comprehend the link between people's bureaucracy and their corruption. They would probably have to use the quantitative technique to analyze this link if they were to conduct corruption, and how they use their resources. The most typical method that to create measurements or employ a survey, a study would be done.

Evidence of corruption activity and bureaucracy success from official sources, and then carry out statistical evaluations to discover any probable links between the elements of bureaucracy and the nature of corruption.

Randolph (2009) illustrate that in quantitative management science investigations, statistical analysis is used. There is a difference between qualitative and quantitative research projects. a significant factor that affects the overall design of the literature review that is included with the reporting of a study. The sort of methodologies a study must employ (e.g., qualitative or quantitative) is often determined by the research topic or numerical).

In this article author present the systematic literature review analysis in the view of several philosopher, its importance, types, and ways to conduct the review analysis.

Methodology

For review this review paper author uses the major scientific data bases. The Following database was used in the literature survey, google scholar, Web of science, and Scopus. The articles are scrutinized on the bases of article title, and abstract. In some cases, their conclusion were also checked.

Implementation of a systematic literature review

To further prepare management researchers to adopt this useful methodology, we detail the methods for conducting a Systematic Literature Review (SLR) in this section. We discovered several instances of SLR execution-step combinations similar to how SLR definitions worked. Besides the fact that there are general implementation guidelines, there are also non-rigid implementation principles (Briner, Denyer, 2012) as well as unique SLR strategies that vary based on the objective of a research (Durach et al., 2017), widely accepted SLR principles (Pati, Lorus). Below, we apply five SLR phases that have been modified from Briner's work and provide implementation advice for each.

Inclusion criterion: The author solely cited articles that offered advice on how to conduct a literature review. Reviews of the literature on a particular subject were not included in our analysis. The author includes papers from all academic fields, including biology, computer science, information systems, education, and medical and health science. The author exclusively cited research articles in English.

An analysis of the related literature should be a part of every discipline. It helps in outlining the present knowledge and identifying any gaps surrounding certain issues, which will help to increase the body of knowledge. In contrast to traditional narrative reviews, systematic literature reviews (SLR) use a repeatable, scientific, and transparent production method. It is advantageous to compile all relevant works and articles that satisfy our pre-established eligibility requirements to properly handle a certain study topic. It uses precise and rigorous approaches to minimize the possibility of bias throughout the search, identification, evaluation, synthesis, analysis, and summary of research. When the procedure is followed properly and with the least number of mistakes possible, the study may provide reliable data and findings that might help scientists and decision-makers act in compliance.

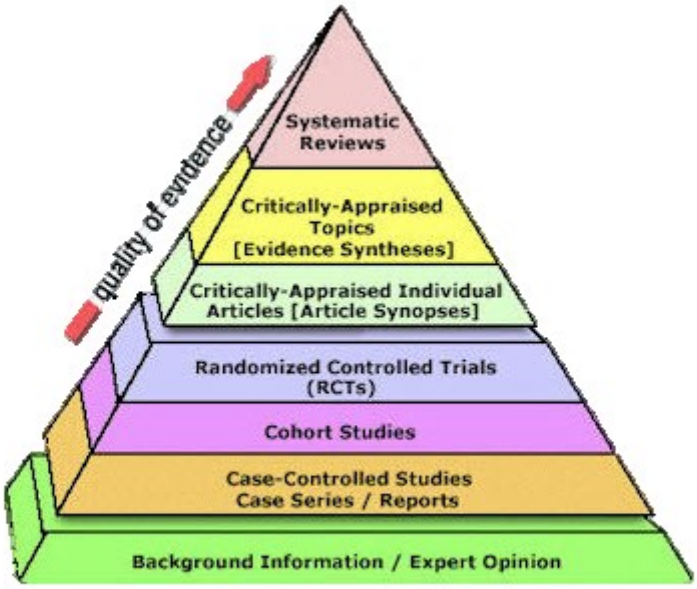

Figure 1. Schematic Diagram For Systematic Literature review.

Systematic review, as stated by Tranfield, Deyer, and Smart generates credible information from a pool of knowledge spread over several research. By doing a systematic review, a researcher is better equipped to chart and assess the existing intellectual landscape. Scholarly study into a certain research topic requires adherence to a strict work framework to make the information discovered more dependable and committed to the research topic.

Pilot search: Despite having its roots in the medical sciences, the systematic review of literature has become a well-established method for analyzing the corpus of knowledge in a variety of fields. It is useful for analyzing and synthesizing a large body of research on a certain topic or problem in an attempt to provide novel insights by combining factual data, identifying knowledge gaps and inconsistencies, and setting research objectives. Therefore, the purpose of this case study is to describe how to conduct a thorough systematic review in research on business and management. We take into consideration our own experiences in-depth analysis of the research conducted on the subject of university-industry cooperation. We provide examples of the many phases, activities, and actions involved in this methodology and talk about the choices we took along the way. We also present lessons learned, emphasize cautions, and make recommendations and recommendations for improving the rigor of future systematic literature review studies.

A comprehensive description of the literature pertaining to a questionnaire is provided by a systematic review, which also synthesizes earlier work to broaden our understanding of a particular topic while adhering to the standards of accountability and risk reduction. Systematic reviews of the literature are helpful in the developing, complex, and dynamic field of management research, but very little has been written on how management researchers may use this technique. Author defines a systematic review and discusses its justification in order to

understand the function of systematic reviews. We next go into how doing systematic literature reviews might improve management research and overcome its existing flaws. Author gives a comprehensive guide for doing systematic literature reviews, explaining the stages to take and offering tips for successful implementation.

The suggested research illustrates how the systematic review method, when used as a rigorous tool, may be used to incorporate multiple the literature pertaining to the phenomenon of university-industry collaboration. Technology's importance in promoting economic growth and enhancing enterprises' competitiveness in a global market has become increasingly clear in recent years. Through one of the three primary channels in-house, independently generated technology, ready-made technology obtained through acquisition, or cross collaboration businesses have been consistently pushed to increase their knowledge bases and capacities.

Figure 2. Steps for the systematic literature reviews for the management sciences.

By depending entirely on internal or pre-made projects, organizations are finding it harder to expand their expertise and technology in the present competitive market. The former takes a long time to manifest, but the latter presents major execution difficulties because of integration issues. For this inquiry, the search databases examined were Google Scholar, Science Direct, and Scopus. The literature searches were completed on June 29, 2019, and the papers were published in scholarly publications from the three data sources. These diverse, globally renowned databases were searched in order to get pertinent information from publications. Science Direct is an online index of academic citations that is also a repository of published scientific research run by publication Elsevier.

An important part of the SLR's reintroduction to management research was Tranfield and colleagues' seminal piece from 2003, in which the authors claimed that SLRs were relevant to the field of management given the development of management methodology, the fragmentation of its issues, and its collaboration with other areas. They emphasized the SLR search's thoroughness and the inclusion process' transparency as being two crucial grounds for using the technique in management. However, management was actually a latecomer of SLR

compared with other industries, and academic researchers were not yet significantly using SLRs, claim (Briner, Denyer, 2012, pp. 112-129).

Research Protocol: The reason for the need of a study procedure for SLR is so that the properties that make a systematic literature review transparency, transferability, and reliability can be taken into account. This reduces the bias by undertaking thorough literature searches the hardest problem at this point is deciding the scope of the investigation. Once the study scope is established, it assists in developing research questions and research limits to decide the most appropriate research methodology. An efficient SLR strategy is essential to creating a solid and objective foundation of information that aids researchers in avoiding elements that compromise dependability and restrict contribution. An SLR plan must at the very least have these components:

- Clearly defined research questions.
- A search strategy.
- Standards for determining whether an article from a search should be included in the review.

The creation of an appropriate systematic research review team is a crucial first step. It is crucial to inform all possible team members about the time and effort needed for an SLR and take into account each member's potential contributions. To enhance the literature review and reduce the possibility of retrieval bias, SRRTs also included at least one member with extensive research knowledge in the area of inquiry Scholars use the term "protocol" to denote an SLR strategy.

For instance, de Arajo Lima, Crema, and Verbano provide the following broad summary of their SLR protocol phases while structuring their SLR of SME risk management: What a comprehensive literature review is meant to accomplish, the study objectives, the methodology, the criterion for selection, the evaluation of the quality, and the methods for gathering and analyzing the data.

Finding related studies: An SLR search aims to prevent bias caused by including just readily available articles and to include all possibly journal links in a database. Since the strength and quality of systematic literature reviews rely on the paper consideration, the quality of a SLR may decline if any pertinent article are not taken into account. A comprehensive SLR search is thus a crucial and time-consuming operation. The abundance of literature search databases gives SRRTs access to a wealth of information. However, it is essential to use various sources since each database generates unique search results (Pati, Lorusso, 2018). Determining the right keywords to use is crucial when doing an SLR search (Siddaway, 2014). A scoping analysis of the literature that takes into account team members' interactions may lead to the development of effective search phrases. Subject matter experts are a potential source of assistance for keywords. Multiple keywords must be used, and SRRTs may do so in the title, synopsis, keyword, or entire text of the article. making a keyword list. For example, in a recent study, we employed three popular search databases and were astonished to discover that each

generated distinct but important findings. As a result, SRRTs should make well-informed decisions when deciding which databases to search. The advice of librarians knowledgeable in the field of interest may be sought by SRRTs as a beneficial resource, one in which SRRTs frequently underutilize.

Conducting the reviews: studies location and criteria

Author use the data on the different database and criteria. An important step in the SLR process is setting the standards to be used in assessing whether an item found during a search deserves review inclusion. The SLR may include publications that are irrelevant to the study aims because to insufficient or incorrect inclusion criteria that generate selection bias. Both the inclusion requirements and the necessary content of the SLR must reflect the SLR's aim (Denyer, 2012). As a result, the SRRT's deliberative procedures should produce criteria, and the SRRT should defend the criteria it used. Criteria must be the result of SRRT's logical decision-making in order to be legitimate (Siddaway et al., 2019). Any modifications to the SRRT's criteria that take place while it is going through the inclusion decision procedure must be noted and disclosed (Briner, Denyer, 2012). Take firm resilience SLR by Conz and Magnani (2019) as an example of inclusion criteria. They applied the subsequent: Think on resilience at the corporate level and adopt the idea of resilience, and be "published in English within the management, business research, or accounting domains, published between 2007 and 2019 in a peer-reviewed academic publication. The calibre rankings of journals where possible papers are published are one inclusion criteria that is discouraged. It is better to evaluate an article using SLR-relevant standards rather than letting journal editor choices influence the decision to include it (Tranfield et al., 2003). Additionally, SRRTs must be impartial when determining inclusion criteria, avoiding favoring works by eminent authors or significant research.

Data analysis and synthesis

Author added the data in his research management science article by using different methods to evaluate the accurate results. The data analysis & synthesis process starts after the proper collection of relevant publications has been gathered. While the goal of analysis is to dissect each research into its component components and define the general links and connections, the goal of synthesis is to find correlations between various study elements (Tranfield et al., 2003). The following subsections serve as a representation of the synthesis and analysis of this research analysis information help to decision making for the management.

Following the selection of publications to be included in the review and the collection of data, the SRRT will begin the process of evaluating and synthesizing the data. Sense making is categorizing occurrences, giving tangible meaning to abstract categories, and then applying this understanding to one's identity or behavior (Obstfeld, 2005). Making sense of things requires taking a step back and reflecting on how things were done or how things turned out in the past. The process of sense making, which occurs when people reflect on the past and ask themselves "What do these events mean?", marks a milestone on the road to knowledge that may be put to practical use. What exactly is going on, though?

Understanding develops in tandem with ongoing events, giving rise to a narrative that is still in progress. We compare sense making in the workplace to how one may process data obtained in a structured learning environment. Research teams examine, classify, and synthesize data from many research to establish a stable and ever-growing body of information.

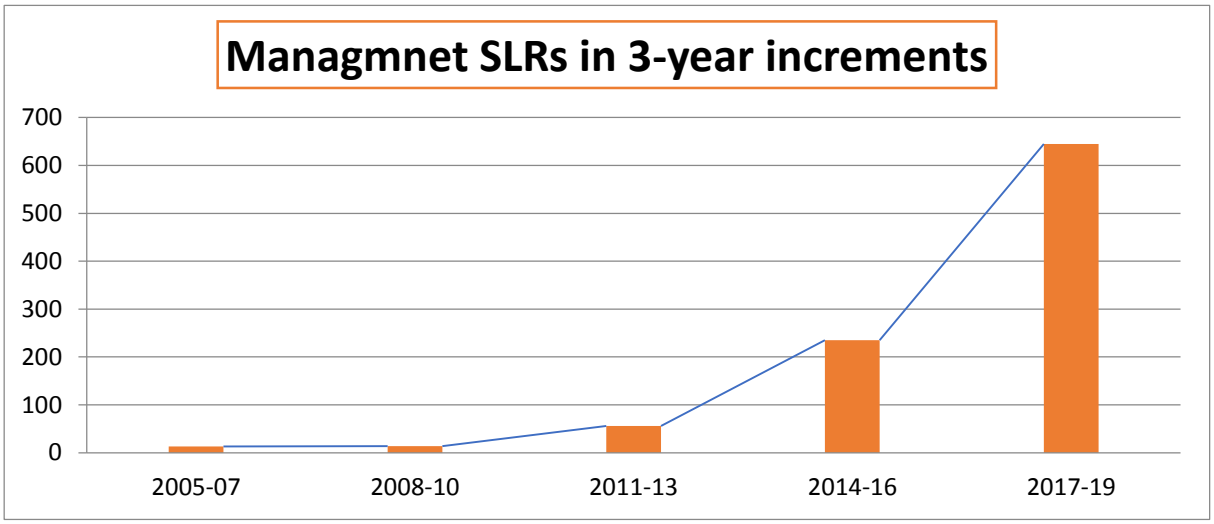

Figure 3. Numbers of the Management SLRs from 2005-2019 by three-year increments.

We searched Scopus to examine the expansion of SLR use in management research. Note that our goal was to get a broad understanding of the emergence of SLRs in management research, not to conduct an SLR of management SLRs. In the article's title, we used the phrase "systematic review," and we only searched inside the Scopus "business, management, and accounting" topic area. We rejected papers from journals covering topics unrelated to management, such as those published in economics, marketing, and accounting journals, based on our results and a careful review of all the journals included in the search. SLRs were discovered in a number of management journals with different rankings, including European Management Journal, Journal of Management Studies, Journal of Organizational Behaviour, Human Resource Management Review, Operations Management Research, Management Review Journal, Knowledge and Process Management, The Leadership Quarterly, and International Journal of Management Reviews, among others.

The previous decade has seen a remarkable growth in the development of scientific and technical knowledge in the area of innovation, which has been a central focus of study on strategic project management. According to Adams, Bessant, and Phelps (2006), innovation is a strategic management process that transforms capabilities and resources into new goods, services, and business models. Keupp, Palmie, and Gassmann describe new methodologies, metrics, and cutting-edge digital gadgets for innovation research. Despite the fact that SLRs are becoming more and more popular, researchers claim that management journals have published only a limited amount of information on how to conduct an SLR (e.g., Briner, Denyer; 2012; Fisch, Block, 2018; Paul, Criado, 2020). Our search for relevant research for the present paper only served to confirm this claim. Furthermore, according to some academics, the SLR process is poorly understood by the majority of management researchers (e.g., Briner, Denyer, 2012; Fisch, Block, 2018). We organize our investigation of the SLR around three major paradigms: the goal of the SLR, how SLRs could advance management research, and the SLR's implementation.

Over time, the globe has shifted toward a digital future, and Industrial revolution 4.0 technologies are now seen as the direction of that future (Kumar et al., 2020). Artificial intelligence is one of the most well-known of these technologies using in the management sciences (encompassing block chain, IoT, cloud technology, etc.) (Dirican, 2015), which is characterized as computers' capacity to interact with people and emulate their skills. When AI is used, problems are solved more quickly, more accurately, and with more inputs that provide the best way to management to take the action on any decision making and progress of the leadership.

Reporting and Disseminating the Review

A systematic review employs clear and methodical techniques to locate, choose out, evaluate, and extract and analyses data from pertinent research. This is not always feasible, and the need for quick evidence syntheses often calls for the adoption of methodological concessions. In order to achieve this need for timeliness, rapid review, a sort of knowledge synthesis, employs streamlined techniques and an expedited methodology to provide information. Depending on the requirements of the manufacturer, the end-user, and other factors, these alterations in a quick evidence product may vary. Research must be presented in a clear and transparent manner in order for knowledge for reader to find it useful. It is crucial that reporting reflect protocol-driven choices, methods, and conclusions since quick reviews are methodologically tailored in order to shorten the review duration. This makes it possible for research results to be adopted and used properly by a range of knowledge reader.

Discussions and results

1. The systematic literature review: Management sciences, definition and search origin

"An investigation of the evidence on such a clearly - defined topic that employs systematic and explicit procedures to discover, select, and critically evaluate relevant independent research, and to retrieve and analyses data from the research studies that are examined in the review" is the definition of a systematic review. The procedures must be clear and repeatable. The world of research interests in advancement has been expanding, diversifying, and therefore offering new issues and scientific frontiers. We are working to create a scientific database for the most recent articles (2000 to 2019). To locate publications that potentially reflect the state of the art in the fields of endeavour management and success, we set out to explore the Web of Science and Scopus databases in this context. Both bases, notably Web of science, were selected since they are the primary international scientific bases (Motta, Garcia, Quintella, 2015).

1.1. What is the Origin of the Systematic literature reviews?

Systemic literature reviews were first used in the medical industry, since it is believed that medical treatment is founded on scientific facts. It is commonly acknowledged that achieving effective collaboration among professionals across business divisions and departments, and increasingly between companies and sectors, poses a significant problem in the area of management research (McAdam et al., 2008). As a result, the team's knowledge must be properly integrated, breaking down various barriers brought on by disciplinary specialization and the diversity of cognitive frameworks (Berggren et al., 2011). As a consequence, the National Institutes of Health supported a strategy designed to comprehensively and methodically combine research relevant to a given medical concern assembling the data and presenting them to decision-makers in a form that was understandable and relevant (Tranfield et al., 2003, p. 209). This research used an evidence-based, systematic literature review strategy to address the inadequacies of a systematic review (Tranfield et al., 2003) and an expert review using ad hoc literature choice (Kitchenham et al., 2009). We used the five-step procedure given by Denyer and Tranfield (2009), along with a pilot research in the first phase to better understand the existing literature, create the selection criteria for the literature, and develop the research question and future phases. Consequently, the five steps of the systematic review we used are.

Research question

A well-constructed, answerable question that directs the investigation serves as the foundation for a thorough literature review (Counsell, 1997). The most important and certainly most challenging aspect of the research design is developing a research question, which then influences the decision of research strategies and methodologies. In other words, research is carried out on the basis of research topic (Bryman, 2007). We came up with the research's

central question after doing a pilot search. Systematic review; *How the management science implement in organization?*

What is the systematic literature review?

There are many definitions of the systematic literature reviews according to (Siddaway et al., 2007). In a systematic review, a particular issue is addressed, a comprehensive literature search is conducted, individual studies are critically evaluated, and conclusions are drawn on what is known and what is unknown about the subject under consideration. "An examination of the evidence on a specific and measurable topic that employs systematic and explicit procedures to discover, select, and critically evaluate relevant original research, and to collect and analyses the data from the studies that have been included in the review" is the definition of a systematic review. The procedures must be clear and repeatable. We identified four key principles characterizing SLRs from the literature. These principles list the following as crucial SLR characteristics of our systematic literature review the literature.

Principle 1: Systematic review of the literature has a clearly established objective.

Existing to doing a literature search on their area of interest, authors undertaking SLRs formulate particular research questions that may be addressed by comprehensively examining and synthesizing prior work. These questions serve as the foundation for their search, the selection criteria for the articles included in the review, and the framing for the information that is gathered from an SLR.

Principle 2: Systematic reviews synthesize a base of knowledge that includes all pertinent information, providing what is already available and highlighting what is lacking.

The samples for an systematic literature review on a secondary research is made up of the primary studies included in the SLR.

Principle 3: Systematic reviews evaluate articles retrieved through a systematic exploration and use specified criteria to decide which articles should be included in the review.

Therefore, established inclusion criteria and associated application protocols are essential to minimize article inclusion bias.

Principle 4: A thorough search strategy is employed during systematic reviews, and it is stated explicitly and transparently.

SLR search queries are comprehensive and aim to locate "all relevant" material. In order for others to reproduce the search and verify that bias was not present or to update results, doing so needs a thorough strategy. Systematic Review Research Teams clearly and openly disclose the processes they took throughout the search process. Reporting search procedure and findings explicitly helps SLR readers believe that search evidence, not researcher judgements or views, produced the conclusions.

2. Systematic reviews forms: comparison with other methods

2.1. Compared a systematic review of the literature with some other review methods

SLRs have taken on a wide range of forms in management research to pursue diverse research goals. McLeod, Payne, and Evert (2016), for example, used an SLR to examine techniques and application of analytical methodologies is a methodological goal in organizational ethics study. The SLR by Junker and Van Dick (2014) aimed to classify the advancements in leadership and followership theory as a theoretical goal. The main objectives of Donaldson's (2019) SLR on entrepreneurial intention research were to identify gaps, provide a future research agenda, and propose future research opportunities. In terms of human resources, SLR sought to identify psychological effects of ELP in organizational contexts with an outcomes target. In order to achieve a theme-centric goal, selected themes that would help to clarify some of the ambiguity in "coopetition" literature. Additionally, as part of its model-building purpose, Dada's (2018) SLR sought mediators and moderators in relation to the development of franchisee autonomy. These instances show a few of the goals that management researchers could work toward using SLRs.

Locating the studies

We choose the search engine, Scopus, and the search terms to find the relevant research. We chose five databases with extensive coverage of the peer-reviewed literature relevant to our research issue, keeping in mind that we needed databases giving wide access to a variety of relevant material throughout a certain time span.

Selection and review of research

Author research on the management science and implantation in the organization. In order to make certain that articles using various vocabularies were found, the key search phrases were somewhat wide. We found 645 articles using the inclusion and exclusion criteria from the pilot search. Since the bulk of the publications and a significant number of new trends and applications that contribute to this issue have appeared between 2007 and 2019, the first criterion focuses on the time period of the literature, which spans 2007 and 2019. Only peer-reviewed journal and research articles were taken into consideration for the evaluation, therefore book reviews, chapters, case reports, talks, and news pieces are not included. The second criterion focuses on relevance and quality.

Traditional reviews and systematic reviews

So how do SLRs vary from conventional literature reviews referred to as "conventional reviews" in the following? Traditional reviews, often known as "narrative reviews," typically seek to provide a basis for the hypotheses in a specific research (Brereton et al., 2007). This concentration could restrict the literature that is sought for and used, which might lead to bias (Petticrew, 2001). Authors performing a typical review may "cherry-pick" literature when deciding which articles to include, focusing mostly on research that support their theories (Briner, Denyer, 2012; Petticrew, 2001). SLRs, in contrast, attempt to respond to research issues

by a comprehensive analysis, evaluating and unravelling all pertinent research and attempting to combine earlier work (Brereton et al., 2007). The phrase "prior research has demonstrated", which is often used in conventional reviews and is frequently based on a limited number of studies, is addressed by the SLR method, SLRs aim to eliminate bias, which is often present in conventional reviews, by thorough literature searches, clear reporting, and repeatable and explicit methods (Pati, Lorusso, 2018; Tranfield et al., 2003). Traditional evaluations also seldom disclose the search strategies used to locate pertinent publications. SLRs, on the other hand, precisely and openly state the search steps that were used (Tranfield et al., 2003). Traditional reviews might be thought of as "news stories," while SLR is more like a "documentary." Table 1 lists and summarises the distinctions between standard reviews and SLRs.

Table 1.
Difference between traditional review and systematic reviews

Traditional reviews vs. systematic reviews		
	Traditional reviews	**Systematic reviews**
Aim	The backdrop of research is to generate support for hypotheses by developing a concentrated grasp of prior research on a subject	It addresses specifically stated aims and research issues by combining prior work, involves a comprehensive evaluation of all pertinent research, and counts as research in and of itself.
Review planning	There is no common or compulsory fixed strategy, allowing for creative experimentation	A precise and comprehensive methodology is chosen. An audit trail is created by the transparent documentation and sharing of the protocol.
Identifying the research for potential review inclusion	Searching thoroughly and looking for pertinent contributions	Comprehensive, thorough, and complete search using well-defined, clear stages and looking for any and all possibly relevant information.
Selection for inclusion in the review	Purposeful choice	Unbiasedly keep to the narrow inclusion criteria developed from the stated aims and research questions.
Analysis and synthesis	Analysis that is pertinent to the question and hypothesis	Strives to objectively and impartially integrate prior research and build upon a basis of evidence-based knowledge.
Methodological report	Nothing anticipated or essential, frequently not presented	A thorough and detailed explanation of the procedures performed, the criteria used in those stages, and the justification for the actions and criteria used is supplied for openness, future reviews, and to establish the legitimacy of the systematic review.

Amended from Jesson et al. (2011, p. 105).

2.2. Comparative advantages of a Systematic Literature Review

SLRs provide scientists and their areas extra advantages above typical reviews, which often only offer enough to support an article's main claims (Briner, Denyer, 2012). SLRs provide a thorough picture of information developed in previous research compared to standard reviews, which may contain results that are incongruent (Siddaway et al., 2019). The present state of knowledge may be accurately understood by using a comprehensive approach, and it may also lead to the creation of new theories that may have gone unnoticed in the past. SLRs demonstrate that the whole is substantially larger than the total of its parts" as compared to individual studies.

Ultimately, SLRs have the benefit of wanting to avoid the following elements of bias: retrieval bias, which occurs in reviews to ensure that articles would not reflect a comprehensive summary of the literature, reporting bias, that also results from journal articles failing to submit research acknowledging previous research or research with non - significant effects (Durach et al., 2017). In order to reduce publication bias, SLRs may search for un-published material or "research papers," or they may evaluate a larger variety of journals or a wider range of topics when choosing relevant literature. In order to find "all relevant" information in accordance with its fundamental notion, an SLR will be required to exert more effort in offering a more complete appraisal of recent research.

3. Systematic literature reviews improve management research?

In this part, we show how SLRs may improve management research by addressing common research issues and encourage increased SLR use in our sector of systematic review on search topic. Meta-analyses may, one would believe, resolve these problems. However, despite the fact that meta-analyses increase statistical power by integrating trials, they may just exacerbate issues in initial investigations.

Hypothesis testing

Another way to enhance the management research through systematic literature review bringing to light unpublished studies that are almost, but not quite, fulfilling the criterions is another way that an SLR might improve management research. Scholars have questioned NHST's dominance in research in general and strict enforcement as the validation of data supporting stated hypotheses in management research in particular. Orlitzky said that Hypothesis testing has adversely impacted theory creation and knowledge expansion due to a false feeling of confidence in outcomes, a concentration on the aim of quantitative investigations, and a lack of attention on qualitative inquiry.

Repeated experiments in research

The repeated experiment in research can enhance the management research. SLRs could also help management researchers fill a gap in management science that concerns replication studies. According to Kohler & Cortina (2019, p. 4), replication, which is defined as "the study of a phenomena being undertaken more than once," is not now a substantial part of management science (Bettis et al., 2016). Given that several major management journals have published papers demanding replication, such as Academic journal (Adam, 2003), Strategic Management Journal (Bettis et al., 2016), and Journal of the Management (O'Boyle et al., 2017; Kohler, Cortina, 2019), we are worried about the relative paucity of replication in our discipline. Ioannidis (2005) found that seven of 49 highly referenced medical research publications published in major medical journals were contradicted in later replication studies, demonstrating how replication is applied in other fields. Kohler & Cortina (2019) called replication "self-correcting science".

Using HARKing and p-hacking

P-hacking and HARKing, which belong under the category of what academics have labelled as Quantitative Research Practices, are likely outcomes of the maxim "e-Publish," which states that authors must publish in peer-reviewed journals in order to survive (González-Mule, 2017). Post-hoc hypotheses developed based on data rather than a priori, HARKing occurs (Pierce, Dalton, 2016). The post hoc hypotheses developed by HARKing researchers often have shaky theoretical basis since they are developed after data analysis is complete (Kerr, 1998). While it is unlikely that HARKing in management research can be completely eradicated by analysing the theoretical growth of hypotheses across studies, SLRs may be able to expose flaws and emphasise the need to prevent HARKing. P-hacking is the practise of manipulating variables, statistical analysis, or data produce findings that are statistically significant p.05 (Nelson, Simonsohn, 2011).

Baum & Bromiley (2019) discovered evidence to back their assertion that academics under professional pressure to publish are much more inclined to participate in p-hacking to influence just-significant coefficients, assuming just-significant coefficients are published. SLRs may expose P-hacking, like HARKing. By posting p-values from their works, maybe in a graph, and highlighting results with just-significant coefficients, management SLRs can alert readers to potential p-hacking. In a SLR's discovery that the majority of papers examining a topic had conclusions that were just barely statistically significant may provide light on those results. Additionally, SLRs may assist call attention to results that disagree with those of multiple other studies, perhaps indicating p-hacking or dubious study conclusions. Editors and reviewers in our discipline may start looking more carefully at suspected cases of p-hacking if highlighting just-significant findings or dubious outcomes were to become a trend in management SLRs. Meta-analyses should, one would think, resolve these problems. However, despite the fact that meta-analyses increase statistical power by integrating trials, they may just exacerbate issues in initial investigations in the management sciences.

Author search the keyword for management science, systematic literature reviews on these articles we have conducted over 645 articles. There were 645 publications found in the search. We evaluated 192 records and looked for 102 records for retrieval after eliminating data flagged as ineligible according to the publishing type and topic area. Since their hypotheses did not pertain to knowledge incorporation and management studies, we ultimately removed 12 works. We searched reference lists for extra deserving papers and utilized Google Scholar to make sure we didn't overlook anything. The final collection includes 82 pieces from more than 31 different sources, representing the notion of border objects' broad range of potential applications. This study is presented in tables, numbers, data, and comments for academics. According to Denyer & Tranfield (2009), the findings and discussion section summarizes the literature's data, emphasizing what is known and what is unknown about the study issued.

Conclusion

SLRs support practitioners and academics in ability to absorb the rapidly growing body of evidence of management research, provide a comprehensive - practical educational at relevant work, reveal the explanations behind conflicting results, open the door to new study avenues and future work, and provide a trustworthy review. SLRs may enhance management research by tackling HARKing & p-hacking and emphasizing replication. An SLR is more time and resource-intensive than a typical review, which may call for a bigger team and greater effort from each individual. Because they are not gathering fresh data, some researchers believe that SLRs will take less time and effort than empirical investigations. However, this assumption is often incorrect. With regard to construction management as well as innovation, it can be seen from an analysis of the sample articles that the following disciplines or concepts were most pertinent: teams, strategy, crisis management, organizational learning, management, entrepreneurship, interconnection, development and research intellectual property, behavioral theory, and human and social capital. It is possible to see that the more conventional ideas about innovation and development, Ten of the fourteen articles in our sample mentioned at least one of these concepts, such as innovative product research and development. There is a plethora of literature on the topic of project management that delves into topics like social and psychological capital, teams, and integration. For those who create health systems and strategy fast evaluations, there is a dearth of reporting and disseminating advice. Despite access to systematic review reporting and disseminating techniques and channels, producers of quick reviews may need to put the demands of the seeking knowledge user ahead of more conventional or academic reporting and dissemination strategies.

Management literature promotes original ideas and is theory-driven; in contrast to replicate, hypotheses may be experimentally evaluated using many frameworks. Researchers may more fully catalogue their work on a theory or notion by using SLR, however it can be challenging to draw conclusions about the body of work when using several constructions. SLRs could be able to explain the tale and define the future research agenda, but they might not be able to determine if a hypothesis is validated. To interpret the data obtained from a theory-concept centered SLR, researchers require further methods, tools, and instructions.

SLRs hold the potential of resolving fundamental management research problems, advancing knowledge, and assisting researchers to go further into qualitative work by highlighting areas of convergence between concepts and measures. SLRs are a useful tool for assessing the theoretical strength of ideas and for promoting robust theoretical development. SLRs provide a way to lessen the effects of cherry-picking journals that could ignore null findings, results that don't support a certain agenda, or articles that do not focus on game-changing concepts and conclusions. In conclusion, SLRs provide a trustworthy technique to minimize bias while incorporating the knowledge of several researchers. In needed for

management researchers that effectively conduct SLRs, Tranifield, Denyer and smart add to the corpus of knowledge management, and make the newly acquired knowledge available to practitioners, it is our intention that the current study will serve to develop or strengthen SLR foundations for management researchers.

Author credit statement

Ayesha Amjad: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. Piotr Kordel: Formal analysis, Methodology.

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References

1. AACSB (2019). *2020 Standards for AACSB business accreditation, exposure draft 1*. Available from: https://www.aacsb.edu/accreditation/business-accreditationtask-force/exposure-draft.
2. Abutabenjeh, S., Jaradat, R. (2018). Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners. *Teaching Public Administration, 36(3),* 237-258.
3. Adams, R., Bessant, J., Phelps, R. (2006). Innovation management measurement: A review. *International Journal of Management Reviews, 8(1),* 21-47.
4. Adams, R.J., Smart, P., Huff, A.S. (2017). Shades of grey: Guidelines for working with the grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews, 19(4),* 432-454.

5. Baumeister, R.F. (2013). Writing a literature review. In: M.J. Prinstein, M.D. Patterson (Eds.), *The portable mentor: Expert guide to a successful career in psychology* (pp. 119-132). New York: Springer Science Business Media.
6. Bergh, D.D., Sharp, B.M., Aguinis, H., Li, M. (2017). Is there a credibility crisis in strategic management research? Evidence on the reproducibility of study findings. *Strategic Organization, 15(3),* 423-436.
7. Bettis, R.A. (2012). The search for asterisks: Compromised statistical tests and flawed theories. *Strategic Management Journal, 33(1),* 108-113.
8. Bettis, R.A., Ethiraj, S., Gambardella, A., Helfat, C., Mitchell, W. (2016). Creating repeatable cumulative knowledge in strategic management: A call for a broad and deep conversation among authors, referees, and editors. *Strategic Management Journal, 37(2),* 257-261.
9. Bosco, F.A., Aguinis, H., Field, J.G., Pierce, C.A., Dalton, D.R. (2016). HARKing's threat to organizational research: Evidence from primary and meta-analytic sources. *Personnel Psychology, 69(3),* 709-750.
10. Brereton, P., Kitchenham, B.A., Budgen, D., Turner, M., Khalil, M. (2007). Lessons from applying the systematic literature review process within the software engineering domain. *Journal of Systems and Software, 80(4),* 571-583.
11. Briner, R.B., Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. In: D.M. Rousseau (Ed.), *Oxford Handbook of evidence-based management: Companies, classrooms and research* (pp. 112-129). Oxford, England, UK: Oxford University Press.
12. Briner, R.B., Denyer, D., Rousseau, D.M. (2009). Evidence-based management: Concept cleanup time? *Academy of Management Perspectives, 23(4),* 19-32.
13. Calabro, A., Vecchiarini, M., Gast, J., Campopiano, G., De Massis, A., Kraus, S. (2019). Innovation in family firms: A systematic literature review and guidance for future research. *International Journal of Management Reviews, 21(3),* 317-355.
14. Cassiman, B., Valentini, G. (2009). Strategic organization of R&D: the choice of basicness and openness. *Strategic Organization, 7(1),* 43-73.
15. Castro, A.A. (2001) Revisão sistemática e meta-análise. *Compacta: temas de cardiologia, vol. 3, no. 1,* pp. 5-9.
16. Cicognani, A. (2000). Concept mapping as a collaborative tool for enhanced online learning. *Journal of Educational Technology & Society, 3(3),* 150-158.
17. Conz, E., Magnani, G. (2019). A dynamic perspective on the resilience of firms: A systematic literature review and a framework for future research. *European Management Journal*.
18. Dada, O. (2018). A model of entrepreneurial autonomy in franchised outlets: A systematic review of the empirical evidence. *International Journal of Management Reviews, 20(2),* 206-226.

19. de Araújo Lima, P.F., Crema, M., Verbano, C. (2019). Risk management in SMEs: A systematic literature review and future directions. *European Management Journal, 78e94*.
20. Donaldson, C. (2019). Intentions resurrected: A systematic review of entrepreneurial intention research from 2014 to 2018 and future research agenda. *The International Entrepreneurship and Management Journal, 15(3),* 953-975.
21. Dorn, S., Schweiger, B., Albers, S. (2016). Levels, phases and themes of coopetition: A systematic literature review and research agenda. *European Management Journal, 34(5),* 484-500.
22. Durach, C.F., Kembro, J., Wieland, A. (2017). A new paradigm for systematic literature reviews in supply chain management. *Journal of Supply Chain Management, 53(4),* 67-85.
23. Eden, D. (2002). From the editors: Replication, meta-analysis, scientific progress, and AMJ's publication policy. *Academy of Management Journal*, 841-846.
24. Fisch, C., Block, J. (2018). Six tips for your (systematic) literature review in business and management research. *Management Review Quarterly, 68(2),* 103-106.
25. Frank, H., Hatak, I. (2014). *Doing a research literature review. How to get published in the best entrepreneurship journals.* 94-117.
26. Ganann, R., Ciliska, D., Thomas, H. (2010). Expediting systematic reviews: methods and implications of rapid reviews. *Implement Sci., 5,* 56.
27. Hart, C. (2018). Doing a Literature Review: Releasing the Research Imagination. *Management sciences reviews sage 4(1),* 3-4.
28. Higgins, J.P.T., Green, S. (2011). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0* [updated March 2011]. The Cochrane Collaboration. Available from: http://www.handbook.cochrane.org.
29. Hunter, J.E. (1997). Needed: A ban on the significance test. *Psychological Science,8(1),* 3-7.
30. Ioannidis, J.P. (2005b). *Contradicted and initially stronger effects in highly cited (continued) Step 3 e Conducting the Review: Determining which Articles from the Search to Include, and Gathering Knowledge Re-review the articles/literature to ensure a consistent application of the inclusion criteria as a full SRRT.*
31. Jackson, K.M., Trochim, W.M. (2002). Concept mapping as an alternative approach for the analysis of open-ended survey responses. *Organizational Research Methods, 5(4),* 307-336.
32. Jesson, J., Matheson, L., Lacey, F.M. (2011). *Doing your literature review: Traditional and systematic techniques.* Thousand Oaks, California: Sage.
33. Junker, N.M., Van Dick, R. (2014). Implicit theories in organizational settings: A systematic review and research agenda of implicit leadership and followership theories. *The Leadership Quarterly, 25(6),* 1154-1173.
34. Kerr, N.L. (1998). HARKing: Hypothesizing after the results are known. *Personality And Social Psychology Review, 2(3),* 196-217.

35. Keupp, M.M., Palmié, M., Gassmann, O. (2012). The strategic management of innovation: A systematic review and paths for future research. *International Journal of Management Reviews, 14(4),* 367- 390. doi:10.1111/j.1468-2370.2011.00321.x.
36. Khosravi, P., Newton, C., Rezvani, A. (2019). Management innovation: A systematic review and meta-analysis of past decades of research. European Management Journal, 694-707.
37. Kohler, T., Cortina, J.M. (2019). Play it again, Sam! an analysis of constructive € replication in the organizational sciences. *Journal of Management, Article 0149206319843985*.
38. Kotera, Y., Sheffield, D., Van Gordon, W. (2019). The applications of neuro-linguistic programming in organizational settings: A systematic review of psychological outcomes. *Human Resource Development Quarterly, 30(1),* 101-116.
39. Kvarven, A., Strømland, E., Johannesson, M. (2020). Comparing meta-analyses and preregistered multiple-laboratory replication projects. *Nature Human Behaviour, 4(4),* 423-434.
40. Linnenluecke, M.K., Marrone, M., Singh, A.K. (2020). Conducting systematic literature reviews and bibliometric analyses. *Australian Journal of Management, 45(2),* 175-194.
41. Lueg, R., Radlach, R. (2016). Managing sustainable development with management control systems: A literature review. *European Management Journal, 34(2),* 158-171.
42. Lune, H., Berg, B.L. (2017). *Qualitative research methods for the social sciences*. Pearson.
43. McGowan, J., Sampson, M. (2005). Systematic reviews need systematic searchers. *Journal Of the Medical Library Association, 93(1),* 74.
44. McKinley, W. (2010). Organizational theory development: Displacement of ends? *Organization Studies, 31(1),* 47-68.
45. McKinley, W., Wood, M.S., Moon, G. (2011). Low heed in organization theory. *M@n@gement, 14(3),* 154e181.
46. McLeod, M.S., Payne, G.T., Evert, R.E. (2016). Organizational ethics research: A systematic review of methods and analytical techniques. *Journal of Business Ethics, 134(3),* 429-443.
47. Meyers, R.A. (Ed.) (2009). *Encyclopedia of Complexity and Systems Science*. New York: Springer, pp. 1-32.
48. Mulrow, C.D. (1994). Systematic reviews: Rationale for systematic reviews. *BMJ, 309(6954),* 597-599.
49. O'Boyle, E.H. Jr., Banks, G.C., Gonzalez-Mule, E. (2017). The chrysalis effect: How ugly initial results metamorphosize into beautiful articles. *Journal of Management, 43(2),* 376-399.
50. Orlitzky, M. (2011). Institutionalized dualism: Statistical significance testing as myth and ceremony. *Journal of Management Control, 22(1),* 47-77.

51. Osareh, F. (1996). Bibliometrics, citation analysis and co-citation analysis: A review of literature I. Libri. *International Journal of Libraries and Information Services, 46(3),* 149-158.
52. Oxman, A.D. (1994). Systematic reviews: Checklists for review articles. *BMJ, 309(6955),* 648-651.
53. Pati, D., Lorusso, L.N. (2018). How to write a systematic review of the literature. *HERD: Health Environments Research & Design Journal, 11(1),* 15-30.
54. Paul, J., Criado, A.R. (2020). The art of writing literature review: What do we know and what do we need to know? *International Business Review, 1e7.*
55. Petticrew, M. (2001). Systematic reviews from astronomy to zoology: Myths and misconceptions. *BMJ, 322(7278),* 98-101.
56. Piper, R.J. (2013). How to write a systematic literature review: A guide for medical students. *National AMR, Fostering Medical Research, 1e8.* syntheses (SSRN scholarly paper 130n09606). Rochester, NY: Social science research network.
57. Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Duffy, S. (2006). *Guidance on the conduct of narrative synthesis in systematic reviews. A product from the ESRC methods programme Version, 1(1), b92*.
58. Randolph, J. (2009). A guide to writing the dissertation literature review. *Practical assessment, research, and evaluation, 14(1)*, 13.
59. Ridley, D. (2012). *The literature review: A step-by-step guide for students*.
60. Sampaio, R.F., Mancini, M.C. (2007). Systematic review studies: A guide for careful synthesis of the scientific evidence. *Brazilian Journal of Physical Therapy, 11(1),* 83-89.
61. Siddaway, A. (2014). *What is a systematic literature review and how do I do one (Vol. I).* University of Stirling, p. 1e13.
62. Siddaway, A.P., Wood, A.M., Hedges, L.V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, metaanalyses, and meta-syntheses. *Annual Review of Psychology, 70,* 747-770.
63. Simmons, J.P., Nelson, L.D., Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science, 22(11),* 1359-1366.
64. Splenda, R. (2020). Systematic Reviews in Business & Management: A New Role for Business Librarians. *Ticker: The Academic Business Librarianship Review, 4(2).*
65. Tranfield, D., Denyer, D., Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management, 14(3),* 207-222.
66. Tricco A.C., Antony, J., Zarin. W., Strifler. L., Ghassemi, M., Ivory, J., et al. (2015). A scoping review of rapid review methods. *BMC Med., 13,* 224.
67. Trochim, W.M. (1989). An introduction to concept mapping for planning and evaluation. *Evaluation and Program Planning, 12(1),* 1-16.

68. Tsafnat, G., Glasziou, P., Choong, M.K., Dunn, A., Galgani, F., Coiera, E. (2014). Systematic review automation technologies. *Systematic Reviews, 3(1),* 74.
69. Van Lange, P., Liebrand, A.M. (2015). *Introduction and literature review. Social dilemmas*. 3-28.
70. Van Maanen, J. (1979). Reclaiming qualitative methods for organizational research: A preface. *Administrative Science Quarterly, vol. 24, no. 4,* pp. 520-526.
71. Webster, J., Watson, R.T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS quarterly, xiii-xxiii*.
72. Weick, K.E., Sutcliffe, K.M., Obstfeld, D. (2005). Organizing and the process of sense making. *Organization Science, 16(4),* 409-421.
73. Williams R.I. Jr., Clark, L.A., Clark, W.R. et al. (nd). 12 clinical research. *Jama, 294(2),* 218-228.
74. Xiao, Y., Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of planning education and research, 39(1),* 93-112.

Appendix

Step 1. Planning the reviews; research protocol

1. **Focus of search and systematic literature review**
   - Choose a topic for the systematic review.
   - To find out whether a systematic review has already been done, search databases.
   - Whether a prior systematic review has been undertaken, decide if another review would be beneficial, how it should be modified or focused, or if it should be abandoned.
   - Describe the advantages of using a SLR and answer the question of the board.
2. **SRRT**
   - Based on the broad focal area mentioned, ascertain the kind of expertise, interests, and time involved needed by potential research team members.
   - Identify possible members of the study team.
   - Before your first SRRT meeting, provide team members a brief introduction to systematic reviews by providing essential articles regarding the procedure.
   - At the first SRRT meeting, choose a team member to serve as the lead organizer for the review.
   - Create guidelines for the SRRT's communication, work progress, and review goals.
3. **Review protocol, criteria for inclusion answer pool**
   - To answer the research question, establish the criteria that the literature must satisfy in order to be included in the first pool.
   - Speak with experts or an advisory group to see if the standards will provide information that addresses the research question (s).
   - Carefully study the wording of the criteria to ensure that all SRRT participants are aware of them.
   - Validate (or test) the use of the criterion by the entire team while examining the same selection of publications to determine if the criteria are adequate to include or reject items. In consideration of the comments, modify the requirements.
   - Select, list, and justify the databases and literary sources that will be used.
   - Specify the search criteria (date, relation to the criterion, types or quality of publications, etc.) and justify them in writing.
   - Identify the justification for removing a particular work of literature and make a note of it.
   - Choose which professions will be searched, making note of why other disciplines won't be taken into account.

Step 2. Reporting of the procedure, data finding

4. Reporting

- Give a thorough overview of what is known, what is unknown, and where research should be done next.
- Share findings in publications that will be seen by other academics in order to contribute to a greater comprehension of the literature.
- When describing the procedure used, be detailed and unbiased.
- Provide practitioners with information that has been gathered in a useful and relevant style.
- Inform leaders and managers of information in plain language that explains the "so-what".
- Consult with professionals for assistance on the most effective way to convey the findings of the comprehensive study.

5. Goal for SRRT

- Create a method for documenting fresh study ideas and subjects for the benefit of future studies.
- Manage member of the team requirements to provide the research required for the systematic review.
- Honor each step of the trip that has been accomplished.
- Make the most of each team member's unique expertise and passion.
- Establish a continual research agenda that calls for the publication of articles or further study utilizing the full systematic review methodology.

6. Research study location

- Create a comprehensive understanding of what is known, unknown, to be known about the research topic in the field of management.
- Identify any gaps or areas requiring additional study.
- Find patterns, themes, or big-picture "solutions" to the research issue by concentrating on ideas and linkages rather than specific studies (s).
- Determine every possible conclusion and evaluate the worth of each on its own.
- Think about using a conceptual model as a tool that displays a flowchart of concepts and connections.

Step 3. Gathering knowledge

7. Criteria for inclusion sample

- To guarantee a consistent implementation of the inclusion criteria as a complete SRRT, check the papers and literature once more.
- Return to the whole spread sheet whenever additional criteria or interpretations are developed to make sure they are applied consistently.

- Review example inclusion criteria to make sure the team is on the same page.
- Instead of rushing outcomes, trust the procedure that the SRRT established.

8. Literature assigning to SRRT for review

- Each article is given to a team member at random for evaluation according to the stated process by a member of the team or graduate assistant.

9. **Decision making for sample SRRT**

- Each team member inputs comments on their evaluation into the shared spreadsheet in advance of the SRRT meeting for assessment by all SRRT members.
- In accordance with the predetermined technique for deliberating and discussing whether an article or piece of literature should be part of the review sample, the SRRT discusses and analyses each item to determine if it fulfils the established criteria.
- The SRRT has regular meetings to go through and debate 15 to 20 articles. The defined criteria are the only factors considered in the debate and decision on inclusion or exclusion.
- Continue to adhere to the established methodology for documenting the judgement process and ultimate choices on inclusion and exclusion.

10. Transparency and replication

- Assign at least 2 SRRT members to examine each article. Have a graduate assistant distribute papers at random or arrange assignments such that the articles are reviewed by a different pair of researchers.
- Make sure the SRRT members evaluate the articles they have been given without taking into account the views of other reviewers.
- Create a culture of SRRT that forbids debate before those SRRT members have had a chance to read the article, preventing potential contamination of viewpoints.
- Continue to record inquiries, judgements, changes, and other actions as the process of reviewing the literature for integration develops.

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TYPOLOGY OF BUSINESS NETWORK MODELS: A PROPOSAL BASED ON A SYSTEMATIC LITERATURE REVIEW

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Purpose: to develop a proprietary typology of a business network based on a systematic literature review.
Design/methodology/approach: the typology method facilitates the analysis and understanding of the essence of business networks by identifying and characterizing their different types. The systematic literature review (SLR) methodology was used to develop the typology, enriched with the snowball method.
Findings: analysis of the content of publications selected during the SLR procedure made it possible to indicate various criteria for the division and types of business networks from widely quoted literature. On this basis, a typology of business networks was proposed, divided into four main types: networks originating from industrial districts, strategic networks, cooperation networks, and global business networks.
Practical implications: the possibility of using the proposed concept in assessing various business network models will enable the formulation of diagnostic findings and comparative and dynamic research.
Originality/value: at the current stage of scientific reflection, the developed typology enriches the theory of organizational networks by systematizing and comprehensively addressing business network models, which may lead to identifying trends in their development. It is addressed to both researchers dealing with network issues and practitioners.

Keywords: business networks, typology, systematic literature review (SRL), typology method.

Category of the paper: literature review, viewpoint.

1. Introduction

In recent years, many studies have focused on describing and conceptualizing phenomena related to the formation and development of the network paradigm in management sciences and on the characteristics of significant implications resulting from the adopted views and research methodologies around this organizational phenomenon.

In line with the ongoing discussion, the article discusses the issue of business network models. Business networks are a challenging and complex subject of study. In the study of

business networks, there are some problems, the most important of which are related to the following features: the infinity of connections, no clear boundaries, the presence of strong and weak relationships, crossing the boundaries of the company, network, and environment, constant interaction, and interdependence.

Business networks are consolidating their importance in the global economy. Nowadays, they are one of the most exciting solutions with several advantages, expanding the number of available strategic options for the company, which may enable easier migration towards profit to more developed industries.

In modern times, business networking has become a widespread practice, both in social and economic life. Organizations create multiple forms of connections or cooperation to obtain both individual benefits and the effect of synergy. There is no doubt that the concept of business networks, which has gained tremendous popularity in recent years and is used in various research areas in management, was created thanks to the development of computer networks, especially the global network, which is the Internet.

Many researchers emphasize that business networks are currently one solution to meet the growing competition (Hannachi et al., 2021; Leitner et al. 2011). They influence the growth of innovativeness of enterprises included in the network, as well as the sectors in which the network operates in general (Camarinha-Matos, Afsarmanesh, 2005).

Numerous studies refer to the benefits for the company of using the network approach and belonging to a business network (Child, Faulkner, 1998; Ricciardi et al., 2022; Barczak, 2020):

- cooperation and integration of domestic, foreign, and global entities,
- cooperation potential among related entities and the possibility of achieving measurable benefits (development potential) from links in the form of, among others: access to resources, cost reduction, use of market opportunities, specialization, risk reduction, and foreign expansion (Cruijssen et al., 2007),
- obtaining better financial results compared to traditional solutions, which is the result of eliminating the costs of the existence of the organizational hierarchy, increasing the flexibility of operation, eliminating the costs of competition about current partners, better allocation of investment funds, reducing the costs of control and bureaucracy, the costs of negotiations, specialization activities, better binding customers to the network through the possibility of comprehensive services, etc. (Forsgren, Johanson, 1994; Leitner et al., 2011),
- the complementarity of resources and competencies within the network (Badraoui et al., 2022),
- rapid exchange of information through network-linking horizontal information and communication channels is conducive to increasing the speed and accuracy of decision-making, increasing competitiveness and mutual learning (Alee, 2000; Camarinha-Matos, Afsarmanesh, 2005)
- an opportunity to acquire new knowledge and increase development skills,

- broad autonomy of individual partners, conducive to innovation, experimentation, and learning,
- increasing the flexibility of action results from eliminating hierarchical dependencies (or their significant weakening), multilateral information and communication links, better use of the ability to act and competencies, and increasing innovation.

It is worth noting that the extraordinary wealth of various forms of cooperation (business network models) causes incredible difficulties in classification. Many forms of functioning in the economy have not been thoroughly recognized. A particular research gap can be noticed in this regard - a need for more studies presenting analyses and systematization of various models of business networks. In addition, some forms of network cooperation are so complicated that it is difficult to classify and mark them as a given type of cooperation. However, the research challenge is not only to classify or distinguish business networks but also to indicate the benefits of such solutions[1]. This issue still has inspiring research potential. Although there are many typologies of network types in the literature, a methodological gap could be noticed related to the ordering and systematization of business network models.

The article's primary goal is to present a proposal for a typology of business networks. This was preceded by a thorough literature review (SLR) in the scope of the described typologies and criteria for the division of business network models.

The issue of business network models taken up in the study is described as its complexity, multithreading, and interdisciplinarity. The indicated features imply the diversity of research and the network models used, which become the specificity of the network approach in management. An original proposal of a multi-level typology of business network models is presented in the article. The starting point was the division based on the criterion of the nature and complexity of the relations occurring in them, as a consequence of which four internally differentiated categories of models were indicated: networks originating from industrial districts, strategic networks, cooperation networks, and global business networks.

The presented concept of the division of business network models is a proposal at the current stage of scientific reflection, considering the lack of comprehensive research in this area.

2. Methodology

The systematic literature review (SLR) methodology was used to achieve the set goals: a thorough and systematic search, selection, and analysis of existing scientific literature on a specific topic. Systematic literature reviews are an essential tool for scientists and researchers, as they can obtain a complete and comprehensive picture of the current knowledge on a given topic, which is necessary to conduct a proper and practical analysis. SLR was carried out in the

[1] In recent years, the dark side trend has been strongly marked, which focuses on the limitations and weaknesses of business networks.

following stages: (1) defining the research question, (2) selecting databases and keywords, (3) searching selected databases, (4) selecting publications, (5) analyzing data, (6) synthesizing literature, and (7) presenting the results: developing a typology of business networks.

The main question is: *What is the typology of business networks?* In addition to the main question, the following auxiliary questions were asked:

1) what criteria for the division of business networks are indicated by researchers in the literature?
2) what typologies of business networks are proposed by various researchers in the literature on the subject?
3) what are the main problems in developing a typology of business networks? (discussion)
4) what are the directions (trends) in developing business networks?

The author chose the Web of Science and Scopus databases for research. These databases contain full texts and links to the most famous journals and are the most comprehensive and reliable scientific databases that systematically increase their potential. Next, the research sequence had to be defined (according to Boolean operators): *"business network*" AND typology OR taxonomy OR "criteria for the division of business network*"*

In further proceedings, it limited the scope of articles to 3 areas in the Scopus database and 3 in the WoS database. I also used the reduction of articles by keywords. As a result, WoS returned 109 articles, and Scopus returned 105 articles for 204 documents. The course of the test procedure is summarized in Table 1.

Table 1.
Conducted procedure in the SLR

	Search string	**Limited to:**				**Total**
		Language	**Document Type**	**Subject area/Categories**	**Keywords/Search within all field**	
Scopus	*„business network*"AND typology OR taxonomy OR "criteria for the division of business network*"*	English (4652)	Article (3218)	Business Management and Accounting (2483), Economics, Econometrics and Finance (546), Environmental Science (237)	Business Networks (48), (21) Business Relationship (18) Typology (26)	109
WoS		English (142,905)	Article (120,206)	Management (1,424) Environmental Science (64), (29) Business (875)	Typology	105
Total						**204**

Source: own work.

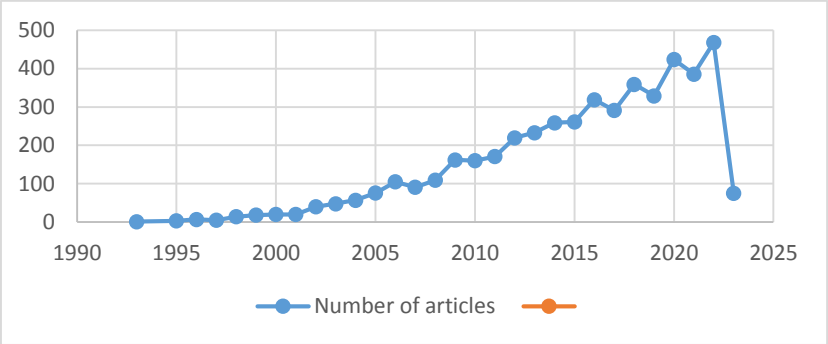


Figure 1. Number of articles since 1993.

Source: own work based on data from Scopus.

Table 1 and Fig. 1 presents the number of publications published from 1993 to 2023. The last access to search in Scopus and WoS occurred on January 15, 2023. It means that some publications of 2023 could still be in the publication procedure. It should be assumed that the number of articles will increase until the end of 2023.

In addition, I used the "snowball" method, i.e., I conducted additional research in which some scientific sources were analyzed that were not included in the selected database.

The second method is typological analysis, which involves identifying and classifying objects or phenomena based on their features and properties necessary for a given study. Typologies can help uncover hidden patterns and trends, making comparing cases and revealing differences between them easier The typology of business networks developed in this article is to perform both a theoretical function - it can help identify trends in the development of business network models, and a practical one, indicating directions for further research.

Typologies serve a distinct purpose in constructing theories. They enable the creation of a structured and concise representation of the subject of inquiry while facilitating subsequent analyses and comparisons to identify the relationships between the typological variable and other variables included in the research. Additionally, typologies allow for the generation of descriptive and prescriptive statements. Thus, their significance extends beyond a purely theoretical function and is crucial for developing principles that inform social and economic practices.

3. Results

3.1. Business network concept

According to the representatives of the mainstream research of the IMP group, a network is a set of long-term connections (relations), formal and informal (direct and indirect), that occurs between two or more entities (Håkansson, Snehota, 1989). The analysis of achievements in the field of shaping the concept of a business network allows defining business networks as systems

created voluntarily by a group of economic actors of enterprises dealing with a similar field of activity, public and private sphere institutions that support their activity - related by relations, interacting with the environment and established to achieve common goals.

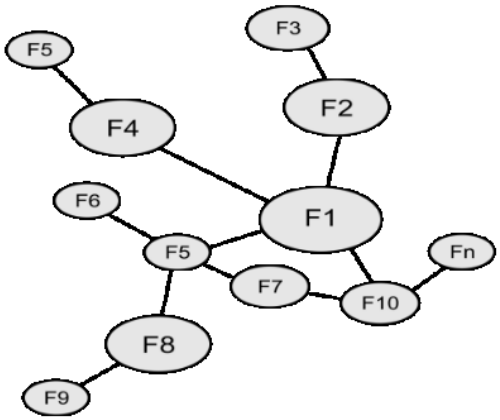
M. Rosińska-Bukowska (2012) defines a business network by referring to the ARA model (actors - resources - activities) built by the IMP Group, in which three issues are emphasized as particularly important: continuity of interactions between participants, resource dependencies of system members and the existence of relationships between them resulting from joint activity (Håkansson, Snehota, 1995). On this basis, he considers a business network a coherent system of horizontal, vertical, and diagonal ties - its inherent feature is coherence. The structure of the network is built by consciously interdependent entities. However, the network is neither a loose bundle of relationships nor a hierarchical structure of a dominated nature. It is a regulatory structure rather than an organizational one. It has an incorporative character, i.e., its entities strive to internalize the offers of their members, although not necessarily based on ownership relations. The bond of the network is the common goal of the participating entities - the strategic context of the established relationships. The role of the network is to integrate the critical areas of competence of individual members and create intra-network knowledge diffusion structures to achieve the synergy effect.

The characteristic of the functioning of business networks is the combination of competition and cooperation while maintaining both individual (competitive) and expected (convergent) goals of the entities (Hirvensalo et al., 2021).

The analysis of achievements in the field of shaping the concept of a business network allows us to present a model approach (Prenkert, Halle´n, 2006; Ricciardi et al., 2022):

- elements (actors) of the network of connections may include companies, business environment institutions, R&D units, and representatives of local government,
- relations can be formal (based on contracts and agreements) or informal (result from interpersonal contacts),
- the relations between the elements of the network are, firstly, of a cooperative nature - mutual dependencies between the elements, and especially the division of activities and cooperation within a specific collective behavior, not always formalized; secondly, apart from cooperation, there may be competition between actors in the network,
- actors in the network share a sense of separateness from entities outside this network,
- it is possible to identify similarities in the field of activity on which the activity of the network elements is focused,
- elements in the network have a defined common goal, which they want to achieve through the operation of the network.

The diagram of connections in a business network is shown in Figure 2.



F5-Fn – entities (business network participants).
——— network connections.

Figure 2. Diagram of connections in a business network.

Source: own work. based (Ratajczak-Mrozek, 2009).

To sum up, based on previous considerations, it can be assumed that business networks are systems created voluntarily by a group of economic actors of enterprises dealing with a similar field of activity, public and private sphere institutions, which support their activity-related by relations, interacting with the environment and established to achieve common goals.

3.2. Review of research on business networks

In the further steps of the procedure, according to the SLR criteria presented in Table 1, content analysis was carried out.

Analyzing the publication's content made it possible to indicate various criteria for the division and types of business networks from the widely quoted literature. Table 2 presents a list of business network typologies according to the adopted criteria from a literature review.

Table 2.
Review of business network typologies

References	Typology	Division criteria
Cruijssen et al. (2007); Pomponi et al. (2013)	Typology of the collaboration network	collaboration structure, integration level, collaboration scope
Knop, Olko (2008)	Typology of network collaboration	level of formalization
Prenkert, Halle'n (2006)	Typology of business networks	types of resources in the exchange system: conglomerate resources, transformation output, composite resources, assortments, congenial resources
Culpan (2009)	Typology of strategic alliances	equity commitment
Martin et al. (2018); Cruijssen (2020)	Typology of collaboration LSPs	collaboration scope, nature, combined assets, and objectives collaboration scope and integration level collaboration nature, scope, objectives, and assets
Leitner et al. (2011)	Typology of collaboration in the automotive industry	collaboration intensity and flow consolidation

Cont. table 2.

Hannachi, Coleno (2012)	Typology of horizontal coopetition	coordination mechanism based on relationship, "mediation arena"
Franco, Haase (2015)	Typology of alliances between small and medium-size firms	collaboration objectives and strategy ascertainment
Chiambaretto, Le Roy 2016)	Typology of competitive branding	the nature of the agreement (hybrid vs symbolical), the type of partners (direct vs. indirect competitors
Ahola (2018)	Typology of inter-organizational projects	marked-based network, dyad-driven network, integrated core network
Zardini et al. (2020)	An operationalizable typology of business networking logic	views, rules, roles, beliefs, and behavioral expectations on business networking
Yrjölä (2021)	Typology of second-hand business models: connector, supporter, and controller	company's role in mediating between consumers, breadth and depth of the product offerings, company's level of control, seller selection and support mechanisms, revenue streams
Ricciardi et al. (2022)	Typology of business networks	basic relationship configurations - from full cooperation (fairness, sharing, and commitment) to full competition (opportunism, control and rivalry)
Badraoui et al.(2022)	Typology of horizontal logistics collaboration (HLC)	structure, nature, activities, intensity

Source: own work.

The conducted analysis showed the diversity of business networks. Many of the presented typologies refer to cooperation and its various forms, alliances, and logistic networks. Some typologies concern narrowed areas, e.g., sectors such as small and medium-sized firms (Franco, Haase, 2015) or the automotive industry (Leitner et al., 2011).

3.3. Typology of business network models

Then, based on the literature analysis, I proposed my typology of business networks, which is presented in Fig. 3. Four main groups of business networks can be identified: networks originating from industrial districts, strategic networks, cooperation networks, and business networks.

We can talk about different types of business networks within each distinguished group. However, the adopted distinction is not mutually exclusive. For example, clusters are a network model derived from industrial districts, but some are long-term and strategic. Therefore, they were qualified for both groups.

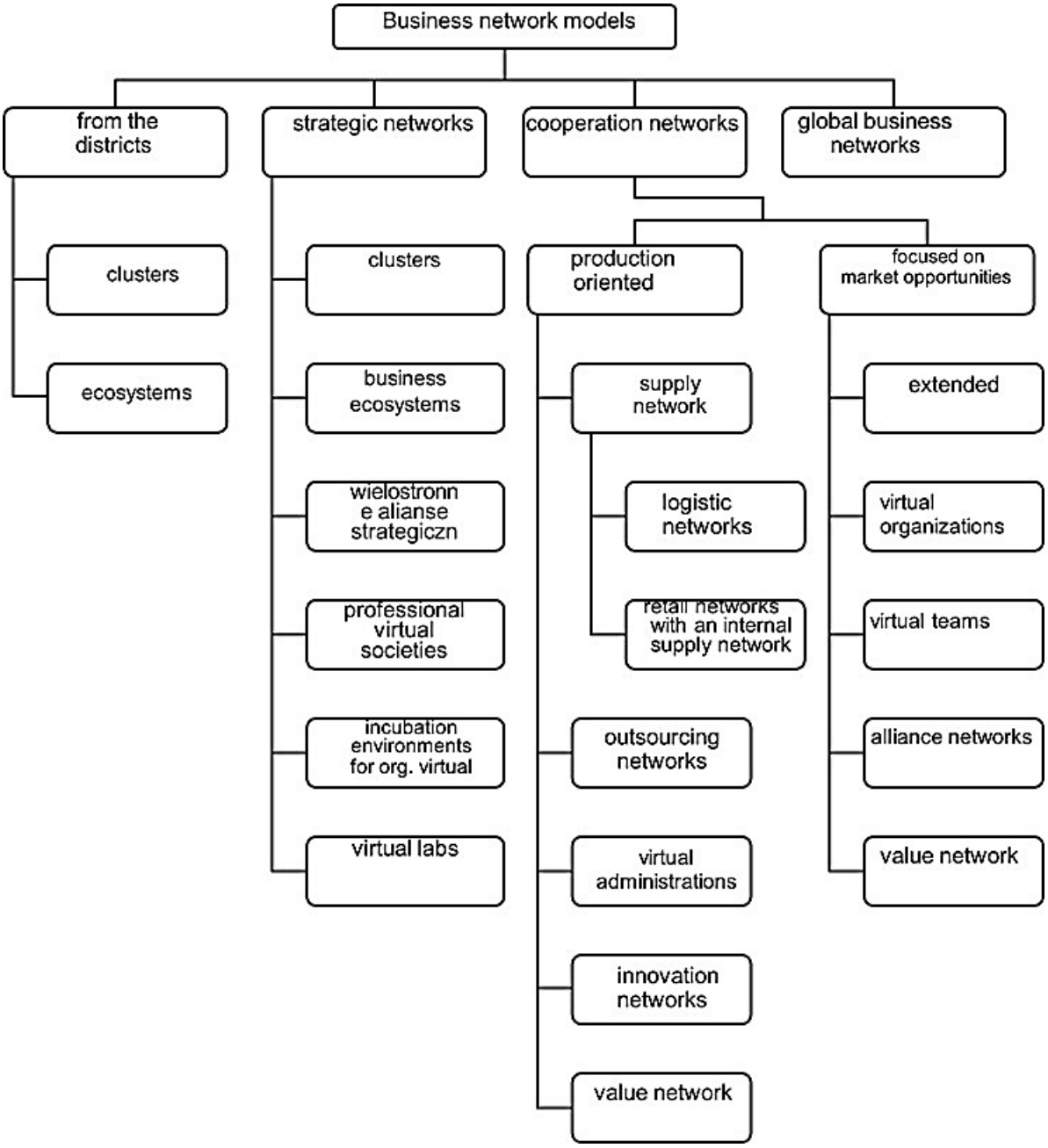


Figure 3. Typology of business network models.

Source: own work.

The first category of business networks is networks from industrial districts: clusters and ecosystems. These are forms of cooperation of organizations of a dual nature, combining competition with collaboration, which arise in all sectors of the economy. They are complex networks of connections between various companies, organizations, institutions, technologies, and other elements that mutually influence each other and the way the market functions. Today, they are often based on digital technologies and innovative solutions.

The second category is strategic (centralized) networks, which are based mainly on vertical integration, are characterized by solid structuring, and have a strategic center that determines the members' typical strategy and areas of activity. Inter-organizational links are of strategic

importance for centralized network partners, regardless of the form of the relationship. In recent years, the creation of so-called alliance networks.

The third category consists of cooperation networks based on cooperation links (horizontal and vertical). This category is the simplest form of inter-organizational network cooperation of enterprises, which gives them relatively large opportunities for the flexible shaping of mutual relationships and joint value building. I mentioned supply, logistics, and outsourcing networks in this category of network models.

The last category is made up of global business networks. The global network is the highest stage of the evolution of network-type solutions, i.e., a form of network thinking adapted to the requirements of corporate globalization. It is a regulatory model rather than just a typical organizational structure. It usually has a hybrid design, meaning that the internal structures of global business networks differ due to combining many types of organizations into one regulatory system.

4. Discussion and research directions

The analysis of the publication's content showed many differences in interpreting the concept of a business network. Many researchers (Kilduff, Tsai, 2003; Hakansson, Snehota; Cook, Emerson, 1978) define business networks as interconnected business relationships. According to the social exchange theory, they constitute exchange networks, i.e., corresponding exchange relations. In the wake of many market researchers, I have adopted the business network interpretation in this study (Easton, Araujo, 1994; Blankenburg, Johanson, 1992; Prenkert, Hallén, 2006), which mainly refers to the theory of market exchange. Business relationships in such networks are interdependent. In addition, some studies also point to the fact that the theoretical conceptualization of a business network derived from social and market exchange contradicts its empirical identification (Prenkert, Hallén, 2006). Theoretically, the network extends in all directions without borders and center, while empirically, it has a clear center and clear boundaries that can be identified.

The above interpretation of the business network leads to the conclusion that it is a comprehensive concept, covering many different network structures that can be described (or distinguished) as models of business networks. The study of network models is one of the current research in network science. In the ongoing discussion on network theory in the literature, there is a solid reference to using various network models in management sciences (Ricciardi et al., 2022; Zardini et al., 2020). Network models constitute representations of a given phenomenon (phenomenon) within the network concept using network data and observations that are not independent. Abstracting the network into a model and its representation requires essential elements, which include:

- nodes (vertices),
- a relationship between at least a pair of nodes (dyad),
- recognition of the network structure.

The analysis of the content of publications resulting from the SLR showed that numerous issues are combined or even identified with the case of business networks (Rosińska-Bukowska, 2012; Knop, Olko, 2008; Franco, Haase, 2015). The study of standard forms of cooperation between enterprises must be deeply rooted in research and literature on the subject. However, there needs to be a systematization of the relationships between the issues mentioned above. Sometimes the topic of network connections needs to be identified with the problem of strategic alliances (Culpan, 2009), a business network is identified with a network organization or a virtual organization (Camarinha-Matos, Afsarmanesh, 2005). In addition, the literature on the subject lacks an answer to whether the term "business network" is not only a general, collective term for various formal forms of cooperation. M. Ratajczak-Mrozek (2009) analyzed the network against various forms and concepts of cooperation. One can agree with the approach presented by her that after meeting additional assumptions that narrow down various forms: standard forms of cooperation, strategic alliances, virtual organizations, networks in logistics, and clusters can be part of a business network according to the network approach. Therefore, including them in the typology proposed in this article seems reasonable.

A literature review shows that business networks are a challenging and complex subject. There are some problems in the analysis of business networks, the most important of which are related to their following characteristics (Barczak, 2020):

- the infinity of connections,
- no clear boundaries,
- strong and weak relationships,
- crossing the boundaries of the company, network, and environment,
- continuous interaction and interdependence.

Researchers indicate that as a consequence of infinite network connections and numerous relationships with the environment, a business network is characterized by a total area of operation, both territorial (network relations go beyond the borders of one country) and objective (Håkansson, Snehota, 1989; Forsgren et al., 1995; Zardini et al., 2020). The network does not have clear boundaries, and they can only be determined by arbitrary judgment. Each participant in the network can set its limits, but in reality, they remain relative (Forsgren, Johanson, 19940. It should be noted that the infinity of network connections implies some additional research problems (Prenkert, Hallén, 2006):

- relationships are far more complex than direct links between the closest links in the supply chain because their functioning is also affected by relations with other market entities,

- due to the lack of clear boundaries, it is difficult to determine their spatial scope fully. There is a risk of adopting a perspective according to which "everything is a network" raises the critical question of how to analyze a permanent structure.

In this regard, it is also worth referring to the concept of strong and weak ties by Granovetter (1973), which is often developed in the literature and the context of business networks. Many authors (Anderson et al., 1994; Jung et al., 2008) transfer this concept also to the area of functioning of business networks, defining first-order relations, i.e., positive and negative effects exerted on two partner companies by their interaction in the primary bilateral relationship and relations second order, which represent as the positive or negative effects exercised on this relationship due to direct or indirect relationships with other relationships.

The company's perception of the external influence exerted on its activities refers to the concept of network context, which is created by the total number of related (directly and indirectly) network links constituted by entities consciously mentioned by a given company as affecting its situation and activities (Blankenburg, 1995). Outside the network context, some entities cannot be identified. Due to the ongoing interactions that constantly lead to the emergence of new relationships, the context of a given company's network (as well as its position in the network) is a variable known only at a given moment. However, regularly visualizing the context of the network is necessary as it allows the enterprise to understand both the conditions affecting it and the far-reaching consequences of its actions.

The conducted analysis also concludes that business networks, being the next (higher) stage of development, contain solutions used earlier, developed within these "lower forms," and then only refined. The analysis of only "sections" of the business network may lead to the erroneous identification of the network with another form of cooperation, which is exposed when viewed from a given perspective. The network model can be established based on the diagnosis of the entire business network, determining the types of internal connections occurring in it, and indicating the dominant organizational forms and the principles of their mutual relations.

The typology of business network models presented in the study plays an important theoretical role. Still, it can also be essential in formulating social and economic practice functioning rules. In this regard, the following theoretical and practical tasks of the developed typology can be indicated:

- systematization, including grouping, ordering, and division of specific categories according to specific criteria,
- analysis of development trends,
- the possibility of making further analyzes and comparisons.

Summing up, the following conclusions can be drawn:

- there is a great diversity in the interpretation of the concept of a business network; in most definitions, researchers refer to the theory of social exchange and the theory of market exchange,

- there is a solid reference to using various network models in management sciences,
- in the literature, there are many approaches to creating typologies (by applying various criteria), as well as many divisions (business network typologies,
- in the study of business networks (and creating their typologies), there are some problems, such as the infinity of connections, the lack of clear boundaries and their penetration, the presence of strong and weak relationships, or continuous interaction and interdependence.
- in the discussion showed that creating a typology of business network models plays an important theoretical role (develops network theories).

The complexity of the issues indicates the need to define directions for further research. Note the following:

Firstly, we are currently observing business integration processes carried out by transnational corporations, i.e., the creation of global business networks (GSB) to implement a competitive strategy adapted to the requirements of a knowledge-based economy.

Secondly, as a consequence of the changes in the global economy, there is a development of multi-level organizational structures in the global space as an expression of the network's adaptation to new challenges. The requirement to benefit from their functioning is to ensure the strategic synergy of resources, structures, and organizational cultures.

Thirdly, business network models will be rapidly developed in the coming years, combined with models based on knowledge and ICT technology. These models are characteristic of the era of the knowledge-based economy, which will gain importance, and information and knowledge will continue to be the critical resources of the enterprise. Business networks are increasingly being digitized, allowing members to connect and collaborate online. This can enable businesses to access new markets, resources, and knowledge and to achieve greater efficiency and innovation.

Geographic expansion is the fourth research direction: business networks can expand geographically by adding new members in different regions. It allows businesses to access new markets, resources, and knowledge.

Fifth, business networks are also increasingly focused on sustainability, incorporating environmentally and socially responsible practices into their operations. It can improve their reputation, attract new customers, and create long-term value.

Overall, the development of business networks is characterized by increasing collaboration and interconnectivity, focusing on geographic expansion, diversification, specialization, digitalization, and sustainability.

5. Summary

In sum, it is worth noting that although analyzing the forms of cooperation between enterprises is deeply rooted in research and literature, there is no systematization of relationships between many issues related to business networks.

The conclusion of the considerations on business network models may be that the essence of the network is not the form of cooperation, but its content, i.e., the nature of the bonds between the participating entities. The network approach is a synthetic and analytical approach using various concepts of cooperation. Therefore it is neither their sum (some elements were rejected and replaced by others) nor none.

In this study, the business network is treated in a broader sense than it results from the assumptions of the origin of the network approach and the model developed by a group of Swedish researchers. It is an internally differentiated category of organizational network models covering various forms of networks, which are included in the study within the four categories indicated earlier. This approach to developing business network typologies is more comprehensive and holistic.

The practical usefulness of the proposal contained in the study is related to the possibility of using the proposed concept in the assessment of various types of business network models, which will enable the formulation of diagnostic findings and conducting comparative and dynamic research in the field of analysis and evaluation of business network models.

The indicated directions of research determine the possibilities of improving the proposed concept. A deeper analysis of business network models and improvement of their typology is recommended, as well as an empirical verification of the proposed concept.

The approach proposed in the study is a response to the growing demand for research on organizational networks, including in the field of a comprehensive approach to business network models. To some extent, it fills the research gap related to the scarcity of studies in this area, although this issue still offers inspiring research potential.

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References

1. Ahola, T. (2018). So alike yet so different: A typology of inteorganisational projects. *International Journal of Project Management, Elsevier, No. 36*, pp. 1007-1018.
2. Alee, V. (2000). Reconfiguring the Value Network. *Journal of Business Strategy*, *Vol. 21, No. 4*, pp. 1-6.
3. Anderson, J., Håkansson, H., Johanson, J. (1994). Dyadic Business Relationships Within a Business Network Context. *Journal of Marketing, Vol. 58, No. 4*, pp. 1-15.
4. Badraoui, I., Boulaksil, Y., Van der Vorst, J. (2022). A typology of horizontal logistics collaboration concepts: an illustrative case study from agri-food supply chains. *Benchmarking: An International Journal, Vol. 29, No. 4,* pp. 1214-1240.
5. Barczak, B. (2020). *Modele sieci organizacyjnych.* Kraków: Wydawnictwo Uniwersytetu Ekonomicznego.
6. Blankenburg, D., (1995). *A network approach to foreign market entry,* In: K. Molier, D.T. Wilson (Eds.), *Business marketing: an interaction and network perspective.* USA: Wilson D.T., Kluwer Academic Publishers.
7. Blankenburg, D., Johanson, J. (1992). Managing network connections in international business. *Scandinavian International Business Review, Vol. 1, No. 1*, pp. 5-19.
8. Camarinha-Matos, L.M., Afsarmanesh, H. (2005). Collaborative networks: a new scientific discipline. *Journal of Intelligent Manufacturing, Vol. 16. Iss. 4-5*, pp. 439-452.
9. Chiambaretto, P., Gurău, C., Le Roy, F. (2016). Coopetitive branding: Definition, typology, benefits and risks. *Industrial Marketing Management, No. 57*, pp. 86-96.
10. Child, J., Faulkner, D. (1998). *Strategies of Co-operation. Managing Alliances, Networks, and Joint Ventures.* Oxford: Oxford University Press.
11. Cook, K.S., Emerson, R.M. (1978). Power, equity and commitment in exchange networks. *American Sociological Review, Vol. 43*, pp. 721-39.
12. Cruijssen, F. (2020). *Cross-chain collaboration typology.* In: F. Cruijssen (Eds.), *Cross-Chain Collaboration in Logistics* (pp. 67-90). Cham: Springer.
13. Cruijssen, F., Dullaert, W., Fleuren, H. (2007). Horizontal cooperation in transport and logistics: a literature review. *Transportation Journal, Vol. 46, No. 3*, pp. 22-39.
14. Culpan, R. (2009). A fresh look at strategic alliances: research issues and future directions. *International Journal of Strategic Business Alliances, Vol. 1, No. 1*, pp. 4-23.
15. Easton, G., Araujo, L. (1994). Market exchange, social structures and time. *European Journal of Marketing, Vol. 28, No. 3*, pp. 72-84.
16. Forsgren, M., Hagg, I., Håkansson, H., Johanson, J., Mattson, L.G. (1995). *Firms in networks. A New Perspective on Competitive Power.* Uppsala: Uppsala University.

17. Forsgren, M., Johanson, J. (1994). *Managing Internationalizationin Business Networks.* In: M. Forsgren, J. Johanson, (Eds.), *Managing Networks in International Business.* London: Gordon and Breach Science Publishers.
18. Franco, M., Haase, H. (2015). Interfirm alliances: a taxonomy for SMEs. *Long Range Planning, Vol. 48, No. 3*, pp. 168-181.
19. Granovetter M. (1973). The Strength of Weak Ties. *American Journal of Sociology, Vol. 78, Iss. 6*, pp. 1360-1380.
20. Hakansson, H., Snehota, I. (1989). No Business is an Island. *Scandinavian Journal of Management Studies, Vol. 5, No. 3*, pp.187-200.
21. Hakansson, H., Snehota, S. (1995). *Businnes Networks.* London: Routledge.
22. Hannachi, M., Coléno, F. (2012). How to adequately balance between competition and cooperation? A typology of horizontal coopetition. *International Journal of Entrepreneurship and Small Business, Vol. 17, No. 3*, pp. 273-289.
23. Hirvensalo, A., Teerikangas, S., Reynolds, N., Kalliomäki, H. Mäntysalo, R. Mattila, H., Granqvist, K. (2021). *Agency in Circular City Ecosystems - A Rationalities Perspective. Sustainability, No. 13*, p. 2544.
24. Jung, D., Wu, A., Chow, C.W. (2008). Towards understanding the direct and indirect effects of Networks: Selecting Partners to Reduce Risk in Economic Development. *The Leadership Quarterly, No. 19*, pp. 582-594.
25. Kilduff, M., Tsai, W. (2003). *Social Networks and Organizations.* London: Sage.
26. Knop, L., Olko, S. (2008). Ewolucja form organizacyjnych sieci współpracy. *Organizacja i Zarządzanie, No. 1*, pp. 101-116.
27. Leitner, R., Meizer, F., Prochazka, M., Sihn, W. (2011). Structural concepts for horizontal cooperation to increase efficiency in logistics. *CIRP Journal of Manufacturing Science and Technology, Vol. 4, No. 3*, pp. 332-337.
28. Martin, N., Verdonck, L., Caris, A., Depaire, B. (2018). Horizontal collaboration in logistics: decision framework and typology. *Operations Management Research, Vol. 11, No. 1-2*, pp. 1-19.
29. Pomponi, F., Fratocchi, L., Tafuri, S.R., Palumbo, M. (2013). Horizontal collaboration in logistics: a comprehensive framework. *Research in Logistics and Production, Vol. 3, No. 4*, pp. 243-254.
30. Prenkert, F., Halle´n, L. (2006). Conceptualising, delineating and analysing business network. *European Journal of Marketing, Vol. 40, No. 3/4*, pp. 384-407.
31. Ratajczak-Mrozek, M. (2009). Sieci biznesowe na tle innych koncepcji kooperacji przedsiębiorstw. *Gospodarka Narodowa. The Polish Journal of Economics, Vol. 233, Iss. 7-8*, pp. 79-91.
32. Ricciardi, F., Zardini, A., Czakon, W., Kraus, S. (2022). Revisiting the cooperation–competition paradox: A configurational approach to short- and long-term coopetition

performance in business networks. *European Management Journal, Vol. 40, Iss. 3*, pp. 320-331.

33. Rosińska-Bukowska, M. (2012). *Rozwój globalnych sieci biznesowych jako strategia konkurencyjna korporacji transnarodowych. Przypadek sektora motoryzacyjnego*. Lodź: Wydawnictwo Uniwersytetu Łódzkiego.
34. Yrjölä, M., Hokkanen, H., Saarijärvi, H. (2021). A typology of second-hand business models*, Journal of Marketing Management, No. 37, Iss. 7-8*, pp. 761-791.
35. Zardini, A., Ricciardi, F., Bullini Orlandi, L., Rossignoli, C. (2020). Business networks as breeding grounds for entrepreneurial options: organizational implications. *Review of Managerial Science, vol. 14, No. 5.* Springer, pp. 1029-1046.

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OVERVIEW OF THE CONCEPTS OF BOTTLENECK IN THE OPERATION PROCESS

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Purpose: This paper aims to provide insight into currently available corporate operation and control management approaches through the examined articles, focusing on bottlenecks and closely related theories.
Design/methodology/approach: The reviewed publications, which focus on the theory of constraints, different approaches, the concept of bottlenecks, and the presentation of related methods, bring us closer to understanding the changes that have taken place in the past decades.
Findings: The immense impact of digitization and changes in demand affect the requests placed on companies; the way consumer needs are met has changed and accelerated, to which companies must adapt. In the case of services and products, the primary goal of manufacturers and service providers is to generate revenue and profit by satisfying consumer needs. For this, creating and maintaining an efficient operating system that does not contain restrictive elements is necessary. This publication provides a comprehensive overview of how the approach to the unified concept of the bottleneck is an effective tool for companies to improve their processes.
Research limitations/implications: The current study analyzed some of the most relevant publications in the ScienceDirect database based on the keywords. This approach certainly serves as a beginning point for the understanding that to focus on the researched problem space, a systematic literature review is required.
Originality/value: This study provides insight and supports the importance of a unified approach to identifying constraints for effective operational processes.

Keywords: operation management, operation control, bottleneck, Theory of Constraints.

Category of the paper: General review.

1. Introduction

This paper aims to provide an overview of the publications related to corporate operations and control management, with a particular emphasis on the concept of bottlenecks and theories that are closely related to it. Specifically, this article will focus on the idea of bottlenecks and

theories. The Theory of Constraints, the concept of bottlenecks, and connected techniques are three of these theories vital for appreciating the alterations that have taken place over the previous few decades and the essential characteristics of the industry.

To get a more accurate view of the bottleneck mentioned above models and the closely related theories, an outline of the new challenges that Industry 4.0 poses to corporations is essential. It will be seen how Industry 4.0 requires organizations to adopt a new approach from different aspects.

The review is based on publications found in the database at sciencedirect.com. These publications reference predefined keywords rather than terms specific to the domain or field being discussed. The selection of the articles was made at random because the purpose of this paper is not to conduct a comprehensive literature review but rather provide an overview of the phenomenon that is being studied. The recent study is fundamental for further research.

Companies can accomplish their management goals by improving their manufacturing processes and their service processes, if they have a thorough understanding of the universal bottleneck and how it works, as well as a definition of the effects of this bottleneck. Undoubtedly, digitalization has had an effect, and not only has it shaped consumer demands, but it has also accelerated and altered how consumer needs are met. As is the case with goods and services, the primary objective of businesses that produce goods or provide services is to generate revenue and profit by catering to customers' requirements. To accomplish this, they will need to design an operating system that is effective and allows them to reach their management objective, which is rare to have fewer customers but rather to have more money.

The casual observation made by Karmarkar and Apte (2007) implies that the focus of research in operations was at the level of the shop floor twenty years ago. This included "process operations, scheduling, batching and buffering, flows, bottlenecks, queues, and routing" (Karmakar, Apte, 2007, p. 450). A significant number of the techniques that were created to address these issues may also be used to improve information processes. For instance, the processing of information at the level of transactions has many similarities with the processing of material. However, there are other components of information processing that are essentially distinct from one another (Karmarkar, Apte, 2007).

2. The importance of bottleneck

Bottlenecks hamper the performance of companies. The interpretation of bottlenecks focused mainly on the processes used in the production environment, neglecting the mechanism of reducing performance in other contexts. Understanding, defining, and examining the convention of bottlenecks in other environments can give us a more complex picture.

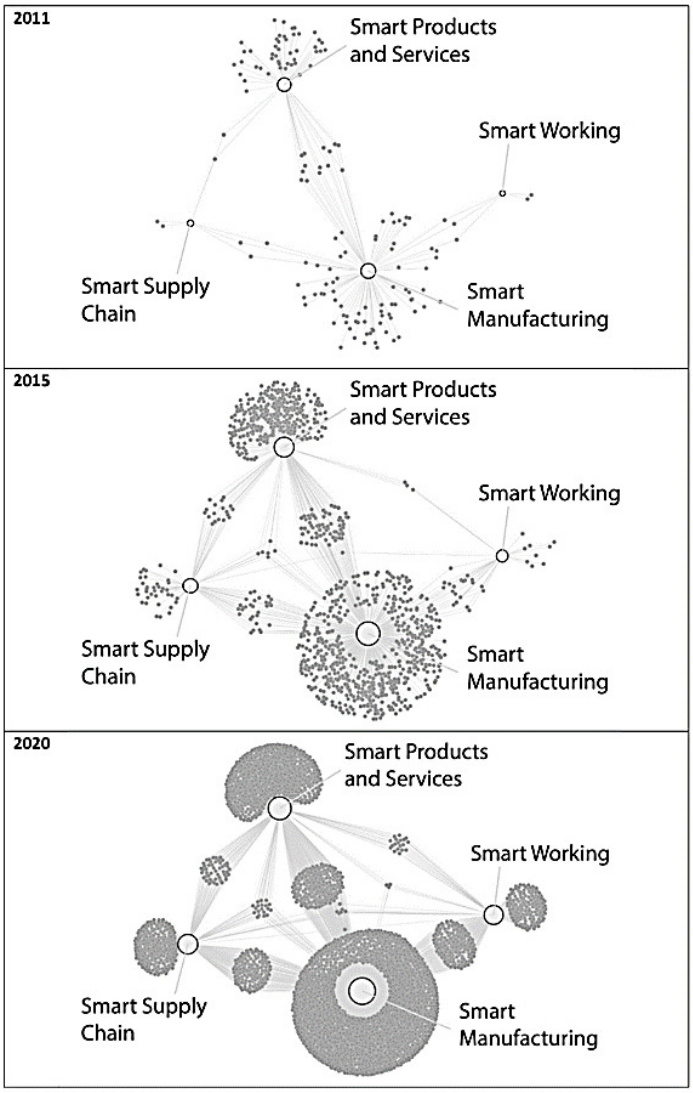
Providing a summary of the requirements of Industry 4.0 is essential before discussing the importance of the bottleneck and the closely related theories. According to Zhou et al. (2015), smart manufacturing is at the forefront of Industry 4.0, the fourth industrial revolution. Industry 4.0 is based on the creation of a cyber-physical system (CPS) that creates a digital and smart factory to make manufacturing more digital, information-driven, customizable and greener. Industry 4.0 aims to create a flexible manufacturing model with real-time interactions between people, goods and technology. A factory that takes customer orders manufactures and ships goods instantly would eliminate the various sales and distribution channels that would affect the current e-commerce sales paradigm. For this to proceed efficiently, decisions on the narrow cross-sections and the optimization of processes are essential. Industry 4.0 will replace old industrial production processes and will impact future manufacturing in Germany and beyond. Digital systems will make future manufacturing systems smarter.

Knowledge-based and thinking factories will increase the efficiency and competitiveness of factories. The German Electricity Association predicts that Industry 4.0 will increase industrial productivity by 30%. In the first three industrial revolutions, mechanical, electrical and information technologies were invented to improve industrial production. The first industrial revolution improved efficiency through hydropower, steam power and machine tools; the second industrial revolution brought electricity and mass production (assembly lines); the third industrial revolution accelerated automation through electronics and information technology; and now the fourth industrial revolution is emerging, spearheaded by CPS technology, which integrates the real world with the digital world (Zhou et al., 2015).

Javaid et al. (2022) argue that Industry 4.0 redefines the digital revolution with new market models, higher engineering investments, streamlined processes, shift detection/projective analysis, and expanded industry collaboration. Increasing data capture solutions enable research by incorporating modern instrumentation technologies and analyzing production processes. Physical devices may now observe energy and utility management quantities, comprehend processes and monitor applied control variables. Data, analytics, and networking drive this transformation in production and distribution. Industry 4.0 may utilize and incorporate quality into a company's technological advantages. Javaid et al. (2022) stated that Industry 4.0 technology and software might develop personalized designs digitally. Production, marking, and packing errors provide apparent dangers. Industry 4.0 technology requires tight testing and monitoring. Early manufacturing shifts used economies of scale to manufacture more of the same product. Mechanical producers must provide. Industry 4.0 promises solutions. Intelligent plants with digitally planned integrated workflows offer incredible design and manufacturing flexibility. Data collection, measurement and assessment, inventory management and quality control, and input, in-process, and completed products application techniques. The consequence is increased product uniformity and processes. Digitalizing manufacturing collaboration processes accelerates and sustains growth. Decentralization, interoperability, and virtualization help reduce errors and expenses. IoT-enabled sensors provide active data to engineers and other

computers. Apps give maintenance alerts. Big Data may discover patterns, themes, and correlations using computerized analytical tools and techniques. Industry leaders want to use big data to enhance procedures (Javaid et al., 2022)

Between 2011 and March of 2020, Meindl et al. (2021) examined the development of articles that referred to the four smart dimensions, the keywords associated with each smart dimension, and the significance of various journals. Figure 1, a visualization of the network, summarizes the result that most research on Industry 4.0 focuses on smart manufacturing. Since 2011, it was discovered that the proportion of publications related to smart manufacturing has remained approximately constant at roughly 70 percent. There is a relation between smart manufacturing and other smart technologies in around 16% of the articles on smart manufacturing. (Meindl et al., 2021)



Note. The white dots represent the smart dimensions. The size of those circles represents the logarithm of the number of edges (relevant articles until the year). Each of the grey dots represents an article. The lines (edges) indicate a relation between a smart and an article (Meindl et al., 2021, p. 9).

Figure 1. Evolution of the network of articles from 2011 to 2020 (March).

Source: Meindl et al., 2021, p. 9.

Aoun et al. (2021) have also examined the foundations, challenges, barriers and constraints of Industry 4.0 and the areas where they believe that so-called blockchain technology can bring new functionality and added value to the implementation of Industry 4.0. The several approaches show that the implementation of Industry 4.0 poses several challenges for both the business sector and researchers (Aoun et al., 2021).

Based on the main features of Industry 4.0, the general application of bottlenecks to manufacturing and service providing and the importance of managing them have been outlined. According to Chatterjee et al. (2022), several definitions of bottlenecks have been formulated in the literature, which is clearly not universally applicable in manufacturing and service environments. As the authors of the paper point out, Henry Ford introduced the moving assembly line as part of his efforts to produce affordable cars, understanding that the workstation with the highest processing demand, the so-called bottleneck, limits the system's performance. The focus on bottlenecks implicitly captured the importance of capacity utilization metrics as the primary tool for management planning and control in such high-volume, low-variety environments. Identifying bottlenecks becomes complicated when moving from a high-volume, low-variety, repetitive manufacturing scenario to low-volume and project workloads. The complexity of operations has increased enormously since the days of Henry Ford. Rigid assembly lines have given way to various forms of flexible manufacturing systems. Continuous product innovation and the resulting need for product multiplication have led to increased product variety. The fact that Karmarkar and Apte (2007) made a transitory comment on the emphasis of research in operations twenty years ago suggests that the observation was made at the same level as the shop floor. "Process operations," "scheduling," "batching and buffering," "flows," "bottlenecks," and "queues" were all covered in this (Karmakar, Apte, 2007, p. 450). A sizeable portion of the solutions that were developed to solve these problems also have the potential to be used in the process of enhancing information systems. For instance, there are a lot of parallels to be drawn between the processing of material and the processing of information at the level of transactions. Nevertheless, there are more aspects of information processing that may be thought of as being fundamentally separate from one another (Culot et al., 2020; Huang et al., 2020; Karmarkar, Apte, 2007).

There is also no universally applicable bottleneck-focused approach that considers the changing manufacturing and service environment and conditions. The management science literature does not provide a bottleneck that is universally valid for all production/service scenarios, so practising managers who operate a production/service facility have an intuitive way of managing the complexity of focusing on the bottleneck.

For example, Sahin (2008), based on Goldratt's (2006) definition, stated that resources could be either bottlenecked or unconstrained resources. Goldratt (2006) interpreted a bottleneck resource as any resource with a capacity equal to or less than the demand for it and a non-constrained resource as a resource with a capacity more significant than the demand. Goldratt (2006) argues that bottlenecks will always remain bottlenecks, and therefore decision-makers

must find sufficient capacity to meet the bottleneck so that it grows close to the level of demand. (Sahin, 2008)

2.1. Theory of Constraints

The lack of a universally applicable definition, i.e., a general approach focusing on bottlenecks, was partially remedied by the Theory of Constraints (TOC) proposed by Goldratt and Cox in 1984 (Chatterjee, Mukherjee, 2022; Pacheco et al., 2021).

Following Rand (2000) briefly, the Theory of Constraints is based on five steps. According to Goldratt (1984), the constraint of a system is the part of the system that constrains the purpose of the system. In the case of a money-producing organization, the main aim is for the present and for the future to make more money. In terms of production planning, the constraint on the system is the bottleneck. The first step is to identify the system's constraints; the second step is to decide how the system exploits the constraints; the third step is to subordinate everything else to the first two decisions; the fourth step is to highlight the system's constraint or constraints. Finally, in the fifth step, if a constraint has been removed in the previous steps, return to the first step, and thus prevent inertia from causing the constraint on the system (Rand, 2000).

Goldratt and Cox (1984) argue that the goal of an organization is to make more money now and, in the future, as mentioned above. To earn income, the throughput of an operating system must increase while inventory and operating costs decrease. Therefore, the performance of any system is limited by the degree of throughput at the system boundary; identifying and eliminating the system boundary as the weakest link in the chain is the main idea of TOC. As can be seen, it focuses on the continuous improvement of the system by managing the boundaries, a theory that can be applied to almost any industry and almost any size of the company. TOC has become accepted as a management philosophy and has received wide attention from practitioners and academics (Şimşit et al., 2014).

Balderstone and Mabin (1998), based on a review of published applications, argue that "TOC works very well, even with only partial application of the methodology"; and that "TOC is not a panacea, not a prescription, but a philosophy to help lead to success". (Balderstone, Mabin, 1998). Izmailov (2014) stated that the Theory of Constraints presents a new challenge to the traditional view of organizational profitability. In a wide variety of organizations and environments, its application helps to achieve goals, provided that the theory is applied according to the purpose or the necessary requirements.

Simsit et al. (2014), based on a historical evaluation of TOC over five eras, as it is shown in Figure 2, found that the Theory of Constraints had evolved into a management theory by the time of publication, both in terms of methodology and scope, whereas it was initially a production method. In parallel with the recognition of the importance of the Theory of Constraints, academics and practitioners have also recognized, and studies have begun to shift the emphasis to TOC measures, the thought process that is an essential tool of TOC. These five

focusing steps are continuous improvement techniques and critical chain project management. More recent applications of TOC involve the use of the thinking process to a relatively large extent, especially in the service sector, where it is often used in the implementation of TOC. Applying the Theory of Constraints focuses largely on how top management manages human behavior in the project network and in post-project management. Rand (2000) formulated the following key messages regarding the technical aspects: avoiding milestones that are integral to project management; focusing on critical areas by identifying the critical chain, and inserting buoys at the appropriate points in the project network. The suggestion to avoid milestones is surprising, in his view, because they can cause delays in project completion. For many, it is counterintuitive. Acceptance of milestone abandonment depends on understanding the psychology of the workforce. Concern about focusing on critical areas is well established in project management, as exemplified by the critical path, so an extension to the critical chain to include activities using scarce resources is unlikely to be rejected out of hand.

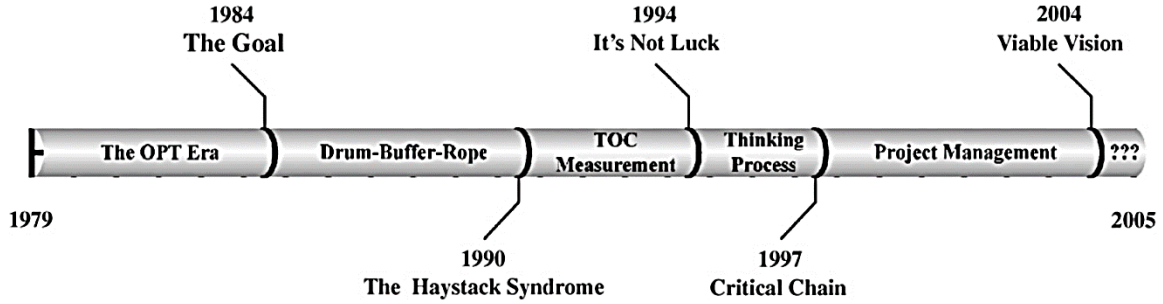


Figure 2. Timelines of major eras in the development on TOC.

Source: Watson et al., 2007; Meindl et al., 2021, p. 9.

The concept of buffers - whether project, feed, or resource - can be easily added to existing approaches, although there may be reluctance to reduce the time of activities that the use of buffers implies.

2.2. Bottleneck

According to Chatterjee et al. (2022), the term bottleneck, widely used in the operational management literature, is defined in few cases, even though practitioners are fully aware of what it means when a resource is classified as a bottleneck. Chatterjee et al. (2022) is quoted by Goldratt (1997), thought that "An hour lost at a bottleneck is an hour lost for the entire system. An hour saved at a non-bottleneck is a mirage" (Chatterjee et al., 2022, p. 3) is the essence of the concept of bottleneck, highlighting its decisive role. In the context of a production/service system, they believe that this means that the improvement of the whole ("whole system") is possible if and only if a significant part of the whole ("bottleneck") improves. All this is based on the setting of the loose conditions applied in the production or service environment.

The system theory interpretation of the bottleneck concept, the new bottleneck management, is Hinckeldeyn et al. (2014) described by system theory as the process of product design and development as the relationship between input and output, as shown in Figure 3. In their opinion, two types of inputs should be considered when dealing with bottlenecks. Input data is received in the product design and engineering process e.g., in the form of customer orders and development projects, which is the first type of input, the second type of input is engineering capacity (Hinckeldeyn et al., 2014). The psychological aspect of the workforce for the examination and understanding of processes also comes to the fore in this model, as was the case with the factors to be taken into account in rand (2000) presented above, since according to Hinckeldeyn et al. (2014), the second type of input, the capacity, comes from engineers and technicians. The combination of the first and second types of input determines the output of the process. In the case of engineering and product design processes, Hinckeldeyn et al. (2014) say the output is entered into the information needed to produce the new product. As an example, drawings, work designs and process descriptions are mentioned. In their view, this approach is intended to improve the performance of the process mentioned above or similar, as it can be used well as a control mechanism. Bottlenecks, in this case, are detected if it exceeds engineering capacity by measuring the line of work facing the engineering resource.

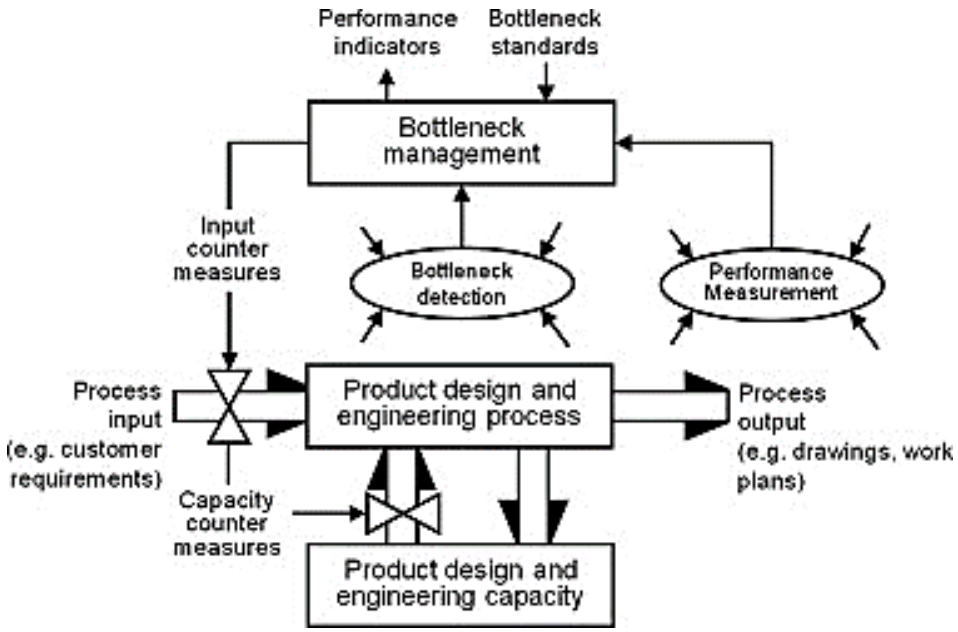


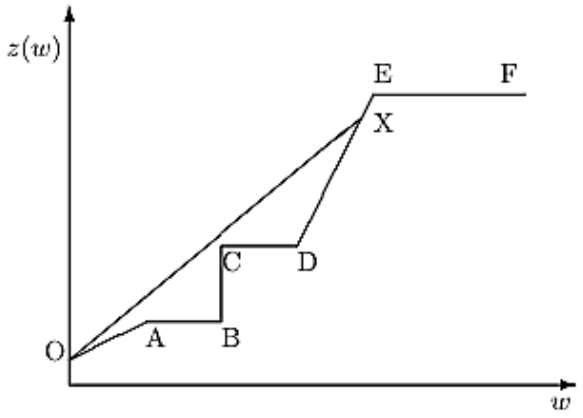
Figure 3. Bottleneck management concept for product design and engineering processes.
Source: Hinckeldeyn et al., 2014.

In their study, Chatterjee et al. (2022) classified bottleneck definitions into five groups based on their basic characteristics, according to whether they are capacity-based, critical route-based, structure-based, algorithm-based, or system performance-based definitions. Bottleneck definition based on system performance is considered, in a different way than that of others, giving it strict shadow price-based frameworks, applicable to various production environments such as projects, jobs, intermittent production, assembly lines and continuous flow processes.

Among the definitions they mentioned, in this case, the definition that respects the additional conditions of looseness mentioned above is mentioned, and the uniqueness of existence is guaranteed. Quoting Chatterjee et al. (2022), the widely available definition does not assume any predetermined features in the production hall that would limit its applicability, does not declare the method of capacity expansion, nor does it define the goals of decision-makers, "A set of constraints with strictly positive average shadow price is defined as bottleneck" (Chatterjee, Mukherjee, 2022).

According to Chatterjee et al. (2022), this universal bottleneck definition means that the bottleneck may consist of a single constraint or a collection of constraints that together constitute the resource. Following Chatterjee et al. (2022), i.e., in a time-indexed formulation of a scheduling problem, the set of constraints that determine the availability of a resource for each time slice may be a bottleneck.

Mukherjee and Chatterjee (2006) agree that before Kim and Cho (1988), there was no valid public interpretation of the concept of average shadow price, as illustrated in Figure 4, for economic integer programming.



Note. In Figure 1, O−A−B−C−D−E−F is the piecewise linear curve obtained by plotting the objective function value zk(w) as w increases. Let X be any point on this curve. The average shadow price ASPCk is then the maximum gradient of the straight line OX (Mukherjee, Chatterjee, 2006, p. 14).

Figure 4. Graphical representation of Average Shadow Price.

Source: Mukherjee, Chatterjee, 2006; Meindl et al., 2021, p. 9.

The inclusion of the average shadow price in the definition of bottleneck provides an opportunity to apply in addition to the service sector and extend the usage of it widespread as manufacturing processes.

Based on this literature processing, there is a clear need for a universally usable framework and its elements to help operating managers make decisions in line with company goals. At the same time, it is crucial to highlight the factor and resource that has been revealed in connection with the research, and that is the human factor in the processes, the approach of which the approach to psychology will not reflect reality only on the assumption of an economic, rational approach. According to Herbert Simon (1987) used the theory of bounded

rationality to establish for economists and economic professionals a shift in the view that ignoring human factors distorts models and is, therefore, less useful in practice (Campitelli, Gobet, 2010; Kuo et al., 2021; Simon, 1984).

3. Conclusion

The fourth industrial revolution, also known as Industry 4.0, redefines the digital revolution by introducing new market models, enhanced engineering inputs, faster processes, and shift detection and predictive analysis. The collection of data will become easier thanks to technological advances and the operations of modern industry. Energy, utilities, and process control are all monitored by various physical instruments. Data, analytics, and networking are revolutionizing the production and distribution processes. In the age of Industry 4.0, quality can be a competitive advantage for a company. Software developed with Industry 4.0 can reportedly create digitally customized designs, as Javaid et al. (2022) stated. Errors in manufacturing, labelling, and packaging can put consumers in danger. The scale was the primary factor in early industrial shifts that increased productivity. Smart factories have digitally connected processes, which allows for more remarkable design and manufacturing flexibility. Applications include data collecting, measurement, assessment, inventory management, quality control, and applications for the input, in-process, and finished product. Both the process and the product's consistency are getting better. The process of digitizing manufacturing contributes to economic expansion. Errors and costs can be cut by reducing centralization, increasing interoperability, and adopting virtualization. The leaders of this industry feel that big data has the potential to improve operations, but in order for this to happen, its decision-makers need to be aware of the bottlenecks that exist in the production processes of both goods and services.

In the manufacturing context, bottlenecks were primarily interpreted in terms of the processes that were carried out there, and the mechanism of lowering performance was neglected. A complete picture may be obtained by first comprehending, defining, and then examining the bottleneck convention in various settings. Henry Ford is credited with the invention of the moving assembly line. He did it with the knowledge that the workstation restricts the system's performance with the highest processing demand. This workstation is referred to as the "bottleneck." The idea behind the TOC is to locate and remove the system boundary that constitutes the chain's weakest link. This is the fundamental notion behind TOC.

Implementing the theory in the right circumstances makes it possible to achieve goals in diverse contexts, such as inside businesses and geographical areas, provided that it is applied suitably. The behavior of individuals who are participating in the project network and post-project management can be governed by using the aspect of the Theory of Constraints that is observed the most frequently. The thinking process is commonly utilized in TOC

implementation, and more contemporary TOC programs use this process extensively, particularly in the service business. This holds especially true when considering the TOC implementation process. Despite the high likelihood of this outcome, extending the critical chain to include activities that call for limited resources is unlikely to be denied. The term "bottleneck," which only has a defined meaning in a select number of specific settings, is frequently utilized in the written material of operational management.

According to Hinckeldeyn et al. (2014), the outcome of the engineering and product design processes is included in the information required to construct the new product. In this scenario, bottlenecks are found when the volume of work the engineering resource must complete exceeds the capacity of the engineering resource. The research conducted by Chatterjee and colleagues in 2022 classified bottleneck definitions into five distinct groups according to the essential qualities shared by each. The definition of a bottleneck, based on the system's performance, is considered differently from the other purposes of the bottleneck. It makes it possible to create rigorous price-based frameworks that may be applied to projects, tasks, intermittent production, assembly lines, and processes with continuous flow. The utilization of the service in industries other than manufacturing is now a distinct possibility due to the inclusion of the average shadow price in the definition of the bottleneck.

Limitations: Based on the keywords, the present research partially reviewed the most relevant publications in the ScienceDirect database. This method undoubtedly represents a starting point that a systematic literature review is necessary to narrow down the examined problem area.

References

1. Aoun, A., Ilinca, A., Ghandour, M., Ibrahim, H. (2021). A review of Industry 4.0 characteristics and challenges, with potential improvements using blockchain technology. *Computers & Industrial Engineering*, *162*, 107746. https://doi.org/10.1016/J.CIE.2021.107746.
2. Balderstone, S.J., Mabin, V.J. (1998). *(PDF) A Review of Goldratt's Theory of Constraints (TOC) -- lessons from the international literature*. https://www.researchgate.net/publication/2497262_A_Review_of_Goldratt%27s_Theory_of_Constraints_TOC_--_lessons_from_the_international_literature.
3. Campitelli, G., Gobet, F. (2010). Herbert Simon's Decision-Making Approach: Investigation of Cognitive Processes in Experts. *Review of General Psychology*, *14*(4), 354-364. https://doi.org/10.1037/a0021256.
4. Chatterjee, A.K., Mukherjee, S. (2022). *The Concept of Bottleneck*. https://www.researchgate.net/publication/228468524.

5. Culot, G., Nassimbeni, G., Orzes, G., Sartor, M. (2020). Behind the definition of Industry 4.0: Analysis and open questions. *International Journal of Production Economics*, *226*. https://doi.org/10.1016/J.IJPE.2020.107617.
6. Hinckeldeyn, J., Dekkers, R., Altfeld, N., Kreutzfeldt, J. (2014). Expanding bottleneck management from manufacturing to product design and engineering processes. *Computers & Industrial Engineering*, *76*, 415-428. https://doi.org/10.1016/J.CIE.2013.08.021.
7. Huang, G.Q., de Koster, R., Yu, Y. (2020). Editorial: Online-to-offline ecommerce operations management (EOM). *Transportation Research Part E: Logistics and Transportation Review*, *138*, 101920. https://doi.org/10.1016/J.TRE.2020.101920.
8. Izmailov, A. (2014). If Your Company is Considering the Theory of Constraints. *Procedia - Social and Behavioral Sciences*, *150*, 925-929. https://doi.org/10.1016/J.SBSPRO. 2014.09.103.
9. Javaid, M., Haleem, A., Singh, R.P., Suman, R., Gonzalez, E.S. (2022). Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability. *Sustainable Operations and Computers*, *3*, 203-217. https://doi.org/10.1016/J.SUSOC. 2022.01.008.
10. Karmarkar, U.S., Apte, U.M. (2007). Operations management in the information economy: Information products, processes, and chains. *Journal of Operations Management*, *25*(2), 438-453. https://doi.org/10.1016/j.jom.2006.11.001.
11. Kuo, T.C., Hsu, N.Y., Li, T.Y., Chao, C.J. (2021). Industry 4.0 enabling manufacturing competitiveness: Delivery performance improvement based on theory of constraints. *Journal of Manufacturing Systems*, *60*, 152-161. https://doi.org/10.1016/J.JMSY. 2021.05.009.
12. Meindl, B., Ayala, N.F., Mendonça, J., Frank, A.G. (2021). The four smarts of Industry 4.0: Evolution of ten years of research and future perspectives. *Technological Forecasting and Social Change*, *168*. https://doi.org/10.1016/J.TECHFORE.2021.120784.
13. Mukherjee, S., Chatterjee, A.K. (2006). Unified Concept of Bottleneck. *Indian Institute of Management Ahmedabad-380015 India*.
14. de Pacheco, D.A.J., Antunes Junior, J.A.V., de Matos, C.A. (2021). The constraints of theory: What is the impact of the Theory of Constraints on Operations Strategy? *International Journal of Production Economics*, *235*. https://doi.org/10.1016/ J.IJPE.2020.107955.
15. Rand, G.K. (2000). Critical chain: the theory of constraints applied to project management. *International Journal of Project Management*, *18*, 173-177. http://www.goldratt.com.A.
16. Sahin, O. (2008). *The Theory of Constraints and Its Application in a Manufacturing Firm*. Istanbul Technical University. https://www.researchgate.net/publication/346266769_ The_Theory_of_Constraints_and_Its_Application_in_a_Manufacturing_Firm.
17. Simon, H.A. (1984). On the behavioral and rational foundations of economic dynamics. *Journal of Economic Behavior and Organizations*, *5,* 35-55.

18. Şimşit, Z.T., Günay, N.S., Vayvay, Ö. (2014). Theory of Constraints: A Literature Review. *Procedia - Social and Behavioral Sciences*, *150*, 930-936. https://doi.org/10.1016/J.SBSPRO.2014.09.104.
19. Watson, K.J., Blackstone, J.H., Gardiner, S.C. (2007). The evolution of a management philosophy: The theory of constraints. *Journal of Operations Management*, *25*(2), 387-402. https://doi.org/10.1016/J.JOM.2006.04.004.
20. Zhou, K., Taigang, L., Zhou, L. (2015). Industry 4.0: Towards Future Industrial Opportunities and Challenges. 978-1-4673-7682-2/15/$31.00 ©2015 IEEE 21472015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), 2147-2152.

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ANALYSIS OF AN ENTERPRISE'S SUPPLY CHAIN MANAGEMENT BY MEANS OF THE MEASURE METHOD

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Objective: The objective of this article is to present the basic issues related to the functioning of a balanced scorecard in an enterprise. Becoming familiar with and analyse selected areas of a monitored enterprise and showing how to make practical use of the information gathered about the occurring problems.
Design/methodology/approach: It was decided to use the tools of a goal-based measure system to determine the causes of the problem, which can be generally applied to supply chain assumptions. It should be noted that this set is only exemplary, but is nevertheless intended to be used as accurately as possible to assess the supply chain in relation to an enterprise's strategy.
Findings: The before-and-after analysis of the changes made it possible to determine whether the problem had been solved and what benefits the enterprise had gained. By examining the timing of individual actions, it was possible to identify a course of action for the future.
Uniqueness/value: The results of the study can be used in strategic decisions of an enterprise in terms of measure optimisation.

Keywords: supply chain, balanced scorecard, logistics measure.

1. Introduction

The individual measures relating to the logistics subsystems present in companies can be used in a factual and logical way in relation to a specific enterprise, as a research tool to assess it. It should be noted, however, that there are a number of specialised tools that are a type of an algorithm for proceeding as well as a well-thought-out detailed area of research (Mesjasz-Lech, 2016, pp. 121-132). One such tool is the balanced scorecard (Karaś 2004, pp. 198-200). The balanced scorecard is defined as a tool to support the implementation of a long-term, effective strategy (Chodyński, Jabłoński, 2007, pp. 51-52). This system enables orientation on the most important aspects of the enterprise and is based on monitoring and control activities, which ensures the effectiveness of the long-term activities carried out (Dąbrowski, 2011, pp. 34-36). Orienting the BSC towards control activities allows errors to be verified faster and

corrective action to be taken. It consists of perspectives (Sierpińska, Niedbała, 2003, pp. 113-114; Staniewska, 2021, pp. 135-137):

- clarifying and agreeing strategies,
- presenting and explaining strategy within the organisation,
- linking the objectives of individual organisational units, teams and employees to the implemented strategy,
- setting up and programming strategic initiatives,
- making a periodic, systematic analysis of the implementation of the strategy,
- acquiring feedback to learn how to improve the strategy.

All these perspectives relate to the vision and strategy of an enterprise (Kaplan, Norton, 2010, pp. 275-276). Each perspective has its own objectives, which can be changed with specific measures. In order to create a comprehensive supply chain measurement tool, it is necessary to design the scorecard accordingly (Kaplan, Norton, 2011, p. 243). All the key perspectives must be modified so that their individual objectives are identical to the assumptions of the supply chain concept and the characteristics of a given enterprise in question (Klepacki, 2021, pp. 23-30). From the point of view of supply chain theory, what is most relevant here is the extension of the enterprise's internal perspective to the cooperating business units within a single supply chain (Kot, 2008, pp. 15-20).

The process of creating a properly designed balanced scorecard must be based on individual, consecutive steps as shown in Figure 1.

Figure 1 illustrates in simple terms the sequence of steps when developing a well-chosen balanced scorecard for the enterprise under study. The initial phase of this process is the necessary development of the strategy, followed by setting task objectives as well as indicators and measures. In the case of a specific enterprise, the shape and design of the tool in question can vary significantly (Emerling, 2018, pp. 108-115). It should also be emphasised that the sample four perspectives is not a fixed value. The number of prospects should be adapted to the individual characteristics of the organisation, the market, the level of competition. It is possible to freely expand the perspectives studied according to the basic assumptions of this tool as well as to limit the BSC to just two areas.

The developed system of measures based on objectives that can be generally referred to the supply chain assumptions; it should be noted that this set is only exemplary, but nevertheless intended to be used as accurately as possible to assess the supply chain in relation to an enterprise's strategy (Kabus, Miciuła, Piersiala, 2020, pp. 467-480). The system of measures included in a balanced scorecard relating to a supply chain differs significantly from those included in it as a standard, when analysing individual enterprises operating outside supply chains. The use of a balanced scorecard can significantly deepen the indicator analysis of the supply chain (Chłąd, 2020, pp. 7277-17286). In addition to providing an overall picture of the state of supply chain operations, this tool can easily refer the entire organisation of cooperation between entities within it to their strategic objectives.

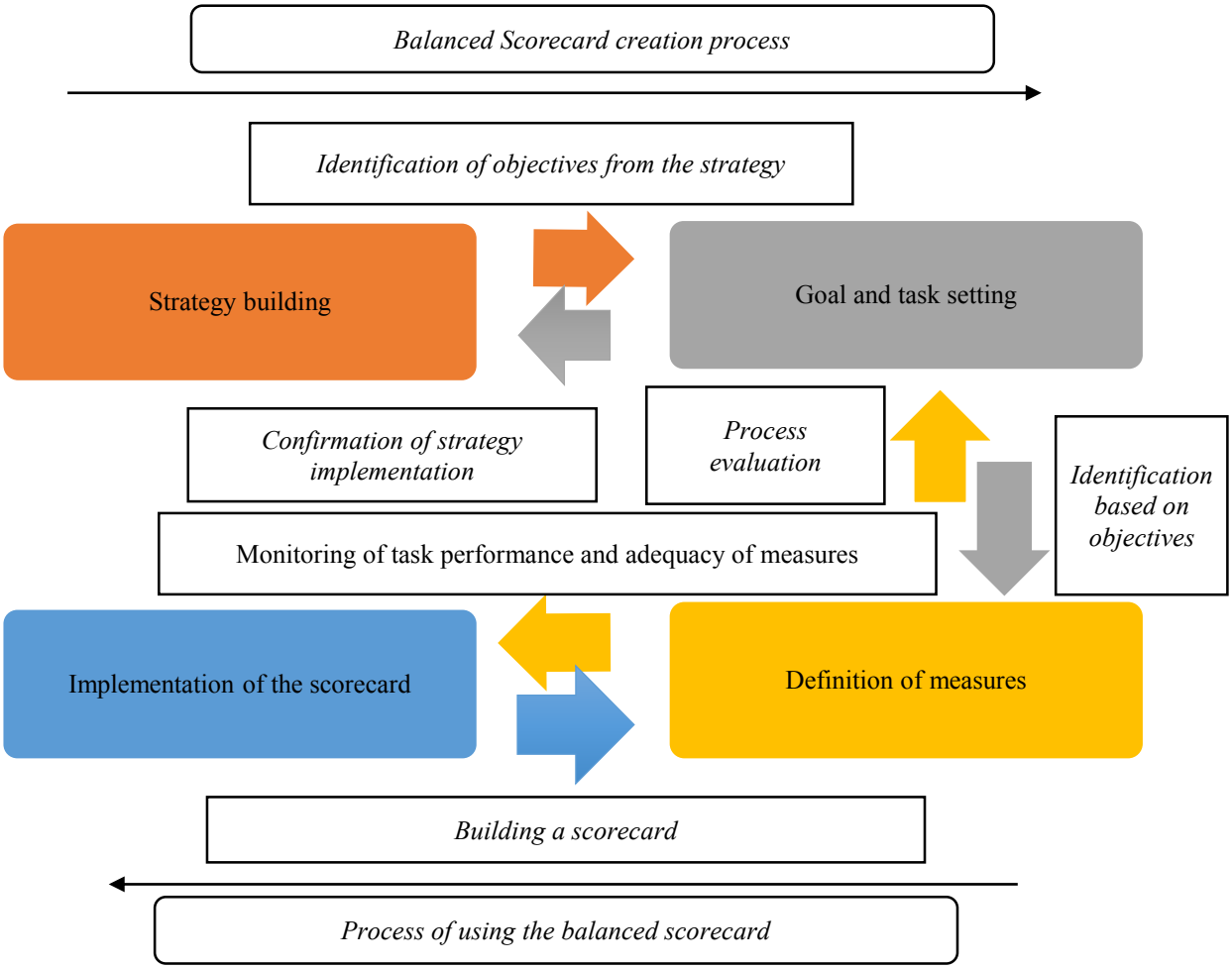

Figure 1. Balanced Scorecard creation process.

Source: Based on Brewer P.C., Speh T.W., (2000). Using the balanced scorecard to measure supply chain performance, "Journal of Business Logistics", Vol. 21, No. 1.

2. Analysis and identification of the cause of the research problem

In free market economy, an on-going battle for the market is essential. One verified method of making a competitive position better is continuous organisational improvement. This process should take place on the basis of an analysis and research conducted beforehand. In order to obtain the necessary data for such activities, it is necessary to be familiar with the organisation as much as possible, including its weakest points, but also those characterised by good or very good performance (Kowalewski, 2012, pp. 37-40). Such activities should be carried out on an ongoing and continuous basis. In the case of the analysed enterprise, it can be concluded that such activities are performed relatively infrequently and chaotically. Analytical activities are carried out only occasionally, or when necessary, for example, to find out the source of a problem (Borowiecki, 2015). The enterprise that was the subject of the research was monitored and analysed over the period of April and October 2022. Information gathered from

the enterprise's records, cooperating entities, data provided by employees and management along with their opinions and individual observations were used for the analyses. Observations were carried out at both the enterprise's head office and the enterprise shop. The observation was made using only part of the data collected by the enterprise. This fact is a result of the security policy of the enterprise and its contractors. An analysis of supply chain efficiency from the point of view of enterprise X was carried out in four areas (Gunasekarana, Patelb, McGaughey, 2005). Table 1 presents an aggregate summary of the level of measures extracted from the analysis process of enterprise X regarding the planning area.

Table 1.
Supply chain performance measures in the planning area

Operation in the supply chain	Level	Measure	Value	Comment
Planning	Strategic	The level of the customer's perceived value of the product	Very high	Personal and telephone interview
		Deviations from budget	32%	Two new product implementation projects
		Order completion deadline	4-10 days	EXTRA 1-3 day deliveries possible
		Cost of information processing	No data	No data
		Profitability index	7%	Net profit * 100/total assets
		Total cycle time	16 business days	Based on two new product implementation projects
		Total cash flow time	29 days	From the customer to PBS supplier
		Product development cycle time	No data	No data
	Tactical	Customer enquiry time	Immediate response	If unclear - up to 4h
		Product development cycle time	No data	No data
		Accuracy of forecasting techniques	92%	For weekly deliveries on customer orders
		Cycle time of the planning process	15 business days	Based on two new product implementation projects
		Order acceptance method	Email form order	Order confirmed by telephone
	Operational	Order acceptance method,	Written instructions on ready forms	In a small number of cases, verbal dispositions
		Employee productivity	PLN 32.00/hour	Net profit/working hours total

Source: Own compilation based on information obtained from the enterprise

Table 1 provides a summary of the indicators and measures that determine the level of supply chain performance in the area of activity planning. However, it should be noted that this analysis has been carried out in relation to the enterprise and on the basis of data and information relating to this entity. At a strategic level, the studied business entity is characterised by a very high perception of the value of the product offered by the studied supply chain. Elements such as the

quality of the product offered, price, timeliness of delivery, reliability of delivery, contact and cooperation with suppliers were included in the product value level. There is a significant underestimation of the costs of introducing new products at around 32% for the measures taken by the enterprise during the study period. Order lead times are set at between 4 and 10 business days for standard scheduled orders, but it is possible to speed up this time at the customer's clear request. The studied entity is flexible in this area. The profitability rate for the entire organisation is around 7%, with a planning lead time of around 15 business days. The cash flow time along the entire studied supply chain counting from the end customer is 29 days on average. At the tactical level, the business unit is characterised by providing immediate responses to enquiries, a very high 92% accuracy of forecasting techniques for weekly deliveries to regular customers. Orders are accepted on the basis of email orders confirmed by telephone. The planning process cycle is approximately 16 days. The operational level is characterised by written forms of disposals and a productivity of PLN 32.00 per hour.

Supply is another area of analysis. This section of the enterprises that are the 'middle links' of the supply chain defines the level of quality of cooperation in the supply area. It reveals the quality of communication with the market, as the quantitative and qualitative and product supply structure is ultimately intended to be the optimal feedback of information impulses from the market. Any well-organised supply chain is expected to provide significant added value for all participants. Supple is one of the primary areas that are intended to create this value, which is optimised in every respect.

The results of the observations and analyses are presented in Table 2 and show the eight primary measures and indicators from this area. However, it should be noted that the characterisation of this element of businesses should be carefully confronted with the profile of the studied entity, its size and the market in which it operates.

Table 2.
Supply chain performance measures and indicators in the area of supply

Operation in the supply chain	Level	Measure/indicator	Value	Comment
Supply	Tactical	Level of delivery	Very large	94% ideal deliveries
		Lead times for ordered deliveries compared to the industry standard	Faster	For urgent orders
		The supplier's price level in relation to the market	Approximately 15% lower	
		Procurement cycle time efficiency	71.5%	
		Financial flows efficiency	No data	No data
		Procedure for confirming orders with the supplier	Order sheet and phone confirmation	
	Operational	Procurement cycle time efficiency	Average	No data for accurate identification
		The supplier's price level in relation to the market	Approximately 14% lower	

Source: Own compilation based on information obtained from the enterprise.

Supply chain activities in the area of supply are characterized at the tactical level by a very high level of delivery of about 94% of ideal deliveries understood as timely, in the right quality, quantity and at acceptable costs. The lead time is faster than the market average, and the price level of suppliers is about 14% lower thanks to long-term integrated cooperation. The order cycle time efficiency is approximately 71.5%. Orders are confirmed by email using weekly cards and by telephone. At the operational level, there is an average utilisation of order cycle time and a price level that is approximately 14% lower. The level of distribution efficiency is analysed in Table 3.

Table 3.
Measures and indicators of supply chain performance levels in the distribution area

Operation in the supply chain	Level	Measure/indicator	Value	Comment
Distribution	Strategic	Service system flexibility meeting customer needs	Average	Part of the permanent procedures
		Efficiency of distribution scheduling	Average	
	Tactical	Service system flexibility meeting customer needs	Average	Part of the permanent procedures
		Efficiency of distribution scheduling	High	
		Effectiveness of delivery invoicing methods	Average	
		Percentage of finished products on the way	62%	
		Delivery reliability level	High	
	Operational	Quality of goods supplied	93%	
		Delivery timeliness	96%	
		Effectiveness of delivery invoicing methods	Average	
		Number of correct proofs of release	96%	
		Urgent delivery percentage	23%	
		Information system in delivery	Telephone contact and documents	
		Delivery reliability level	Large	

Source: Own compilation based on information obtained from the enterprise.

The level of efficiency of the supply chain measures in the area of distribution show enterprise X as having a medium flexibility of the service system to meet customer needs at a strategic level. This is due to a predefined procedural framework regarding delivery times, safety stocks, procurement procedures and algorithms for dealing with orders. The efficiency of delivery schedule planning is also average at the strategic level due to similar reasons. The effectiveness of the tactical level of the service system in meeting customer needs can also be described as average. Activities in this area are subject to specific guidelines. The efficiency of distribution scheduling at the tactical level can be described as high due to significantly less formalisation of activities and much greater knowledge of market and customer needs. The effectiveness of the delivery invoicing methods can be described as average due to the lack of an integrated order processing system.

The percentage of finished products on the way is at the level of 62%. The delivery reliability level is very high. The policy of the enterprise identifies this element of the business as a priority. The quality of the goods delivered is at the level of 93%. The most common elements reducing the level of this indicator are errors in the method of storing goods. The operational level characterises distribution as very timely, the efficiency of the means of invoicing delivery is also average. The number of correct proofs of release is at 96%. The percentage of urgent deliveries is 23% of the total, the information system in the delivery is based on telephone contact and documents. The delivery reliability level is also high.

Implementing changes

Analysis of supply chain performance can take place through a system of measures of the individual processes handling the chain. Enterprise X was analysed through this type of solution in the areas of procurement, warehousing, transport, distribution, and customer service. The individual processes were analysed using data obtained from the enterprise. The individual indicators were chosen to make the supply chain analysis system optimal, as comprehensive as possible, but also based on the availability of data in the analysed business entity. The set of individual measures identified for the studied enterprise is included in Table 4.

Table 4.
A set of individual measures defined for the studied enterprise

No.	**Measure**
1.	Time from order to delivery
2.	Time from order to delivery when stock is held
3.	Percentage of deliveries on time
4.	Specific delivery frequency
5.	Highest possible delivery frequency
6.	Minimum order quantity
7.	% of deliveries in accordance with the order
8.	Compliance of the goods with the accepted goods specification
9.	Quickest possible processing of minimum batch orders
10.	The fastest possible delivery from making changes in the delivery
11.	Does the supplier require an order forecast?
12.	Transport

Source: Own compilation based on information obtained from the enterprise.

Based on Table 4, conclusions can be drawn about all the processes occurring within the analysed enterprise in relation to the supply chain in which the said enterprise operates. This analysis has been carried out on the basis of information obtained from the enterprise and own observations. The level of detail of the analysis is directly related to the specific characteristics of the studied entity and the level of availability of data constituting the basis for such studies.

Within the supply process, parameters are visible regarding the fundamental aspects of this area's operation. The average delivery time in this case is 20h and the lead time is 48h. It should be noted that these times are set according to the weekly delivery schedule. The total of all delays over the two months was 12h, and the average for the previous year was at a very similar level. There is an approximate 10% overload within storage. This is due to excessive stock stored, while it should be noted that the storage areas outside the building are not full. Transport is characterised by delivery quality of 90%, while delivery reliability determining the level of advertised deliveries is around 3%. The speed of delivery, understood as that beyond the sequence from the weekly cards, is approximately 4h. On-time delivery is at 95%. Within the distribution process, an average lead time of 5h and delivery time of 4h can be observed. Delivery readiness is 85%. The share of late deliveries of products is around 5%. The aggregate marginal rate on customer service defining orders completed perfectly as assessed by customers is around 89%. Specific objectives within the ZKW were set on the basis of the enterprise's long-term strategy and consultation with the management of the analysed enterprise.

Summary

On the basis of the observations and analyses, a balanced scorecard was created with specific targets and measures for defining their level in each perspective. In the case of company and product perception, it is the number of representatives and, in the case of timeliness perception, the speed of order completion. The business process perspective sets objectives such as (Tyagi, Gupta, 2010, pp. 25-32):

- increasing flexibility,
- increasing the speed of delivery,
- transparency of delivery processes.

Specific measures have been assigned to these objectives. The last perspective is the area of growth and development, where the greatest emphasis in accordance with the strategy should be placed on the level of innovation, information flow and integrated partnership in management, where due to the commercial nature of the enterprise, one should focus on creating product offers. This type of scorecard determines the level of alignment of the supply chain with the enterprise's strategic plans and demonstrates quickly and transparently its ability to make appropriate strategic decisions.

References

1. Biniasz, D., (2014). Role and function of internal transport of small manufacturing enterprises – case study. *Logistics, 3*.
2. Borowski, P.F. (2015). Strategic risk in enterprise development in the 21st century. A case study. *Organisation Review, No. 2*.
3. Brewer, P.C., Speh, T.W. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics, Vol. 21, No. 1*.
4. Chłąd, M. (2020). *Organisation of Transport Process on the Example of an Enterprise*. International Business Information Management Association (IBIMA).
5. Chodyński, A., Jabłoński, A., Jabłoński, M. (2007). *Balanced Scorecard in the implementation of organisational development assumptions.* Kraków: AFM Publishing House.
6. Dąbrowski, M. (2011). Balanced scorecard. *"e-mentor" academic e-learning, No. 1(38).*
7. Emerling, I. (2018). Strategic scorecard and its role in business management. *Scientific Papers of the Wrocław University of Economics, No. 514*.
8. Gunasekarana, A., Patelb, C., McGaughey, R.E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics, Vol. 87, Iss. 3*.
9. Kabus, J., Miciuła, I., Piersiala, L. (2020). Risk in Supply Chain Management. *European Research Studies Journal, Vol. 23, Iss. 4*.
10. Kaplan, R.S., Norton, D.P. (2010). *Implementing strategies to achieve competitive advantage.* Warsaw: PWN.
11. Kaplan, R.S., Norton, D.P. (2011). *Alignment in business. How to use a strategic scorecard.* Gdańsk: Gdańskie Wydawnictwo Psychologiczne Sp. z o.o.
12. Karaś, R. (2004). Strategic scorecard in the area of personnel function: Philips Lighting Poland SA in Piła. In: A. Pocztowski (ed.), *Best practices in human resource management in Poland.* Kraków: Economics Publishing Office.
13. Klepacki, B. (2021). *Logistics*. CeDeWu.
14. Kot, S. (2008). Supply chain management in small and medium-sized enterprises according to the concept of sustainable development. Warsaw: PWE.
15. Kowalewski, M. (2012). Systems of measurement of enterprise achievements. In: E. Nowak (ed.), *Measurement and reporting of achievements.* Wrocław: CeDeWu.
16. Mesjasz-Lech, A. (2015). *Cooperation in supply chains and the economic performance of enterprises.* Cracow: Foundation of the Cracow University of Economics.
17. Sierpińska, M., Niedbała, B. (2003). *Operational controlling in an enterprise. Centres of responsibility in theory and practice.* Warsaw: PWN.
18. Staniewska, E. (2021). Selected aspects of supply chain security management. *Military Logistics Systems, Vol. 54, No. 1*.
19. Tyagi, R.K., Gupta, P. (2010). Strategic scorecard of service provision companies. Warsaw: PWN.

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INDUSTRY 4.0 WORKFORCE: ENCYCLOPEDIA OF THE DIGITAL PROFESSIONS BY GROUPS OF TECHNOLOGICAL INNOVATION

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Purpose: The purpose of the paper was the need to systematise the digital professions of Industry 4.0. With the development of new technologies, the demand for new employees is increasing. Companies need more and more employees with digital skills. The question arises: who do companies need for their Industry 4.0 strategy.
Design/methodology/approach: The paper consists of two parts: an overview of the competences of the Industry 4.0 workforce and a list of IT professions. The list of occupations is based on a review of government websites: www.praca.gov.pl; www.prace.cz. The paper presents occupations according to the innovative technologies of Industry 4.0.
Findings: Demand for employees is driven by the key technologies of Industry 4.0. The analysis of IT professions is presented by the following technologies: ITC systems and networks, automation and robots online, AI, Big Data, Big Data Analytics, IoT, Cloud Computing, Cybersecurity.
Research limitations/implications: The list of professions included in the paper is not complete, but exemplary (it was made on the basis of job offers posted on the websites in December 2022). The list was created during a review of Polish and Czech government websites, which are both job listings and encyclopedias of occupations.
Practical implications: This paper is an overview of IT professions that are particularly needed in Industry 4.0. The prepared description of professions according to the innovative technologies of Industry 4.0 can help companies plan the development of human resources.
Originality/value: The topic of the human factor in Industry 4.0 is important and topical. Technologies are constantly changing and industrial concepts are evolving (currently Industry 4.0 is changing into Industry 5.0). In the technological and industrial innovations taking place, the question of the competence of the modern company's employee is still relevant.

Keywords: Industry 4.0, workforce, digital skills, digital professions.

Category of the paper: general analysis.

1. Introduction

The current period of economic development is characterised by major technological, legal, business and social changes that are driving traditional industry towards Industry 4.0 (also known as the fourth industrial revolution). Automation and robotization are at the heart of Industry 4.0. Nine technologies are transforming current industrial production. These are: simulation, augmented reality, autonomous robots, the industrial 'Internet of Things', the cloud, cyber security, incremental manufacturing, horizontal and vertical systems integration, and Big Data and analytics (Booth Welsh, Erboz, 2017; Senn, 2019). New technologies are strongly influencing the labour market. Working in the new production environment and in a dynamic technological environment (artificial intelligence, internet of things, big data, cloud computing, quantum computers, etc.) will require adapted competences beyond - hitherto considered key and traditionally understood - technical and digital competences. Given the breadth of applied technologies of the fourth industrial revolution, a worker may be a database designer, a data scientist, a robot teacher, a robot controller, a robot assistant, a manager for robots, an online robot programmer, a machine learning programmer, a CPSs architect, a machine-to-machine liaison, an artificial intelligence operator, a CAD operator, a computer applications operator, a cloud computing architect, a 3D printer operator, etc. The list of professions that are emerging with the development of Industry 4.0 technology is getting longer every year (Astor, 2017; Gajdzik, Wolniak, 2022; Cedefop, 2019; Gajdzik, Grebski, 2022). Companies that have announced plans to invest in the technologies of the fourth industrial revolution need new employees to help them realise their Industry 4.0 strategies.

According to the latest DESI2022 report, in 2021 there were around 9 million people working as ICT professionals in the EU. The highest number was in Germany, where 2 million ICT professionals were working (22.5% of the EU total). The EU's goal is to have 20 million ICT professionals by 2030, which is about 10% of total employment (DESI Report, 2022). Human beings will be influenced by strong synergy technologies (mechanics, robots and cobots, computing and electronic control, mobile devices, IoT, computing/software, artificial intelligence, etc.) (Rotman, 2013).

New technical and digital skills must find an important place in vocational education. The place for acquiring new competences and raising their level are educational organisations and production companies that implement their Industry 4.0 strategies. On the basis of the companies' job offers, a list of occupations related to the key technologies of Industry 4.0 has been drawn up. The descriptions of each type of occupation are preceded by an overview of the characteristics of the Industry 4.0 workforce based on scientific publications and reports. The aim of this article is to analyse the digital professions by government websites: www.praca.gov.pl; www.prace.cz.

2. Who Industry 4.0 needs

Surrounded by new technologies of Industry 4.0 - artificial intelligence, big data, cloud computing, virtual reality and others - employees' skills and proactive attitudes are coming to the fore, becoming a major driver of business development. Businesses need IT and digital-skilled employees with knowledge of engineering and industrial informatics. The digital skills required in the workplace are more advanced than they used to be, and companies expect most employees to have them (Berger, 2016; World Econ. Forum, 2018).

The labour market is still lacking employees with digital competences. According to reports by the European Commission, which assesses the digital society every year (the DESI index), at least 80% of people with at least basic digital skills and increase the number of ICT specialists to 20 million (around 10% of total employment), with convergence between men and women by 2030. In 2021, 54% of Europeans had at least basic digital skills (DESI Report, 2022). In practically every EU country, there is a problem of insufficient competencies of the industrial workforce in relation to the needs for effective technological transformation. The only differences lie in the scale of the problem and the countries' ability to address the skills deficit.

The problem of the lack of digital competences was already highlighted in the third industrial revolution. Nowadays, in the fourth industrial revolution, industry is still reporting a need for digital competences but the scope of digital competences has changed significantly compared to the third industrial revolution. An important change concerns the superstructure of digital competences with soft competences and the diversification of the scope of digital competences. The digital competence of employees can be divided into low, medium and specialised (highly advanced). The first level of competence enables the use of technology in daily work for accessing online information or using software. The second level includes specific competences enabling work in the creation of digital products and services, websites, e-commerce applications, using big data and the cloud, and including knowledge of programming, application development and/or network management. The third level includes complementary competences - enabling IT problem solving, processing complex data sets, building cloud architecture, robotic programming (online), etc. (DESI Report, 2022; OECD, 2016).

Information and computer technologies (ICTs), starting in the 1990s (and earlier) is changing businesses worldwide. With the technological advances of the third and fourth industrial revolutions taking place, a field of knowledge called industrial computing has emerged. Universities are educating IT engineers to work in Industry 4.0 companies. Education organisations (schools, universities) educate not only computer scientists, but also engineers and technologists, who should have basic IT knowledge and digital skills. Technical competence needs digital competence, and vice versa, digital competence needs engineering knowledge. A new type of hierarchy of jobs is taking shape in Industry 4.0, the key to which is the collaboration of humans with advanced technologies with artificial intelligence and machine

learning algorithms, as well as the operation of information and computer systems to support business processes, including autonomous information systems with access to the cloud and the Internet of Things (Rotman, 2013; Daugherty, Wilson, 2018, Flores et al., 2020). There is no doubt that the next generations of IT tools are increasingly digital and increasingly autonomous (McKinsey Digital, 2015). Well-educated employees with technical and IT competences are already at the top of the occupational pyramid in the companies that make up Industry 4.0. Companies need IT specialists with different specialisations and operators of new technologies. Industry 4.0 opens up new opportunities for employees with qualifications and skills related to new technologies. Skills such as technological design, computer programming, database architecture, data analysis, production automation, robotics, etc. are growing in importance (PwC, 2019). Workers are needed with knowledge enshrined in the STEM model (science, technology, engineering and mathematics) (World Economic Forum, 2019) and with competences written in the form of the letter "T" (the letter "T" represents a combination of general competences, which are useful in many fields, and specialised competences, needed in at least one field. The 'T' arrangement is made up of basic technical competences, digital competences of varying degrees and soft competences. The 'T' model has been adapted to the needs of different industries (PwC, 2018; EC, 2020). Digital competences are built on the basic technical digital competences needed to make informed use of the Internet and service applications and to operate digital devices in or out of the workplace, and, for higher level skills, programming, i.e. creating code for IT programmes (EC Definition) Industrial digital competences are strongly linked to the technologies used in companies. Employees need knowledge, skills, behaviours, attitudes, competencies, abilities and character traits to interact with technologies (Kispeter, 2018). Digital skills include technical competences, ranging from basic to advanced skills to enable the use of digital technologies, and the cognitive, emotional and social competences necessary to use technical competences in the workplace (Ferrari, Comp, 2013; European Parliamentary Research, 2017). Among the 'human' competences, creativity, originality and own initiative, critical thinking, persuasion, negotiation skills, attention to detail, resilience, flexibility and complex problem solving are important (PwC, 2019; Astor, 2017; PARP). Other important qualities desirable in employees are emotional intelligence, leadership, as well as having influence and social networks (World Economic Forum Report, 2018). Companies need employees with technical, digital, social, communication and interpersonal skills (Głomb, 2020). There is a strong diversification of IT professions in companies with the automation of work and the development of ICT. The technologies of Industry 4.0 are a large set, consisting of both advanced manufacturing technologies and process technologies ancillary to manufacturing, as well as global business communication and cooperation technologies. Industry 4.0 companies need teams of applied IT specialists. The team, as a structural and functional creation, is better equipped to collaborate with the diversity of functions of Industry 4.0 technologies than the individual (employee). In Industry 4.0, technical competence encompasses a broad range of technological skills that

are supported by knowledge and defined based on the concept of so-called Key Enabling Technologies (KETs). The competence structure adapted to the needs of industry includes the use of manufacturing and advanced manufacturing technologies, the use of advanced materials and nanotechnologies, the use of life science technologies, the use of digital technologies -micro and nan electronics, photonics and artificial intelligence, as well as the use of cyber technologies for digital security and connectivity. Basic digital competences include the user's ability to operate basic digital solutions, and advanced digital competences include working with technologies using artificial intelligence, cloud computing and the Internet of Things. Artificial intelligence with machine learning, Big data and cloud computing, and the Internet of Things are three key segments that are considered to be fundamental in the development of digital competences of employees hired to operate production processes. (ARP, 2019). The period up to 2030 is expected to be a period of rapid development for machine learning and artificial intelligence. It is estimated that by 2030, more than 80% of process handling tasks will be performed by artificial intelligence systems. Tasks in the area of quantitative reasoning will be carried out by humans and machines combined, with humans still responsible for completing 80% of tasks in the area of multifunctional reasoning. The use of cloud computing is also expected to grow exponentially. 5G technology will create the conditions for a strong flowering of various smart city functionalities and services. Tools based on VR (Virtual Reality) and AR (Augmented Reality) will commonly enter education and management. Companies will use the Internet of Things (IoT) more widely than before. Robotization and automation of production will drive Industry 4.0 (ARP, 2019).

In Industry 4.0, technology is rapidly accelerating its development, so humans must learn to adapt to new situations and function in dynamic production systems. Increasingly, operators' tasks will be hybrid - a combination of human and machine skills. On the one hand, workers interact strongly with Industry 4.0 technologies, and Industry 4.0 operators support machines during their training phase (teaching them to work intelligently) and participate in explaining and interpreting the results of their work and maintaining them. On the other hand, machines in Industry 4.0 empower people and enhance their cognitive, communication and physical abilities (Daugherty, Wilson, 2018; Flores et al., 2020). First attempts to structure the interactions between human and machines are made by Romero et al. (2016) and Ruppert et al. (2018). The next was Fantini et al. (2020). The impact of Industry 4.0 technologies on machine operators has also been studied by other authors: Kaasinen et al. (2020), Zolotov´a et al. (2020), Segura et al. (2020), Mattsson et al. (2020), Taylor et al. (2020), Neumann et al. (2021). In their paper the operator is interpreted in different roles, depending on the technologies used. The results of these scientists' research were more or less developed Operator 4.0 profiles. Based on the first publications about Operator 4.0, Table 1 summarises the types of Operators 4.0.

Table 1.
Operator 4.0 based on Romero et al. (2016) and Ruppert et al. (2018)

1	Operator + Virtual Reality = Virtual Operator
2	Operator + Wearable Tracker = Healthy Operator
3	Operator + Intelligent Personal Assistant = Smarter Operator
4	Operator + Collaborative Robot = Collaborative Operator
5	Operator + Social Networks = Social Operator
6	Operator + Big Data Analytics = Analytical Operator
7	Operator + Augmented Reality = Augmented Operator
8	Operator + Exoskeleton = Super-Strength Operator

The widespread use of new technologies in Industry 4.0 increases the demand for new skills, which are a set of multiple skills to undertake and perform tasks in a new work environment that is increasingly flexible, geographically dispersed, prone to frequent and rapid change, and in which it implies the need to handle digital technologies and to collaborate with automated systems and machines using artificial intelligence (Report: Manual 4.0, p. 17). Companies need employees with technical, digital, social, communication and interpersonal skills. The World Economic Forum (2018), based on the O*NET Content Model, anticipates that the need for cognitive skills, content skills, systems skills and process skills will increase as technologies develop (Berger, 2016).

3. Methodology

The aim of this article is to analyse the digital professions by government websites: www.praca.gov.pl; www.prace.cz.

The analysis was based on job offers conducted by Job Centres One form is Internet offers reported on portals. The study of Internet job offers included offers in Poland and the Czech Republic. Information was aggregated to the country level. The subject of the study was job offers, pertaining to the period studied, in the form of advertisements seeking an employee for a single position, published once during the studied period. The analysis of job offers on the Internet boiled down to their collection, removal of repetitive ones, as well as those duplicating with offers reported to labour offices. The study was of a fragmentary nature. The survey is a kind of "snapshot" of offers presented in December 2022, January, 2023, and February 2023 (data was collected at the end of the month). The method presented, as mentioned, gives information of a piecemeal nature.

The results of the research showed that there is no significant difference between job offers addressed to occupational groups according to the Classification of Occupations and Specialities in Poland and the Czech Republic, so the offers were analysed together. The differences in the information content of the offers concerned only the offer of the employer itself, resulting from the scope of activities, therefore the analysis of the scopes of activities was omitted in order to unify the offers. The selected professions were presented in the order of key technological innovations of Industry 4.0 (Figure 1).

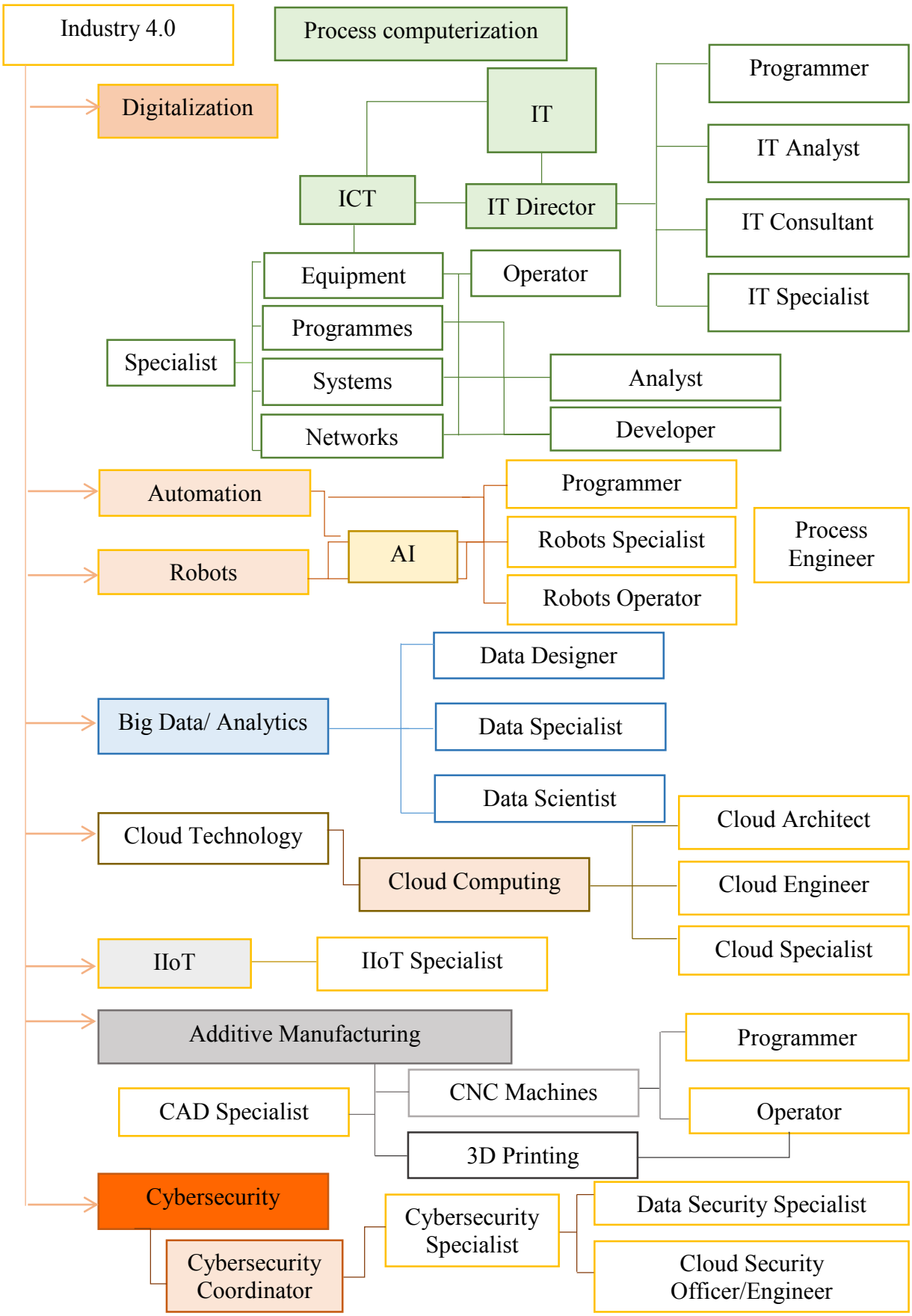

Figure 1. Structure of the list of occupations with digital competences (Own elaboration).

4. Example list of occupations with digital competences

There is a growing number of jobs for people with advanced digital skills in the labour market. Many of these jobs remain unfilled. More and more companies need employees with advanced digital skills. Here is a sample list of ICT professionals, advanced digital users and those with more than basic digital skills needed. This list is based on a review of the job listings of the websites: www.pracuj.pl; www.prace.cz. The structure of the list was presented in Figure 1. The paper uses the job descriptions available on these websites. The descriptions were shortened and their forms were put in order.

Process computerization

- **IT Programmer**: responsible for the entire development process and is the 'creative force' behind the programme. The person works a lot directly with clients to create the conceptual design and then works with other developers to figure out what the software code should look like.
- **IT Analyst**: responsible for analysis of requirements and process needs, schematic design (diagrams of parts of IT systems and their units), technical design analysis, analysis of functional requirements and legislative conditions, design of data structures, definition of interfaces, performance testing of IT devices/systems.
- **IT Consultant**: collecting data on the performance of IT systems, identifying opportunities for improvement, assessing feasibility, coordinating maintenance and development activities, performing technical project analyses, technical maintenance of computer systems and other hardware.
- **IT Director**: strategic responsibility, formulation of the organisation's system requirements; analysis of IT trends; assessment of IT management effectiveness and performance, analysis of IT systems, assessment of system reliability and performance, representation of the company in negotiations with IT suppliers and other parties.
- **Process Visualisation Specialist**: responsible for the graphical representation of equipment, operations and company conditions, ensuring clear graphical presentation of processes, overseeing the optimisation of various visualisation elements, including the improvement of event control.

ICT/Equipment, Programmes, Systems, Networks

- **Computer Applications Operator**: ensuring the flow of information from applications within the company; installing typical applications; configuring applications to operate peripheral devices; testing the correct installation of applications; operating applications; ensuring the security of the computer system (reporting any failures or malfunctions of applications); archiving data from supported applications.

- **Computer Equipment Operator**: supervising the operation of the computing centre equipment and all peripheral equipment installed in the company; computing centre upgrading (replacing packages, panels, etc.) and computer equipment, repairing simple defects; performing maintenance on system and application programs; participating in the installation of local computer networks; recovering subdirectories and their contents from damaged directories) and computer hardware, repairing simple defects; maintaining system and application programs; participating in the installation of local computer networks; recovering subdirectories with their contents from directories damaged during operation; marking bad clusters on (PC) disks damaged during operation; optimising the operation of hard disks (interleave, compress, etc.); installing and running application programs; creating new partitions on hard disks with different divisions and for different (PC) operating systems.
- **Computer Network Operator**: supervising the functioning of the network; diagnosing network faults; reconfiguring the network on the basis of documentation; replacing network devices; configuring network devices on the basis of documentation; carrying out minor repairs to the network; connecting end devices to the network (e.g. workstations, printers); periodically testing the condition of the network and network devices; reporting malfunctions of the network and network devices to the **network administrator**; carrying out technical support for network users.
- **Application Developer**: responsible for interpreting application assumptions and requirements, application architecture; preparing and creating algorithms; creating and using data structures; creating and modifying application code; testing code to detect and fix bugs; ensuring application reliability and security; preparing technical documentation and application manuals.
- **Application Improvement and Development Specialist**: managing application capacity and performance; undertaking application development activities, managing licences, security certificates, etc.; producing reports and statements from within the application; managing application maintenance costs; testing and configuring applications.
- **Computer Network Analyst**: network managing and operation; network developing - improving the functions and performance of the network; supervising the devices, supervising the documents; checking the correct operation of the network; creating a system of passwords to access the devices, supervising the compliance with the rules of their protection.

Automation, Robots, Artificial Intelligence (AI)

- **Automation and Robotics Engineer/Robots Programmer**: automated workstations by designing of continuous and discrete control systems; preparing the application of numerical methods for identification and optimization; designing of control structures and algorithms in the area of automated and robotic manufacturing systems; designing of industrial robot systems to perform activities such as welding, painting, machine operation, assembly; designing of transducer and sensor systems; computer programming and control; constructing of transducers and measuring devices; developing of technical and construction and technological documentation of designed equipment.
- **Robot Programmer**: writing the necessary programmes (the number of which increases with a larger base of manufactured parts); commissioning the robot (offline, online); participating in the programming process of robotised production lines; supervising the operation of the robots; making corrections and optimising existing solutions.
- **Industrial Robot and Manipulator Operator**: inspecting the technical condition of the industrial robot, finding and rectifying minor faults in the robot's mechanical and control assemblies, which may include faulty operation of the robot's axes, gripper, joints, control cabinet (contactors, switches, fuses), signalling systems, control panel; carrying out periodic technical inspections of the robot's general condition, organising a safe workplace; observing instructions and regulations on the operation and safety of the robot.
- **Artificial Intelligence Specialist**: responsible for the development of computer programmes or systems that simulate human thinking; development of algorithms and technological approaches (e.g. natural language processing, text analysis and data mining, semantic technologies and machine learning); other activities in the field of cognitive and robotic automation.

Data/Big Data/Big Data Analytics

- **Database Designer**: designing databases and system requirements; building logical and physical data model and mapping systems; commissioning systems; administering and managing relational databases; working with development team and data warehouse analyst team.
- **Database Specialist**: maintaining installations; administration of database systems; developing system installations (system upgrades, developing application sub-modules, etc.); data security control and backup; resolving and eliminating emergency situations.

- **Data Scientist**: reporting on data from information systems; providing support to users of databases by preparing analyses of data collected in information systems; optimising the structure of databases and working to improve information systems in order to report from them the necessary data for analysis.
- **Database Security Specialist**: managing the security and performance of databases; building the company's data protection system; overseeing compliance with data usage policies.

Cloud Technology/Cloud Computing

- **Cloud Engineer/Cloud Architect**: designing cloud application; cloud building; cloud model improving, cloud web services design (many companies are looking for cloud engineers with experience with OpenStack, Linux, Amazon Web Services, Rackspace, Google compute engine, Microsoft Azure and Docker. Familiarity and experience with APIs, orchestration, automation, DevOps and databases such as NoSQL are also important; companies that hire cloud specialists are most often planning to deploy cloud services or are looking to expand the use of cloud technologies in their business); overseeing the migration of data to the cloud.
- **Cloud Computing Specialist**: designing cloud applications, drawing up plans for uploading data to the cloud; creating new solutions for using cloud applications; administering the cloud and the data uploaded to it, including: transferring, managing and analysing data stored in clouds; designing and implementing cloud and hybrid IT solutions and new improvements to the cloud computing model; preparing the cloud; overseeing the implementation of cloud solutions; liaising with cloud stakeholders.
- **Cloud Architect**: responsible for data integration, migrating data to the cloud, deploying new data analytics, business intelligence and data science applications to the cloud, integrating tools and services across all areas of cloud computing.
- **Cloud Engineer/Cloud Software Engineer**: responsible for all technological tasks related to the operation of cloud computing platforms, including: design, planning, management, maintenance and support; his/her job description entails assessing an organization or a business’s infrastructure and transferring various functions to a cloud-based system; he/she is a software developer who is a specialist in the process of working on cloud computing systems.
- **Cloud System Engineer:** responsible for designing and maintaining cloud-based systems; developing new features or applications to help improve the overall user experience.

- **Cloud Network Engineer**: responsible for designing, building, and maintaining the network infrastructure of a cloud-based system. They work closely with IT teams to ensure that cloud resources are provisioned, managed, and maintained in an efficient and secure manner.

IIoT

- **IIoT Engineer/Specialist/Embedded Software Engineer**: responsible for the completion of all IIoT project requirements/ programmer, implementer, project analyst/ responsible for designing and implementing IIoT solutions.

Additive Manufacturing/3D Printing/CNC Machines

- **3D Printer Operator**: responsible for the spatial design of models of individual parts and assemblies; operating 3D printed computer modelling programmes; supervising the production of printed parts; managing consumables; maintaining equipment documentation; supervising printer maintenance work.
- **CAD Operator**: preparing 2D and 3D computer drawings, providing support for technical and maintenance functions in CAD design work; updating, testing new CAD/CAE tools; creating and applying changes to technical drawing models; managing changes to models, supporting engineers and designers.
- **CNC Operator**: setting up, fixing, configuring and calibrating CNC machines and accessories; checking dimensions of manufactured objects and performing error corrections; day-to-day control of the operation of the machine/CNC machine so that it can work in full cycles of the production of a large number of parts; checking the working area and the CNC machine; servicing the CNC machine and its diagnostics to ensure functionality following all company safety protocols
- **CNC Programmer**: programming of the CNC machine.

Cybersecurity

- **IT Security Specialist**: analysing, evaluating and proposing information security, ICT and IT security measures against identified threats; developing conceptual solutions to increase security in the use of direct communication and sales channels (Internet, telephone sales, etc.); resolving ongoing problems with the use of security in direct communication and sales channels.
- **Information Security and Online Communications Coordinator**: responsible for data oversight, proactive monitoring of network functionality; receiving reports/errors (written and telephone communication); liaising with the technical team, overseeing the improvement of systems security; basic network diagnostics, domain management, etc.

- **Cloud Security Specialist**: participation in the preparation of a plan for migration of applications/services to the cloud; assessment of technical documentation and participation in the development of cyber security analyses for implemented projects, taking into account compliance with internal regulations and market standards; preparation and coordination of security tests for implemented implementations; proposing the scope of optimisation of the security architecture of applications/services as part of cloud solutions in a multi-cloud environment; active cooperation with other teams taking care of the security and continuity of the operation of applications/services.
- **Systems/Networks/Equipment Security Officer**: setting up an access and security protection system; controlling the correct operation of the systems/network on an ongoing basis by monitoring it and responding to any disruptions and anomalies, reacting when users are found to be using the network inappropriately, adhering to network/systems access protection rules, regularly checking compliance with security rules (company security policy); indicating, where necessary, the need to install appropriate protection and threat detection mechanisms; providing training to employees on the use of networks/systems.
- **Cloud and Security Engineer/Officer**: responsible for adherence to ergonomics, professional ethics, health and safety and data protection legislation; participating in contract negotiations and setting the terms and conditions of cooperation with cloud service providers (ensuring that the conditions and requirements set out in the contracts are met); collaborating with legal departments and procurement agencies.
- **Cybersecurity Coordinator**: responsible for Cybersecurity strategy in the company.

5. Discussion

Digitalization or increasing usage and developments in ICT infrastructure, has created not only new ways of running the business. Managing a business in a digital environment means and includes running an e-business or, so-called, e-commerce via the Internet and other online electronic networks (Hafezieh, Akhavan, Eshraghian, 2011; Hafkesbrink, Schroll, 2010). George Pakein in 1975, said that technology would allow workers to merely press one button and information would reach all audiences (Huđek et al., 2019). Today, there are many terms for the transformation in the economy that are occurring under the influence of developments in ICT, e.g. post-industrial economy, knowledge economy economy, on-line economy, e-economy, and digital economy (Hafzieh, Akhavan, Eshragian 2011; Anckar, 2016, p. 36; Huđek et al., 2019).

The spread of digital technologies is having an impact on the changing employment structure, leading to the automation of routine tasks and the creation of different types of occupations, consequently leading to a demand for a workforce with developed ICT skills in almost every industry sector. Digital transformation is an effort to accelerate business through the use of information technology tools and the creation of new business development opportunities that can support companies' processes to make their target markets broader (Schallmo et al., 2018; Fitzgerald et al., 2013).

Digital skills are understood as characteristics that enable businesses to exploit the opportunities offered by information and communication technologies (ICT), thereby ensuring more efficient operations and discovering new ways of doing business (ITU, 2020). Digital competence is considered as the ability to understand and express by making analytical, productive and creative use of information and communication technologies and social software to transform information into knowledge, actions and services (Ferrari et al., 2012; Prospective Technological Studies, 2011; Torres-Coronas, Vidal-Blasco, 2011; Drydakis, 2022).

An employee in a digital enterprise encounters many applications (Drydakis, 2022): communication apps, networking apps, social media apps, customer relationship management apps, payments apps, accounting and finance apps, managing inventory apps, team and time management apps, project management apps, process management apps etc. The number of applications that an employee supports in a company is constantly increasing. Industry 4.0 takes advantage of modern technologies and the cyber environment and thus requires employees to have the knowledge and skills to seamlessly navigate this space. Technical skills and job-specific knowledge are important in the assessment of employees and necessary for the smooth functioning of the organisations.

The number of applications that an employee supports in a company is constantly increasing. The development of ICT makes it necessary for employees to continuously develop their competences and, in the event of a shortage of IT-competent employees in the company, employers make job offers. According to EU report (2022, p. 35), from 2012 to 2020, an average of 21% of all enterprises in the EU provided training to develop/upgrade the ICT skills of their personnel. The trainings in enterprises are organised for both IT and non-IT staff.

Eurostat (TESPR_SP410) defines four levels of digital skills: information skills, communication skills, problem-solving, software skills. Each group consists of several levels, which are constantly being completed. The list of competences is open, as new technologies are emerging. According to the EU report EU report (2022, p. 43), in the coming years there will be an increasing need for employees who can cooperate, use, handle, such technologies as: Big data and Analytics, Cloud computing, Green ICTs, cybersecurity, robotics process automation (RPA), AI and machine learning, software system for company management. In order to keep up with technological advances, two paths to competence development must be pursued in parallel: external education and training, both paths with forms of learning (different learning methodologies: blended, online, in-post, learning styles: visual, interactive and learning contexts: classroom, workplace.

Our analysis shows that employers are looking for employees with digital skills for various areas of business service in the strongly popularised concept of Industry 4.0. Industry 4.0 needs a wide range of competencies for employees operating next-generation technologies. This has already been pointed out by the authors of the publication (Cedefop, 2019; Daugherty, Wilson, 2018; Fantini et al., 2020; Ala-Mutka, 2011; Romero et al., 2016; Ruppert et al., 2018) and the topic is still relevant. On the Polish publishing market, a catalogue of digital competences was prepared by a team of Jasiewicz. The team of researchers divided competences into IT, communication and functional competences. The division seems to be the most accessible for grouping job offers on the basis of our analysis. In the first category, there are medium and high level ICT competences. In communication competences there are job offers for people dealing with the transmission of digital information. In the last group are the remaining job offers, which are strongly differentiated according to the processes carried out in the companies that are looking for employees. And although our analysis was presented according to the technologies and occupations in demand, in the future our scope of research will evolve towards describing levels of competence or only skills in relation to the technologies being developed.

The positions outlined in our analysis are closely related to automation in the manufacturing industry with a particular emphasis on programming skills. This means that a technical education or diplomas in electrical engineering, engineering or computer science will be useful in the roles listed. Employers are also looking for specialists with additional training in the area of robotics. It is worth remembering that working in automated production also requires soft skills like curiosity, creativity, empathy, problem-solving, and communication (Jelonek et al., 2020; Gorustowicz, 2019; Hecklau et al., 2016; Pezer, 2015, Gajdzik et al., 2022, Gajdzik, 2012, Gajdzik, Grebski, 2022). According to Jelonek et al. (2020) soft skills are related to the ability of emotional self-control, self-organization, but also coexistence with others in the community or the degree of openness to change. The ideal candidate should be able to solve problems efficiently and react quickly to change. In addition, the most important trait - both among entry-level employees and those in management positions - is to be courageous in the development process and to see Industry 4.0 not as a threat but as an opportunity.

6. Conclusion

Demand for IT professions in companies is growing with the development of the technologies of the fourth industrial revolution. IT professionals are needed by companies to improve digital business and build Industry 4.0. Digital competences take on particular importance in view of the development of digital technologies and widespread access to vast amounts of electronic information. At the same time, these skills are a prerequisite for action in almost all areas of the use of digital technologies digital technologies. Different groups of

innovative technologies need different IT competencies. Big Data and the Cloud need architects, specialists and researchers. Robotisation needs online and offline robot programmers, operators and other specialists. In additive manufacturing, programmers and operators, as well as CAD specialists, are needed to operate 3D printers and CNC machines. To build the company's cyber security, at every level of technology, people are needed for the digital security of the technology used. IT professions in companies need the support of engineers and technologists, as they are then better able to adapt technology to the needs of the company. In the further our research will focus on systematising process engineering professions.

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References

1. Ala-Mutka, K. (2011). *Mapping digital competence: Towards a conceptual understanding*. Seville: Institute for Prospective Technological Studies, http://www.kmu-digital.eu/de/publikationen/tags/prozessestrukturen/286-mapping-digital-competence-towards-a-conceptual-understanding/file.
2. Anckar, R. (2016). *Digital Entrepreneurship in Finland–a Narrative of a finish digital entrepreneur*. Innovative (Eco-) Technology, Entrepreneurship and Regional Development. Conference proceedings, 28.11.2018.
3. ARP (2019). Polityka rozwoju sztucznej inteligencji w Polsce na lata 2019-2027. Godna zaufania sztuczna inteligencja. *Autonomia i Konkurencja*. Retrieved from: https://arp.pl/documents/41/Kompetencje_cyfrowe_ARP_part_I.pdf, 2023.02.20.
4. ASTOR (2017). *Inżynierowie Przemysłu 4.0 (Nie)gotowi do zmian?* Whitepaper, Cracow. Retrieved from: https://www.astor.com.pl/images/Industry_4-0_Przemysl_4-0/ASTOR_Inzynierowie_4.0_ whitepaper.pdf, pp. 43-45, 2019.09.05.
5. Berger, R. (2016). WHITEPAPER *Skill Development for Industry 4.0* BRICS Skill Development Working Group.
6. Booth Welsh. *Our Understanding of the pillars of Industry 4.0*. Available online https://boothwelsh.co.uk/defining-pillars-industry-4-0/, 2019.12.12.

7. Cedefop (2019). *Metal & machinery workers: skills opportunities and challenges. Skills Panorama*. Retrieved from: https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/metal-machinery-workers-skills-opportunities-and-challenges, 2019.06.05.
8. Daugherty, P.R., Wilson, H.J. (2018). Human + Machine: Reimagining Work in the Age of AI. Boston, Massachusetts: Harvard Business Review Press.
9. DESI2022: Digital Economy and Society Index 2022. Human Capital. Available online: https://digital-strategy.ec.europa.eu/en/policies/desi-human-capital, 2023.02.26.
10. Drydakis, N. (2022) Improving Entrepreneurs' Digital Skills and Firms' Digital Competencies through Business Apps Training: A Study of Small Firms. *GLO Discussion Paper, No. 1078*. Essen: Global Labor Organization (GLO). Retrieved from: https://www.econstor.eu/bitstream/10419/251757/1/GLO-DP-1078.pdf.
11. Erboz, G. (2017). *How To Define Industry 4.0: Main Pillars of Industry 4.0*. 7th International Conference on Management (ICoM 2017), At Nitra, Slovakia, November 2017. Retrieved from: https://www.researchgate.net/publication/326557388_How_To_Define_Industry_40_Main_Pillars_Of_Industry_40, 2019.06.09.
12. European Commission (2020). *Blueprint European vision on steel-related skills* (…), May.
13. European Parliamentary Research… (2017). *Digital Skills in the EU Labour Market*. European Parliamentary Research Service.
14. EU report: *Strategies to address the digital skills gap in the EU*. April 2022 https://www.europeandigitalskills.eu/sites/TDSG/uploads/files/white-paper-eu-digital-skills-gap.pdf.
15. Eurostat TESPR_SP410.
16. Fantini, P., Pinzone, M., Taisch, M. (2020). Placing the operator at the centre of Industry 4.0 design: modelling and assessing human activities within cyber-physical systems. *Comput. Ind. Eng*. *139*, 105058.
17. Ferrari, A., Comp, D. (2013*). A Framework for Developing and Understanding Digital Competence in Europe*. Seville: Joint Research Centre – Institute for Prospective Technological Studies. Retrieved from: https://publications.jrc.ec.europa.eu, JRC83167.
18. Ferrari, A., Punie, Y., Redecker, C. (2012). Understanding digital competence in the 21st century: An analysis of current frameworks. In: A. Ravenscroft, S. Lindstaedt, C.D. Kloos, D. Hernández-Leo (Eds.), *21st Century Learning for 21st Century Skills*. EC-TEL. 7563. Berlin-Heidelberg: Springer. Retrieved from: https://doi.org/10.1007/978-3-642-33263-0_7.
19. Fitzgerald, M., Kruschwitz, N., Bonnet, D., Welch, M. (2013). Embracing digital technology: A new strategic imperative. *MIT Sloan Management Review*. Cambridge, https://www.capgemini.com/seen/wpcontent/uploads/sites/29/2017/07/embracing_digital_technology_a_new_strategic_imperative.pdf.

20. Flores, E., Xu, X., Lu, Y. (2020). *Human Cyber-Physical Systems: A skill-based correlation between humans and machines*. 16th IEEE International Conference on Automation Science and Engineering (CASE), August 20-21, 2020, pp. 1313-1318.
21. Gajdzik, B. (2012). *Pracownik wiedzy inicjatorem zmian w przedsiębiorstwie*. Opole: PTZP, http://www.ptzp.org.pl/files/konferencje/kzz/artyk_pdf_2012/p082.pdf.
22. Gajdzik, B, Grebski, M.E. (2022). Human factor in Industry 4.0: about skills of operators in steelworks 4.0. Zeszyty *Naukowe. Organizacja i Zarządzanie*, *z. 57*, pp. 119-132. Politechnika Śląska, DOI 10.29119/1641-3466.2022.157.7.
23. Gajdzik, B., Grebski, M.E., Grebski, W., Tobór-Osadnik, K., Wolniak, R. (2022). *Czynnik ludzki w twórczej organizacji*. Toruń: TNOIK.
24. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *J. Open Innov. Technol. Mark. Complex*., *8*, 68, https://doi.org/10.3390/joitmc8020068.
25. Głomb, K. (2020). *Kompetencje 4.0. Cyfrowa transformacja rynku pracy i przemysłu w perspektywie roku 2030. Część I.* Warszawa: Agencja Rozwoju Przemysłu ARP, Retrieved from: https://kometa.edu.pl/uploads/publication/1005/b26d_Kompetencje%20cyfrowe_ARP_part%20I_digitalfinal.pdf?v2.8.
26. Gorustowicz, M. (2019). Soft skills and enterprise 4.0 (Kompetencje miękkie, a wyzwania przedsiębiorstw 4.0). *Academy of Management*, *3(3),* 71-73.
27. Hafezieh, N., Akhavan, P., Eshraghian, F. (2011). Exploration of process and competitive factors of entrepreneurship in digital space: a multiple case study in Iran. *Education, Business and Society: Contemporary Middle Eastern Issues, 4(4),* 267-279, 28.11.2018.
28. Hafkesbrink, J., Schroll, M. (2010). Organizational Competences for open innovation in small and medium sized enterprises of the digital economy. Competences Management for Open Innovation. Tools and IT-support to unlock the innovation potential beyond company boundaries. *Lohmar*, 21-52, 3.12.2018.
29. Hecklau, F., Galeitzke, M., Flachs, S., Kohl, H. (2016). *Holistic approach for human resource management in Industry 4.0.* 6th CLF - 6th CIRP Conference on Learning Factories.
30. Huđek, I., Širec, K., Tominc, P. (2019). Digital skills in enterprises according to the European digital entrepreneurship sub-indices: cross-country empirical evidence. *Management*, *Vol. 24, No. 2,* pp. 107-119. DOI: 10.30924/mjcmi.24.2.8.
31. ITU (2020). *Digital Skills Insights*. Geneva: International Telecommunication Union, ISBN: 978-92- 61-35061-1.
32. Jasiewicz J., Filiciak, M., Mierzecka, A., Śliwowski, K., Klimczuk, A., Kisilowska, M., Tarkowski, A., Zadrożny, J. *Ramowy katalog kompetencji cyfrowych*. Available: https://depot.ceon.pl/bitstream/handle/123456789/9068/Ramowy_katalog_kompetencji_cyfrowych_Fra.pdf?sequence=1&isAllowed=y.

33. Jelonek, D., Nitkiewicz, T., Koomsap, P. (2020). Soft skills of engineers in view of Industry 4.0 challenges. *QPI Quality Production Improvement*, *vol. 2,* pp. 107-116, doi: 10.2478/cqpi-2020-0013.
34. Kaasinen, E., Schmalfuß, F., Özturk, C., Aromaa, S., Boubekeur, M., Heilala, J., Heikkilä, P., Kuula, T., Liinasuo, M., Mach, S., Mehta, R., Petäjä, E., Walter, T. (2020). Empowering and engaging industrial workers with operator 4.0 solutions. *Comput. Ind. Eng., 139*, 105678.
35. Kispeter, E. (2018). *Digital Skills and Inclusion Research Working Group Evidence Brief. What digital skills do adults need to succeed in the workplace now and in the next 10 years?* Warwick Institute for Employment Research, Warwick University.
36. MANUAL 4.0. *Metodologia organizacji szkoleń i doradztwa w dobie przemysłu 4.0.* Inspire-Consultung. Retrieved from: www.inspire-consulting.pl.
37. Mattsson, S., Fast-Berglund, Å., Li, D., Thorvald, P. (2020). Forming a cognitive automation strategy for Operator 4.0 in complex assembly. *Comput. Ind. Eng., 139*.
38. McKinsey Digital (2015). *Industry 4.0: How to navigate digitization of the manufacturing sector*. New York: McKinsey and Company. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/Industry%2040%20How%20to%20navigate%20digitization%20of%20the%20manufacturing%20sector/Industry-40-How-to-navigate-digitization-of-the-manufacturing-sector.ashx.
39. Neumann, W.P., Winkelhaus, S., Grosse, E.H., Glock, Ch.H. (2021). Industry 4.0 and the human factor – A systems framework and analysis methodology for successful development. *Int. J. Production Economics, 233*, 107992. Retrieved from: https://doi.org/10.1016/j.ijpe.2020.107992.
40. OECD (Dec. 2016). *Skills for Digital World, Working Party on Measurement and Analysis of the Digital Economy*. Retrieved from: https://www.oecd.org/els/emp/Skills-for-a-Digital-World.pdf.
41. PARP Polska. *Raport. Czwarta rewolucja przemysłowa i jej wpływ na rynek pracy*.
42. Pezer, D. (2015). *The importance of soft skills in technical education*. 7th International Scientific and Expert Conference of the International TEAM SocietyAt: Belgrade, Serbia. Retrieved from: https://www.researchgate.net/publication/305360275_THE_IMPORTANCE_OF_SOFT_SKILLS_IN_TECHNICAL_EDUCATION.
43. PwC (2019). *Skills for Smart Industrial Specialisation and Digital Transformation*. Brussel: Interim Report. EC.
44. Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å., Gorecky, D. (2016). *Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies*. Proceedings of the International Conference on Computers and Industrial Engineering (CIE46). Tianjin, China, pp. 1-11.

45. Rotman, D. (2013). How Technology Is Destroying Jobs. *MIT Technology Review*, *12 VI.* Retrieved from: http://www.technologyreview.com/featuredstory/515926/how-technology-is-destroying-jobs/.
46. Ruppert, T., Jaskó, S., Holczinger, T., Abonyi, J. (2018). Enabling technologies for operator 4.0: a survey. *Appl. Sci., 8*, 1650. Available online: https://doi.org/10.3390/app8091650.
47. Schallmo, D., Williams, C.A., Boardman, L. (2018). Digital transformation of business models-best practice, enabler, and roadmap. *Int. J. Innov. Manag., 21(8),* 1740014 (17 p.).
48. Segura, Á., Diez, H.V., Barandiaran, I., Arbelaiz, A., Álvarez, H., Simões, B., Posada, J., García-Alonso, A., Ugarte, R. (2020). Visual computing technologies to support the Operator 4.0. *Comput. Ind. Eng., 139*.
49. Senn, C. (2019). *The nine pillars of Industry 4.0*. Retrieved from: https://www.idashboards.com/blog/2019/07/31/the-pillars-of-industry-4-0/, 2019.02.07.
50. Taylor, M.P., Boxall, P., Chen, J.J.J., Xu, X., Liew, A., Adeniji, A. (2020). Operator 4.0 or Maker 1.0? Exploring the implications of Industrie 4.0 for innovation, safety and quality of work in small economies and enterprises. *Comput. Ind. Eng., 139*.
51. Torres-Coronas, T., Vidal-Blasco, M.A. (2011). Adapting a face-to-face competence framework for digital competence assessment. *International Journal of Information and Communication Technology Education*, *7(1),* 60-69, https://doi.org/10.4018/978-1-4666-2017-9.ch027.
52. World Economic Forum (2018). *The Future of Jobs Report 2018*. Insight report (World Economic Forum). Geneva. Retrieved from: http://www3.weforum.org/docs/WEF_ Future_of_Jobs_2018.pdf, Feb. 2019.
53. Zolotová, I., Papcun, P., Kajáti, E., Miškuf, M., Mocnej, J. (2020). Smart and cognitive solutions for Operator 4.0: laboratory H-CPPS case studies. *Comput. Ind. Eng., 139*.

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BARRIERS AND DETERMINANTS OF RESTRUCTURING EMPLOYMENT IN THE MINING INDUSTRY UNDER THE JUST TRANSFORMATION MECHANISM. SURVEY RESULTS

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Purpose: The purpose of using the method is to obtain information on the social perception of the employment restructuring process in the mining industry, taking into account the phase of design, implementation, monitoring and impact assessment for the industry and local communities.
Design/methodology/approach: The theses presented in the article have been verified using: literature review, critical literature analysis, document research and comparative analysis. The article presents a research method enabling social assessment of barriers and determinants of the employment restructuring process in the mining industry under the just transition mechanism. The method of researching the social perception of the hard coal mining employment restructuring process, due to the specificity and complexity of the issue under consideration, uses various, mutually complementary methods and techniques of social research: quantitative and qualitative.
Findings: As a result of the analyzes and surveys carried out, a set of conclusions can be presented, the most important of which include conclusions relating to social issues – implementation of the economic transformation in mining communes and poviats is possible in the coming years, but the communes are not prepared for the transformation. The negative effects of the employment restructuring process on the local economy may be noticeable in significant liquidation of enterprises cooperating with entities restructuring industry, reduction of revenues to the budget of local government authorities and reduction of demand on the local market.
Originality/value: The article enriches knowledge and develops a discussion in the area of social perception of the employment restructuring process in the mining industry. The attempt to capture the phenomena and processes presented here that may result from the transformation of hard coal mining in Poland is aimed at a better comprehension of the task that may be played by the local government in the area of which operating or closed mines and mining companies are located. On the basis of the results of the survey, it is mainly noticed that there is a need to define the challenges and tasks that should be undertaken in real action by the institutions responsible for the transformation of mining communes – especially due to the need to limit the social and economic consequences that may appear in the transformation process, both in the area of mining communes mining and in their surroundings.

Keywords: human being, economy, region, model, restructuring.
Category of the paper: Research paper.

1. Introduction

For many years, Poland was among the top five countries with the largest hard coal extraction. At the end of the seventies of the last century, it reached its highest level, exceeding 200 million tones. However, since then, its systematic decrease was recorded and in 2004 it did not exceed 100 million tones (GUS, 2022). In 2021, Poland was ranked 9th in the world mining ranking, supplying 55 million tons of coal (Production..., 2022).

The transformation of the Polish economy, implemented since 1989, entailed the need for deep structural changes, including in the hard coal sector. The restructuring of the industry was carried out through successive government programs. As a result of the implementation of the first of them, entitled "Restructuring of hard coal mining in Poland" (1993-1995), employment in the mining industry fell from over 415 thousands in 1989 to 268 thousands people in 1995 (Tkocz, 2006). This change was mainly due to natural departures (retirements, disability pensions) and redundancies of dual-professional, non-local people, as well as workers employed on the surface of mines related to the non-production function of workplaces. The second restructuring program "Hard coal mining, state and sector policy for the years 1996-2000", which was approved for implementation in 1996, resulted in a relatively slight decrease in employment – to 245 thousands people in 1997. In 1998, the most important restructuring program was adopted to change the size and structure of employment, "The Reform of Hard Coal Mining in Poland in 1998-2002". In the period 1998-2000, 80 thousands people left the mining industry, and the level of employment was 155 thousands. Ultimately, as a result of the actions taken, employment by 2002 fell by 102 thousands people to the level of 140 thousands people. The restructuring carried out – apart from a profound decline in the number of employees, also resulted in changes in the structure of employment. The share of blue-collar workers decreased by 2% in the underground and by 0,4% at the surface (Guminski et al., 2008). On the other hand, the share of engineering and technical employees in the underground (by 1,7%) and the surface (by 1%) was increased, as was the share of administrative and office employees (by 0,5%) (Gumiński et al., 2008). The largest number of people who left from mining during this time, took advantage of the shielding instrument called Mining Social Package (67,026 people, including 36,826 people who chose miners' leaves, 419 people – social benefits, 29,475 people – one-time unconditional severance pay), 23,097 people retired (Gumiński et al., 2008). Since 2004, the "Program for restructuring the hard coal mining industry in the years 2004-2006 and the strategy for the years 2007-2010" have been implemented. As a result of its implementation, in the years 2004-2006 employment in the hard

coal mining industry decreased by another 17,1 thousand people occurred mainly as a result of the retirement of employees and the use of mining benefits (Informacja..., 2007) and resulted in further changes in the employment structure – the share of blue-collar workers in the underground decreased (by 0,7%) and on the surface (by 0,6%) and the share of administrative and office workers (by 0,1%) (Informacja..., 2007). On the other hand, the share of engineering and technical workers in the underground (by 0.8%) and on the surface (by 0.7%) increased (Informacja..., 2007). As a result, at the end of 2021, 75,5 thousand people were employed in the Polish hard coal mining industry, of which 77,5% were underground workers (Zatrudnienie..., 2022). Thus, in the period 1989-2021, 339, 5 thousand people left the hard coal mining industry.

The article presents a research method enabling social assessment of barriers and determinants of the employment restructuring process in the mining industry under the just transition mechanism. This subject is a difficult research area, because the speed and deepening dynamics of changes cause overlapping of various elements. The subject of the method is the diagnosis of barriers and determinants of employment restructuring under the just transformation mechanism, including such issues as: assessment of the instruments proposed to be used to manage surplus employment, effects in the area of local economy and economy, effects in the area of natural environment, specific local problems (e.g. economic, social), as well as an indication – based on experience – of other instruments to mitigate the effects of restructuring as part of a just transition. The method was verified in pilot studies carried out in mining communes. The obtained results should be treated rather in terms of demonstrating the possibilities of the method itself than as a real picture of the situation.

As a result of the economic transformation of mining subregions, entire value chains will be liquidated or their current business profile changed (Magretta, 2014)[1], in which currently, there are workplaces focused on mining hard coal and companies associated with them. Closing mines will be accompanied by a change in the production profile of mining-related companies, which will lose their existing customers for their products and services. In order to support the diversification of the activities of companies from the mining and mining-related industries, it will be necessary to implement the necessary production and logistics investments contributing to changing the profile of activity, introducing new products, services, processes or gaining new markets, as well as maintaining or creating new jobs that will enable employment for people leaving from declining sectors.

In connection with the long-term goal of carbon climate neutrality adopted by the European Union by 2050 (Komisja Europejska, 2019), the Śląskie Voivodeship faces a huge challenge to carry out a just transition (Kiewra et al., 2019; McCauley, Heffron, 2018)[2], which will require

[1] The value chain is the sequence of activities undertaken by a company to develop, manufacture, sell and deliver a product and then provide after-sales services.

[2] A just transition is a process of systematic and gradual changes which, in the long perspective, will allow the region's economy to be based on modern, environmentally neutral industries. Approximately one million people working in mining and mining-related industries will be directly affected.

changes at the social, economic and technological level as well as the transition from carbon-intensive industries and energy sources to clean energy technologies.

In order to mitigate the effects of the energy and socio-economic transformation, including the liquidation of employment in the mining sector, it will be necessary to provide by 2030 almost 82,5 thousand new jobs, including those working in mining-related companies (Umowa społeczna..., 2021). The effects of actions taken in the process of just transformation of the region will be felt mainly in the mining sector, but will also be noticeable in sectors requiring deep restructuring, such as energy, metallurgy, chemical, mineral, machinery and transport.

In order to mitigate the socio-economic consequences of the transformation of the region, it is necessary to prepare the key stakeholders of the transformation process for the upcoming changes, establish and maintain permanent cooperation between employee organizations, employers' organizations, economic self-governments and scientific and research institutions, systematically inform local communities of mining subregions, and support the process of managing the socio-economic transformation. One of the challenges will also be the proper functioning of social dialogue as the basis for effective problem solving. The subject of social dialogue is the joint shaping of professional relations, working conditions, wages, social benefits, as well as other issues of economic policy that are of interest and competence to all parties, as well as relations between partners and their mutual obligations. Dialogue, however, allows for the search for a practical consensus and balanced decisions, especially in such an important topic as transformation, which facilitates their social acceptance.

In view of the problems described above, it is also important to correctly define the term transformation, which will be used in all analyses, research and expert opinions. The term transformation has its origin in Latin – "transformation" and means conversion – applying to social, economic, political, technological or IT areas. The term transformation is commonly synonymous with another term, which is change. It is significantly rarely associated with the term development or progress (Lipiński, 2017).

In such a context, it should be noted that the term transformation is perceived as more complex and, at the same time, narrower than the term change mentioned above. On this basis, it can be concluded that known transformations are changes, but not every change will be a transformation. This is how the term is perceived by R. Lipiński, who simultaneously defines the term change as follows: change is any noticeable modification of any element of reality. Meanwhile, transformation in its source should be perceived as a non-trivial and intentional process of changing one fragment of the environment implemented at a given time, which is designed to create a new and sustainable state of the environment (Lipiński, 2017).

2. The social diagnosis method of assessing the barriers and determinants of the hard coal mining employment restructuring process - a quantitative element

The purpose of using the method is to obtain information on the social perception of the employment restructuring process in the mining industry, taking into account the phase of design, implementation, monitoring and impact assessment for the industry and local communities.

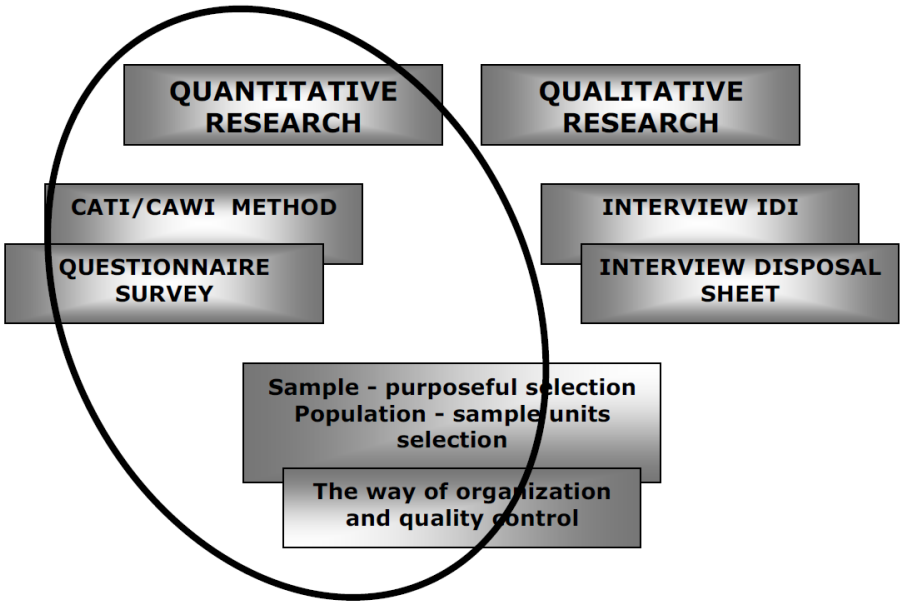

Figure 1. Social assessment diagnosis method of employment restructuring process.

The method of researching the social perception of the hard coal mining employment restructuring process, due to the specificity and complexity of the issue under consideration, uses various, mutually complementary methods and techniques of social research (Figure 1):

- quantitative evaluation studies – which include: a survey, a survey technique (CATI/CAWI), which is a technique of collecting information consisting in filling in questionnaires by the respondent himself, usually with a high level of standardization. CAWI (Computer Assisted Web Interview) and optional CATI (Computer Assisted Telephone Interview) will be used, if necessary, to supplement the study. However, the basic method will be a survey carried out via the Internet (Batorski, Olcoń-Kubicka, 2006). The CAWI research technique is an interview conducted by receiving a questionnaire or survey via the Internet and completing it online. It is currently one of the most popular and dynamically developing methods of scientific research. Thanks to the sense of anonymity and the possibility of participating in the survey at a time convenient for the respondent, it allows you to collect reliable data. A feature of CAWI research is also the fact that we are sure of reaching a specific target group, which was extremely important from the point of view of this research. This type of survey also

allows you to eliminate the "pollster effect", i.e. the influence of the person conducting the survey on the answers given, which is of great importance for the reliability of the results obtained.

- qualitative research – described in separate article.

The purpose of quantitative research is to assess the impact of actions taken in the field of employment restructuring on the immediate environment, which include:

1. Social assessment of the impact on the condition of local communities and the local economy.
2. Evaluation of instruments used at the local level to mitigate social and economic effects.
3. Specific local problems, including positive phenomena (e.g. social, economic, environmental) related to the course and results of restructuring.

The tool used for quantitative research is a questionnaire covering four thematic blocks:

1. Factors determining the need for economic transformation.
2. Financial preparation of the region for economic transformation.
3. The impact of the closure of mining plants on the local environment, e.g. entrepreneurs, labour market.
4. Anticipating and mitigating the possibility of negative social consequences related to the process of closing mines and protecting employees from dismissal.

One of the most important issues to be examined (questions in the questionnaire) is the assessment of the instruments used to mitigate the effects of employment restructuring in terms of their adequacy and effectiveness, as well as the sustainability of the achieved results. It is worth noting that the studies carried out so far have not focused on a comprehensive assessment of the solutions applied from the point of view of the support beneficiaries themselves.

In quantitative research, the proper population of respondents are representatives of local government authorities, labour market institutions, local economic self-government institutions and local development agencies, i.e. people (sample unit) with knowledge about the effects of industry restructuring for the poviat. Due to the spatial area of the research (poviats where business entities of the restructuring industry were or are located), significant diversity of the population of research participants (knowledge about the effects of restructuring) and the substantive scope of the research (social, economic and environmental issues at the local level), purposeful selection of the research sample, taking into account the following criteria:

- spatial – the research will cover the selected poviat in which the economic entities of the restructured industry were located (28 poviats),
- knowledge and activities of experts to mitigate the effects of industry restructuring at the local level – it was assumed that the sample would include representatives of: local government authorities (city/poviat board or head of the department related to the industry restructuring process), labour market institutions (employment offices), local economic self-government and local development agencies (related to the restructuring of the industry).

The general characteristics of the research used in the model of social assessment of barriers and determinants of the employment restructuring process are presented in Table 1.

Table 1.
Purpose and sample of methodology that enables carry out barriers and determinants diagnosis of social assessment of the employment restructuring process

	Quantitative research	Qualitative research
Purpose	Impact evaluation of the undertaken restructuring activities on the immediate environment	Evaluation of employment restructuring in the industry (design, implementation, monitoring phases along with the instruments used) and its effects in the economic, social and environmental dimensions
Sample selection criteria	Spatial – 28 poviats where business entities of the restructured industry were or are located (with a significant impact on the local economy). Competence - knowledge and activities of experts to mitigate the effects of industry restructuring at the local level	Knowledge resulting from participation in design, programming or executive (implementation, monitoring) restructuring processes
Study population	These are people with knowledge of the effects of industry restructuring for the poviat, representing: – local government authorities, – labour market institutions, – local economic self-government institutions, – local development agencies.	Representatives: – government administration at the voivodeship level, – enterprises in the industry, – industry organizations (associations, associations), – sectoral/regional trade union structures.

Source: Own elaboration.

3. Results of the pretesting application of the method

3.1. Research assumptions

In order to determine the social assessment of the barriers and determinants of the employment restructuring process under the just transition mechanism, a survey was conducted in the third quarter of 2022 on a target sample of 50 experts. Research participants are 100% representatives of local government units that operate in the area of 28 mining communes. According to the adopted research assumptions, these are employees of local government units performing managerial functions in their workplace, characterized by long work experience and life and professional experience. The selection of experts for the survey was dictated primarily by the purpose and problem scope of the survey developed for the purposes of the survey, and the complexity of the questions it contains. In this light, only the indicated persons – as demonstrated by the pilot study of the research tool – could fully refer to the issues and problems posed in the study. The study used the method of questionnaire interview conducted as a tool, which is a questionnaire, and the interview technique CATI (Babbie, 2005).

After pretesting, which was carried out on a sample of three experts, the survey consists of five questions regarding the characteristics of the respondent, 26 basic, closed and open questions. Questions relating to the characteristics of the respondent concerned:

1. Respondent's gender.
2. Age of the respondent.
3. Respondent's education.
4. Workplaces.
5. Type of work performed.

The main questions – as indicated earlier – included issues related to:

1. Factors determining the need for economic transformation.
2. Financial preparation of the region for economic transformation.
3. The impact of the closure of mining plants on the local environment, e.g. entrepreneurs, labour market.
4. Anticipating and mitigating the possibility of negative social consequences related to mine closure process and protecting employees against dismissal.

As part of the pretesting, the following elements of the questionnaire were verified:

1. Technical correctness: analysis in terms of transition rules, logic and order of questions asked, instructions for interviewers, etc. (technical notes),
2. linguistic correctness: analysis in terms of the complexity and logic of sentences, comprehensibility of the used vocabulary and abbreviations (language and editorial comments),
3. substantive correctness: analysis of the selection (relevance, validity, completeness) of questions (e.g. control) and indicators (cafeteria) for closed questions (substantive comments).

Based on the comments and opinions obtained in the pretesting, the structure of the questionnaire, questions and cafeteria was clarified and the questions were unified in terms of language and the response categories used were standardized. As a result, a research tool was obtained that was technically, linguistically and substantively correct. This tool was used for the proper research as a source of research material for analyses.

The results of the survey were developed with a division into previously adopted problem groups, according to thematic blocks, closed and open questions, using the technique of statistical inference. Cross tables and descriptive statistics were used in statistical inference techniques. Main measures and parameters used in descriptive statistics are: arithmetic average, standard deviation, median and modal.

The surveyed respondents expressed their opinions by choosing the answers: "Yes" or "No" and "Difficult to answer" on the basis of an extensive scale of ratings, according to the level of importance: very high, high, medium, low and irrelevant and justification of the answers provided. In order to obtain the correct categorization, the answers with the indication of very high and high importance and the answers with the indication of medium, low and not important were summed up.

3.2. Description of the research sample for the survey

GIG address data was used to construct the research sample. The sampling frame for the development of the sample is the list of local government units (LGU) operating in mining communes, received from the GIG database.

On the basis of the operator, a random sample of 50 experts was selected for the research, according to the following criteria: commune, local government unit, place of work. All experts accepted the invitation to participate in the research.

The distribution of the sample according to the following criteria is presented below: gender, education, type of work performed, place of work, commune/poviat.

The target sample of experts from the surveyed mining communes by gender, carried out in the research, was as follows: 16 interviews were given by women (33,3%) and 34 by men (66,7%). All respondents holed higher education. In turn, due to the type of work performed, in alphabetical order, the surveyed persons are: career advisor, director, expert, head of department, head, chairman of the Commune/Town Council, specialist, deputy director, deputy manager.

Analyzing the distribution of the surveyed people according to the criterion of the place of work, in relation to the commune – in alphabetical order – they represented: Bieruń, Bytom, Jastrzębie-Zdrój, Rybnik, Rydułtowy, Siemianowice Śląskie, Tychy. According to the administrative unit criterion, the experts represented the following poviats: Bieruńsko-Lędziński, Bytom, Jastrzębie-Zdrój, Pszczyński, Rybnicki, Siemianowice Śląskie, and Wodzisławski.

3.3. Findings

The first of the issues raised concerned the factors determining the need for economic transformation. Nearly 92% of respondents believed that the EU energy and climate policy is not the only factor determining the need for economic transformation of mining communes and poviats. The systematic increase in the cost of coal mining (27,3% of respondents), the degradation of the natural environment (24,1%) and the depletion of minerals (21,2%) were also considered important factors. Less often, it was indicated that the reason for abandoning coal is high CO2 emissions (12,1%) and the development of renewable energy sources RES (9,1%).

The next question concerned the assessment of moving away from coal in favour of alternative energy sources as a prospective solution for the country's economy. In the case of this question, the question of leaving has been unequivocally resolved. More than 50% of respondents believed that this is a prospective solution, from which there is no way out. Only 33% of respondents were of the opposite opinion. 16% of respondents were unable to answer this question, stating that it was difficult for them to answer it.

In the context of the development potential of mining communes and poviats, it is interesting to ask about the possibility of economic transformation in mining communes and poviats in the coming years. The result obtained from the study indicates an optimistic approach

to the fulfilment of the transformation. Three-quarters of respondents considered this solution possible. Nearly every sixth expert (16,7%) was of the opposite opinion. It should be noted that more than 8% of experts could not resolve this issue. The conditions indicated by the experts limiting the fulfilment of the transformation are also important, among which the most important include the lack of a vision of new employment for professionally active mining personnel leaving work in the sector, the lack of economic preparation of mining communes for the transformation, social resistance to the challenges resulting from the transformation. In the macro dimension, the problem of destabilization of the country's energy security, raised by experts, is interesting.

The assessment of six factors that are important for the economic development of mining communes and poviats in the transformation phase was the content of the next question posed to experts representing local government units from mining communes and poviats. It asked about the importance of the indicated factor for the development of the study area. In order to organize the obtained results, the following steps were taken. First of these is the ordering of the factors by summing up the answers according to importance: high and very high. In the second phase, the assessed factors were categorized due to the level of their importance for the economic development of mining communes and poviats in the transformation phase. For this purpose, the factors were arranged in a system from the highest to the lowest level of importance (Table 2).

Table 2.
Factors of importance for the economic development of mining communes and poviats in the transformation phase

Factors	Importance assessment in %						
	1	**2**	**3**	**4**	**5**	**6**	**7**
supporting activities in the area of searching for new coal enrichment technologies in order to produce environmentally friendly fuel	66,7	16,7	0,0	16,7	16,7	50,0	0,0
development of ecological and innovative coal combustion installations	58,3	0,0	25,0	16,7	25,0	33,3	0,0
supporting high-efficiency energy generation technologies based on hard coal	50,0	0,0	33,3	16,7	25,0	25,0	0,0
efforts of the government, entrepreneurs and the social side to change the climate policy, which includes taking action on the European Union forum aimed at changing the provisions of the climate policy, including, inter alia, climate package with regard to the use of coal	58,3	16,7	25,0	0,0	25,0	33,3	0,0
implementation of solutions that will allow Polish coal to be competitive with raw material imported from other countries	50,0	8,3	25,0	16,7	25,0	25,0	0,0
support for coal companies in the process of obtaining financing for the implementation of investments in the form of sureties and/or guarantees for investment loans granted by, for example, Bank Gospodarstwa Krajowego and the State Treasury	50,0	25,0	25,0	0,0	33,3	16,7	0,0

Legend: 1. importance level, 2. Not applicable, 3. Low, 4. Average, 5. High, 6. Very high, 7. No response.

Source: Own elaboration.

In accordance with the adopted analytical approach, it is possible to distinguish the factors of the highest importance for the economic development of mining communes and poviats in the transformation phase. These are the following three factors (Table 2):

- supporting activities in the area of searching for new coal enrichment technologies in order to produce environmentally friendly fuel,
- development of ecological and innovative coal combustion installations,
- efforts of the government, entrepreneurs and the social side to change the climate policy, which includes taking action on the European Union forum aimed at changing the provisions of the climate policy, including, inter alia, climate package with regard to the use of coal.

Experts assessed the support of coal companies in the process of obtaining financing for investment implementation in the form of sureties and/or guarantees for investment loans granted by, for example, Bank Gospodarstwa Krajowego and the State Treasury.

The issue of the possibility of planning the process of a complete departure from coal mining in mining communes and poviats is another cognitive area in the completed studies. Based on the results of the research, it should be stated that, according to experts, it is impossible to plan a complete retirement. Such an assessment was expressed by nearly 60% of the respondents. Only every sixth of the respondents was of the opposite opinion. Nearly every fourth respondent could not answer this question (23,3%).

Another problem area taken up in the research is the financial preparation of mining communes in Poland for economic transformation. When diagnosing this area, experts clearly recognized that mining communes are not financially prepared for the transformation process. This assessment was indicated by all respondents.

Analyzing the sources from which the economic transformation of mining communes and poviats can be financed, based on the results obtained, it can be concluded that two such sources predominate. These are: Fund for Just Transition Program for Silesia, National Fund for Environmental Protection and Water Management, which were mentioned by every third respondent. Every fourth respondent saw the Cohesion Fund as a source of financing the transformation process.

The next question is related to the issue of the transition period of mining communes and poviats to a new model of economic development not based on mining. In response to this question, the experts unequivocally decided that 10 years and more (83,3% of responses). The other answers were not relevant to the issue raised in the question.

In the area of economic issues, the next question concerns the reference to the new model of economic development not based on mining for mining communes and poviats. The answers given by the experts do not solve the dilemma contained in the question. This is evidenced by the percentage of responses, which was as follows. 50% of the respondents answered yes, 25% did not and 25% did not know. Interesting in this cognitive area there are statements of experts recognizing the existence of mining communes based on a different solution than the

model based on the liquidation of mining. Experts see the opportunities in the implementation of activities and legal solutions at the national and regional level that will allow the operation of profitable mines, assuming the introduction of innovative solutions for coal enrichment, in the perspectives related to obtaining hydrogen as a result of using the coal gasification process, technologies related to wind energy and photovoltaic.

Are mining communes and poviats prepared to move to a new model of economic development as a result of the transformation and do they have a vision of economic development unrelated to mining? Experts, expressing their assessments in the first cognitive scope of the above questions, unequivocally recognized that mining communes and poviats are not prepared to move to a new model of economic development as a result of transformation. Such an assessment was expressed by more than seven out of 10 respondents. Every fourth respondent was unable to answer the question asked. Respondents who considered that mining communes and poviats were not prepared to transition to a new model of economic development justified their assessments with the following arguments:

1. no clear national agenda for transition,
2. lack of assumptions and funds for the implementation of the transition to the new model,
3. mining communes do not have adequate economic strength,
4. in this area, there are no funds for the implementation of the transition, as well as no legal regulations and guidelines and regulations regarding financing the transition,
5. heavy and very difficult budgetary situation of mining communes for a long time block readiness to pass,
6. communes will be deprived of significant budget revenues,
7. lack of mental preparation of the inhabitants of mining communes–social resistance,
8. lack of measures and implementing regulations, e.g. regarding development post-mining areas,
9. lack of alternative jobs for employees of closed mines.

Another issue concerns the identification of the possible future significance of the factors determining the economic transformation of mining communes and poviats. To this end, experts determined the level of importance for 12 factors.

The results of the answers obtained were ordered in the same way as the factors that are currently important for the economic development of mining communes and poviats in the transformation phase, i.e. in the first stage of the analysis, the ordering of factors by summing up the answers according to importance: high and very high. In the second phase, the assessed factors were categorized according to the level of their future importance for the economic development of mining communes and districts in the transformation phase. For this purpose, the factors were arranged in a system from the highest to the lowest level of importance (Table 3).

Table 3.
Factors of future importance for the economic development of mining communes and districts in the transformation phase

Factors	Importance assessment in %						
	1	2	3	4	5	6	7
widespread thermal modernization of buildings and improvement of energy efficiency in industry and services	33,3	16,7	25,0	25,0	0,0	33,3	0,0
zero waste policy - more recycling and reasonable waste disposal	58,3	0,0	33,3	8,3	33,3	25,0	0,0
supporting the development of cheaper modern energy technologies	100,0	0,0	0,0	0,0	33,3	66,7	0,0
development and implementation of the concept of ecological education - covering the population from the youngest age groups	41,7	0,0	25,0	33,3	16,7	25,0	0,0
creation of an efficient public transport network - all vehicles are emission-free and public transport is free	41,7	8,3	16,7	33,3	25,0	16,7	0,0
shaping active civic attitudes	50,0	8,3	25,0	16,7	33,3	16,7	0,0
prepare a long-term heating plan and reduce air pollution	83,3	0,0	0,0	16,7	33,3	50,0	0,0
developing a system of social support in the field of energy poverty	75,0	0,0	0,0	25,0	41,7	33,3	0,0
stable level of taxes and local law	50,0	0,0	16,7	33,3	8,3	41,7	0,0
principles of sustainable development based on basic human and animal rights and combating climate change	33,3	0,0	41,7	25,0	25,0	8,3	0,0
create mechanisms to limit imports of used, high-emission cars	25,0	25,0	50,0	0,0	8,3	16,7	0,0
transition to community energy, which is the foundation of the energy transformation in Poland and moving away from fossil fuels towards energy based on renewable and distributed sources	58,3	8,3	0,0	33,3	25,0	33,3	0,0

Legend: 1. importance level, 2. Not applicable, 3. Low, 4. Average, 5. High, 6. Very high, 7. No response.

Source: Own elaboration.

In accordance with the adopted analytical approach, it is possible to distinguish the factors of the highest importance for the future economic development of mining communes and poviats in the transformation phase. These are the following three factors (Table 3):

- supporting the development of cheaper modern energy technologies,
- preparation of a long-term plan for heating and reducing air pollution,
- developing a system of social support in the field of energy poverty.

The second group consists of factors of moderate importance, to which the participants of the study included:

- creation of an efficient public transport network – all emission-free vehicles, and public transport is free,
- shaping active civic attitudes,
- stable level of taxes and local law,
- transition to community energy, which is the foundation of the energy transformation in Poland and departure from fossil fuels towards energy based on renewable and distributed sources.

Factors that, according to experts, are the least important are:

- principles of sustainable development based on basic human and animal rights and combating climate change,
- setting up mechanisms to limit the import of used high-emission cars,
- widespread thermal modernization of buildings and improvement of energy efficiency in industry and services.

The next twelve questions were aimed at diagnosing the current and future situation of mining communes determined by the process of just transformation and its impact on the direction of development of the transformed areas. The first was the opening question, which focused on the occurrence of communes and poviats in the area of economic transformation well-developed communication with stakeholders (local governments, employment offices). The answers to the question described above unequivocally resolve the issue posed to the experts. More than 55% of the participants in the survey stated in their answers that the existence of properly developed communication with stakeholders in the area of economic transformation of mining communes and poviats is overlooked. Only nearly 17% of respondents were of the opposite opinion. The remaining percentage of respondents (25%) had difficulty in answering.

Communication with stakeholders in the preparation of the transformation process takes place mainly through informing about the preparations, course and expected effects (66,7% of respondents) and evaluating the developed solutions (33,3%). None of the respondents pointed to active participation in the preparation of the transformation programme.

When asked about the direction and strength of the impact of the employment restructuring process as part of the just transition mechanism for the local community and the labour market on the condition of the local community and economy, no clear answer was received.

Nearly half of the respondents stated that no social dialogue was conducted in the communes and poviats as part of the transformation process. The question posed in the study determined the next one, in particular regarding the knowledge of the study participants about civic organizations opposing plans to open new mines. In the case of this question, the answers given settle the issue clearly presented to the experts in the question. Over 83% of the survey participants who answered that they had knowledge indicate that this phenomenon in mining communes may take place and be significant for the economic transformation of mining communes.

Another cognitive area was outlined by the question about the smooth transition of mining personnel to other economic sectors. As in the question on the direction and strength of the impact of the employment restructuring process, the participants of the study were unable to give a clear answer. Every third respondent indicated that there was no smooth transition. It is worth noting that 41% had difficulty answering on this question.

In the next question, the experts were asked to determine whether the restructuring of employment in the mining industry will have a negative impact on social phenomena at the local level. Among the most frequently cited social phenomena were:

- number of unemployed growth,
- appear of the phenomenon of low labour mobility,
- number of addicts growth.

It should be noted that, according to experts (41,2%), there is no question of an increase in the number of homeless people.

When asked whether the restructuring of employment in the mining industry will have negative effects on the local economy, the respondents mainly pointed to:

- liquidation of enterprises cooperating with entities of the restructured industry,
- reduction of revenues to the budget of local government authorities,
- reduction of demand on the local market.

Restructuring of the mining industry is associated by the inhabitants of mining communes with both negative and positive changes. Among the opportunities that may occur, the respondents indicated increasing the reserve of undeveloped land, changing and improving professional qualifications, positive impact on the natural environment and reviving other sectors of the economy.

In the last question, the experts were asked to assess the importance of the indicated ones in the questionnaire of the survey of activities for the labour market of mining communes and poviats in the phase of potential economic transformation. The results of the answers obtained were ordered in the same way as the factors of future importance for the economic development of mining communes and poviats in the transformation phase, i.e. in the first stage of the analysis, the ordering of the factors by summing up the answers according to their importance: high and very high. In the second phase, the assessed factors were categorized due to the level of their future importance for the economic development of mining communes and districts in the transformation phase. For this purpose, the factors were arranged in a system from the highest to the lowest level of importance (Table 4).

According to the adopted analytical approach, three factors of the highest importance for the labour market of mining communes in the transformation phase can be distinguished. These are the following actions (Table 4):

- promoting vocational training for former miners, with the need to certify them,
- guaranteeing aid measures encouraging former miners to remain professionally active on the labour market,
- limiting the number of students educated in mining professions.

Table 4.
Actions of future importance for the labour market of mining communes and poviats in the transformation phase

Factors	Importance assessment in %						
	1	2	3	4	5	6	7
promote retraining and other forms of active labour market policy as a form of support only for people leaving jobs in the mining industry who cannot find a new job	16,7	0,0	0,0	83,3	16,7	0,0	0,0
guaranteeing aid measures encouraging former miners to remain professionally active on the labour market	58,3	0,0	25,0	16,7	33,3	25,0	0,0
limiting the number of students educated in mining professions	58,3	0,0	8,3	33,3	33,3	25,0	0,0
stimulating demand for labour in areas integrated with coal mining, especially in production and construction	16,7	0,0	0,0	83,3	8,3	8,3	0,0
promoting vocational training for former miners, with the need to certify them	75,0	0,0	0,0	25,0	41,7	33,3	0,0
taking advantage of the ageing of the population in the area of earlier professional deactivation of mining staff	41,7	0,0	8,3	50,0	25,0	16,7	0,0

Legend: 1. importance level, 2. Not applicable, 3. Low, 4. Average, 5. High, 6. Very high, 7. No response.

Source: Own elaboration.

The second group consists of factors of moderate importance, to which the participants of the study included:

- promoting retraining and other forms of active labour market policy should be treated as forms of support only for people leaving jobs in the mining industry who cannot find a new job,
- stimulating demand for labour in areas integrated with coal mining, especially in production and construction.

The factor which, according to experts, is of the least importance is the use of the ageing of the population in the area of earlier occupational deactivation of mining staff.

4. Conclusions

Following the analyzes and surveys carried out, a set of conclusions can be presented, the most important of which include conclusions about social issues – also considered at the political level. In this light, it is worth quoting the view from 10 years ago, in which experts studying the restructuring of the Polish mining industry note that the liquidation of an unprofitable mine is not a problem from an economic or technical point of view, but is, above all, a serious social and political problem (Stalewski, Szpak, 2000).

The attempt to capture the phenomena and processes presented here that may result from the transformation of hard coal mining in Poland is aimed at a better understanding of the role that may be played by the local government in the area of which operating or closed mines and mining companies are located. On the basis of the results of the survey, it is mainly noticed that

there is a need to define the challenges and tasks that should be undertaken in real action by the institutions responsible for the transformation of mining communes – especially due to the need to limit the social and economic effects that may appear in the transformation process, both in the area of mining communes mining and in their surroundings.

The scope of the research conducted in selected mining communes, due to their pretesting nature, does not allow for the presentation of a full diagnosis of the social assessment of barriers and determinants of the process of restructuring employment in the mining industry under the just transition mechanism, but it does allow for the presentation of certain regularities:

1. The energy and climate policy is not used to determine the economic transformation of mining communes and poviats. Equally, important are the systematic increase in the cost of coal mining, the degradation of the natural environment and the depletion of minerals.
2. Moving away from coal in favor of alternative energy sources is prospective for the country's economy.
3. Implementation of the economic transformation in mining communes and poviats is possible in the coming years. The same factors limiting its implementation can be seen as new employment for mining workers leaving active employment, lack of economic process of mining communes for transformation, as well as social resistance to the threats related to the participation from the transformation.
4. It is important for the economic development of mining communes and poviats in the transformation process to support activities in the area of searching for new technology of coal engagement in order to produce a friendly environment, ecological development and installation of coal installations, as well as striving to establish and the social community to change the climate policy, which is confirmed by the activities on the European Union forum in order to change the provisions of the climate policy, including climatic environment for the use of coal.
5. Mining communes and poviats in Poland are not prepared for social transformation. Analyzing the sources from which the transformation of the organization of mining communes and poviats can be financed, the Fund for Just Transformation of the Program for Silesia and the National Fund for Environmental Protection and Water Management.
6. Mining communes and poviats are not used to transition to a new model of economic development, due to the lack of a clear program for a given process, lack of resources and resources to enter the new model, no economic impact, no impact on this model and no mental preparation of the inhabitants of mining communes – social resistance.
7. The highest importance for the future economic development of mining communes and poviats in the transformation phase are to support the development of cheaper modern energy technologies, development of a long-term heating plan and development of a social support system in the field of energy poverty.

8. The negative impact on the source of the community can appear on principle in the increase in the number of the unemployed, phenomenon of low labour mobility and increase in the number of addicts.
9. The negative effects of the employment restructuring process on the local economy may be noticeable in significant liquidation of enterprises cooperating with entities restructuring industry, reduction of revenues to the budget of local government authorities and reduction of demand on the local market.
10. Important activities for the labour market of mining communes in the industry may include promoting vocational training for former miners, with the need to certify them, guaranteeing aid measures encouraging former miners to remain professionally active on the labour market and limiting the number of students educated in mining professions.

References

1. Babbie, E. (2005). *Badania społeczne w praktyce*. Warszawa: PWN, 297-298.
2. Batorski, D., Olcoń-Kubicka, M. (2006). Prowadzenie badań przez internet – podstawowe zagadnienia metodologiczne. *Studia Socjologiczne, Vol. 3(182),* 99-131.
3. Castillo, J.J. (2009). *Snowball Sampling*. Retrived from: Experiment-resources.com, 15.11.2022.
4. Gumiński, A, Karbownik, A., Wodarski, K., Jędrychowski, S. (2008). Restrukturyzacja zatrudnienia w polskim górnictwie węgla kamiennego w latach 1998-2006. *Wiadomości Górnicze, No. 8,* 168-169.
5. GUS (2022). *Rocznik Statystyczny*. Warszawa: GUS.
6. *Informacja o przebiegu restrukturyzacji górnictwa węgla kamiennego w 2006 z uwzględnieniem syntetycznych wniosków dotyczących niepełnego wykonania założeń programowych na lata 2004-2006* (2007). Warszawa: Ministerstwo Gospodarki, 13.
7. Kiewra, D., Szpor, A., Witajewski-Baltvilks, J. (2019). Sprawiedliwa transformacja węglowa w regionie śląskim. Implikacje dla rynku pracy. *IBS Research Report, No. 2.* Warszawa.
8. Komisja Europejska (2019). *Dyrekcja Generalna ds. Działań w dziedzinie Klimatu, Neutralność klimatyczna do 2050 r.: strategiczna długoterminowa wizja zamożnej, nowoczesnej, konkurencyjnej i neutralnej dla klimatu gospodarki UE*. Urząd Publikacji.
9. Lipiński, R. (2017). Organizacja, efektywność, zmiana i transformacja: rozumienie podstawowych pojęć. *Zeszyty Naukowe Wydziału Informatycznych Technik Zarządzania Wyższej Szkoły Informatyki Stosowanej i Zarządzania, No. 1*.
10. Magretta, J. (2014). *Zrozumieć Michaela Portera*. Warszawa: MT Biznes, 74.

11. McCauley, D., Heffron, R. (2018). What is the 'Just Transition'? *Energy Policy, Vol. 119*, 1-7.
12. *Production of hard coal in Poland from 1980 to 2021*. Retrieved from: https://www.statista.com/statistics/1117828/poland-hard-coal-production, 9.11.2022.
13. Stalewski, T., Szpak, A. (2000). Likwidowanie kopalń węgla kamiennego w małym mieście górniczym. *Studia Regionalne i Lokalne, No 4*. Warszawa: Uniwersytet Warszawski.
14. Tkocz, M. (2006). Efekty restrukturyzacji górnictwa węgla kamiennego w Polsce. *Prace Komisji Geografii Przemysłu, No. 9*. Warszawa-Kraków, 28-39.
15. *Umowa Społeczna dotycząca transformacji sektora górnictwa węgla kamiennego oraz wybranych procesów transformacji województwa śląskiego* (2021). Katowice: Ministerstwo Aktywów Państwowych, 3.
16. *Zatrudnienie, wydajność, płace i przepracowany czas pracy w górnictwie węgla kamiennego w Polsce w styczniu 2022* (2022). Katowice: ARP, 5.

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ANALYSIS OF THE IMPLEMENTATION OF CHANGES IN SUPPLY CHAINS TOWARDS A CIRCULAR ECONOMY

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Purpose: The purpose of the publication was to present the opportunities offered by the implementation of Cleaner Production projects in terms of improving the efficiency of supply chains, in accordance with the principles of transformation to the circular model, and to review indicators characterizing green supply chains, indicating the direction of further, in-depth research in a given area.
Methodology: Fourteen entities that implemented implementation projects under the Cleaner Production Academy were analyzed. On this basis, the degree of adaptation of selected enterprises to functioning in the circular model in such areas as transport, reverse logistics, cooperation, and eco-design was discussed. The economic account related to the above was balanced. implementations, then the results of the projects were summarized in the form of economic, environmental, and social indicators.
Findings: Confrontation of the ways of implementing changes in the area of improving the efficiency of the functioning of the supply chains of the analyzed companies with the effects that have been achieved, showed the greatest commitment to projects reducing material losses and reducing the costs of internal logistics. The least involvement was found in the area of activities such as establishing cooperation with other companies or developing the service sphere.
Research implications: Further research should focus on an in-depth analysis of examples of good practice in the area of cooperation and development of services for companies taking action to improve the efficiency of supply chains. Enterprises have a chance to significantly reduce costs and improve the environmental effect through activities in this area, which should be confirmed by examples of implementations.
Practical implications: The analysis of the indicators suggested in the literature related to the transformation of supply chains towards closing the loops indicates the need to create standards that, on the one hand, will enable verification of the effects of implementations implemented as part of Cleaner Production projects, and on the other hand - will constitute know-how for companies. These activities, so far rarely undertaken by companies, are generally low-cost and probably enable achieving very good economic effects in the long term, which should be checked.

Social implications: The development of activities in the social area by companies in the field of development of the service base and cooperation will have an impact on other indicators (economic and environmental), which is indicated by numerous examples of effects in this area in the world literature.
Originality: The article takes a very important direction of further research in the area of know-how for taking actions aimed at closing supply chains. The authors look for the most universal indicators and pay attention to the need for their mutual complementation. The collected material is the starting point for further in-depth analyses.

Keywords: circular economy, supply chain, cleaner production.

Category of the paper: Viewpoint, Conceptual paper.

1. Introduction

The classic supply chain, according to the simplest definition, is a sequence of events in the movement of goods. Sequences of events occur between producers and service providers, who, in cooperation with each other, process and move goods and related information and financial resources, from the raw material to the end user (Kisperska-Moroń et al., 2017). The linear model of the supply chain, now common, ends at the target customer. The entire effort related to the movement, its main cost is the cost of transport, which in Poland is almost 78% for road transport, and the vast majority of this is dependent on crude oil, more than 33% from Russia, almost 12% from Norway and almost 9% from Saudi Arabia, which has its obvious economic consequences (Bachorz, 2017). Environmental consequences are the second very important argument in looking for solutions. The implementation of the assumptions contained in the "White Book" (Biała Księga, 2011) assumes a 60% reduction in greenhouse gas emissions by 2050 (the reference year 1990). The "Book" indicates the need to develop the use of new fuels and propulsion systems, the increase in the use of multimodal solutions, and the development of IT systems for transport fleet management. Changes in the transport also include the development of local and regional transport, while the most expensive international transport is losing its importance (which is possible because of moving production closer to the customer, also from distant regions of the world to Europe). The process of switching to the circular economy model means various solutions for supply chains that short it, loop it, and are not limited only to changes in transport.

Placing products with a longer service life on the market increases the share of the so-called "third participant" (Kisperska-Moroń et al., 2017), which is the service sector, and thus activates/unblocks channels operating in the opposite direction to the classical chain (Fig. 1).

The development of warranty/service facilities (which is also associated with the more frequent leasing of products by the customer than buying), makes enterprises narrow the scope of their operation to local areas, because this is the only way they can guarantee customers

quick service. It also requires easy and quick access to spare parts, which further narrows the scope of cooperation to local entities. Thus, it becomes necessary to cooperate within the framework of cooperation, clusters, and finally industrial symbioses, which, as well-defined both in the literature (Doniec, 2011). and proven in practice (e.g. the city of Kalundborg in Denmark) (Doniec, 2019), are the form of action recommended by the European Commission for market transforming towards a circular economy (Roadmap…, 2019).

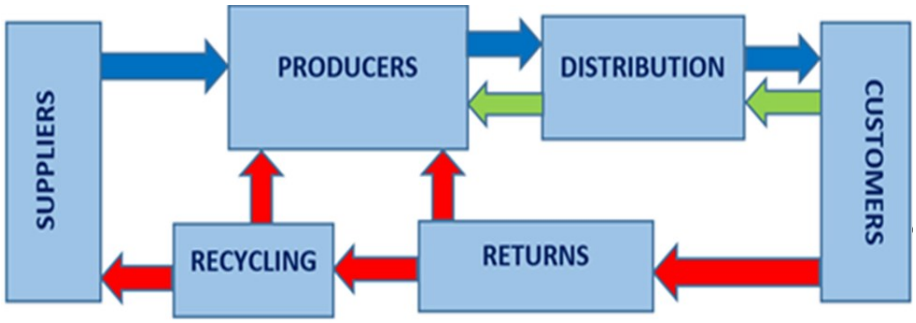

Figure 1. Logistic flows.

Source: Hordyńska, 2017.

Closed Loop Supply Chain allows you to manage your own materials, components and products in a closed cycle, and companies operating within the framework of symbiosis use all resources and energy at their disposal as efficiently as possible, exchanging utilities with each other in accordance with the principle "your waste it's my product".

There are many different forms of cooperation between the actors involved in the supply chain. Such cooperation also takes the form of a logistic partnership, with different levels of involvement of participants. The literature distinguishes (Kisperska-Moroń et al., 2017) four levels of cooperation as part of a partnership in the supply chain, ranging from the least durable form - having a short-term and competitive character, through the next two levels with increasing intensity of involvement, up to the fourth level, completely unique, characterizing a long-term partnership between participants. The fourth level, the so-called in-house, is based on the principles of partnership, transparency, and coordination of processes in achieving common goals. Of course, the most important for the development of all forms of cooperation in the supply chain are the possibilities of reducing the operating costs of enterprises, and these are primarily generated by: transport and storage. According to research (Kisperska-Moroń et al., 2017), the factors in the area of corporate social responsibility are the least motivating for cooperation, except for one factor, namely the increase in customer satisfaction, which is the second, after costs, strongest incentive for cooperation among all taken into account in the study. The least attractive for enterprises are the intentions to achieve pro-ecological goals and improve working conditions, therefore the first motivator, justifying the rightness of

undertaking it, must always be the economic factor, and the second - the well-being of the client (final recipient). And just as the economy in the supply chain will depend mainly on the costs of transport and warehousing, the well-being of the customer will depend on the degree of involvement in the supply chain of the service sector. The main two factors motivating to redefine the classical supply chain (economy and customer), at the same time have a decisive impact on reducing the impact on environment participating in the chain of entities. In this way, the efforts made spontaneously translate into a pro-environmental effect.

2. Cleaner Production Strategy

The concept of Cleaner Production was developed in the late 1980s on the basis of the idea of sustainable development. Even then, it was obvious that quick action was needed in view of the increasing amount of pollution in the environment and dwindling resources. It was becoming more and more aware that removing the effects of human activity requires the intensification of the so-called "At the source", and not only the interest in activities "at the end of the pipe" (sewage and exhaust gas treatment, safe disposal of waste). Acting "at the source" requires commitment by both producers and consumers, but above all - a change of mind. To broadly promote the new approach worldwide, in 1989, the United Nations Environment Program (UNEP) initiated the global Cleaner Production program, which today operates in more than 50 countries. The first national CP program was established in Poland and in 1998 it received the UN Global 500 award for its achievements. Since the beginning of CP's operation, 783 implementation projects have been carried out in Poland (www.cp.org.pl, 2021).

Both CP, EMAS, and ISO 14 000 contribute to the development of the megatrend (www.cp.org.pl, 2021), referred to as the Economy of Closed Circuit (circular economy), but the Cleaner Production strategy is the least formalized standard. Like all the others, it is based on the Deming cycle (PDCA - Plan-Do-Check-Act) and is based on continuous improvement. In practice, it means the realization and implementation of Cleaner Production Projects. The circular economy, like the CP, also promotes activities reducing pollution "at the source", recommending, for example, eco-design, i.e. designing production and service processes, supply chains, the functioning of product recipients, etc. the cradle-to-cradle principle (the product then becomes the raw material). However, he does not give up on improving the already existing solutions in every area of the company's operation and transforming them into more and more environmentally friendly solutions. The closed loop of GOZ is, like in the case of CP, continuous improvement, carried out on many levels.

Transformation towards a circular economy is the only way to counteract climate change that the 21st century has to face. Changes in supply chains are particularly important due to the need to reduce greenhouse gas emissions, and according to the calculations

(https://przemyslprzyszlosci.gov.pl, 2021), transport is responsible for 25% of greenhouse gas emissions in Europe. Solutions such as electric and hydrogen drive for cars, increasing the share of renewable energy, or solutions enabling an increase in the share of rail and sea transport in supply chains will contribute to a significant reduction in emissions by 2050. The involvement of individual countries in legislative processes and supporting enterprises and society in change processes (Roadmap…, 2019). Cleaner Production is one of the ways to initiate the transformation process, as mentioned - the least formalized one, enabling the start of changes using the so-called "Little steps" or "low-hanging fruit". It is a method that activates all employees of the company. The action begins with an audit, the aim of which is to search for such opportunities for changes that do not require large financial outlays (or do not require them at all), and give spectacular economic effects. The economic effects and, at the same time, the reduction of environmental pressure make employees engage in new projects. There is one more effect that strongly motivates action - the social effect, which in the case of supply chains plays a great role in acquiring suppliers on the one hand, and on the other - has a strong marketing impact on the customer. Therefore, it is a serious advantage compared to the competition.

3. Characteristics of selected enterprises

Adapting to the new reality requires changes in action, but most of all in thinking about one's own business and encourages to take a number of initiatives within the closed loop of the supply chain (Karwacka, Łuba, 2016). The implementation of Cleaner Production Projects enables the implementation of the assumptions of the circular transformation at a pace adapted to the specificity of the industry, financial and human resources capabilities of the company - it enables comprehensive transformation in the following areas: ecological, environmental, and social, in accordance with the assumptions of sustainable development (https://kampania17celow.pl, 2021).

The analysis covered 14 entities implementing an implementation project (Cleaner Production Project) in 2010-2018, improving the functioning of the supply chain: 7 production companies, 3 production and service companies, 1 educational institution, 1 NGO, 1 city office, 1 service company. All projects were implemented showing economic effects in the first year after implementation or showing a payback period (from approx. 1.5 to 12 years). The implemented changes mainly concerned the improvement of waste management. They concerned both high-cost and non-costly investments related, for example, to organizational changes in the enterprise.

Table 1.
List of selected companies implementing CP Projects in the period 2010-2018 in the area of changes in supply chains towards circular economy with an indication of the economic benefits of the implemented project

No.	Enterprise	Changes in supply chains in selected companies in areas such as:				
		Transport	**Reverse Logistics**	**Cooperation**	**Eco-designing**	**SAVED AMOUNT [PLN/year]**
1	Production			**X**	**X**	return after 2 years
2	Production/ services	**X**				17 346
3	Production/ services		**X**			return after 3-4 years
4	Town hall		**X**			516 510
5	NGO		**X**	**X**		16 038
6	School		**X**			2 826
7	Services		**X**			return after 34 mth
8	Production		**X**			3 351
9	Production		**X**			373
10	Production/ services		**X**			return after 12 years
11	Production		**X**		**X**	24 960
12	Production		**X**	**X**		29 518
13	Production		**X**		**X**	166 000
14	Production		**X**	**X**		28 502
The amount of investment: Gain [in 1 year] **SUM:**		**1**	**12**	**4**	**3**	**607 287**

Source: own study.

In the vast majority of cases, changes were made to the internal and external organization of the supply chain and waste was redirected to own production processes or transferred segregated to specialized companies. Significantly less investments, but also in the area of eco-design, - three companies redesigned their production processes, thus improving the flow in supply chains. Cooperation with another entity, enabling changes in the supply chain, was undertaken by two companies and only one made changes towards a more effective vehicle (Table 1).

Table 2.
List of economic, environmental and social indicators in selected companies implementing CP Projects in 2010-2018 in the field of innovation in supply chains towards circular economy

No.	Enterprise	Economic indicators		Environmental indicators		Social indicators		SUM
		Drop in internal logistics costs	Decrease in external logistics costs	Reduction of material losses	Reduction of CO_2 emissions	Cooperation	Services	
1	Production	+	-	+	+	+	-	**4**
2	Production/ services	-	-	+	+	-	-	**2**
3	Production/ services	+	+	+	+	-	-	**4**
4	Town hall	+	+	+	-	-	-	**3**
5	NGO	+	+	+	-	+	-	**4**
6	School	+	+	+	-	-	-	**3**
7	Services	+	-	+	-	-	-	**2**
8	Production	+	-	+	-	-	-	**2**
9	Production	+	+	+	-	-	-	**3**
10	Production/ services	+	+	+	-	-	-	**3**
11	Production	+	+	+	-	-	-	**3**
12	Production	+	+	+	+	+	-	**5**
13	Production	+	+	+	+	-	-	**4**
14	Production	+	+	+	+	+	+	**6**
SUM:		**23**		**20**		**5**		**48**

Source: own study based on (Kulczycka, 2020).

The highest economic indicators in the field of circular economy (Table 2) (23 in total - the highest result) result in the overwhelming majority of cases from the reduction of environmental charges incurred by enterprises so far. The next (20 in total) environmental indicators owe their high result to the reduction of raw materials and energy consumption. The lowest result was achieved by social indicators due to the very low level of cooperation and development of services by the analyzed enterprises and entities. Examples of social benefits by generally lofty-sounding entities: education, increasing ecological awareness, motivating to act, stimulating ecological sensitivity, raising awareness of ecological problems, learning ecological responsibility, etc. - usually without specific examples, and therefore without the possibility of their verification.

Table 3.
Examples of indicators related to the transformation of supply chains towards closing loops

No.	Action	Effect
1	Changing materials or packaging	Transport weight reduction
2	Product redesign, material change, modular construction	Extending the product life cycle
3	Reduction of energy and material consumption in the production and use phases	Lowering energy bills, purchasing raw materials
4	Limiting the use of hazardous materials, harmful substances in products and production processes	Reducing the risk of occupational diseases and absenteeism at work, the risk of environmental contamination
5	Designing with material logistics in mind, selection of components	Facilitating production and assembly processes
6	Development of the service base (maintenance/repair)	Additional income from business expansion, maintaining control of the reverse chain
7	Cooperation/collaboration/symbiosis /creating clusters/cooperatives	Lowering the cost of operating in the market for common economic benefits
8	Creation of conditions conducive to better consumer choices (lease, rental, sharing), which are an alternative to owning products	Full control over return streams, the possibility of stable development of the service area and recovery (certain quality and quantity of raw material)

Source: own study based on (Tundys, 2015; Kronenberg, Bergier, 2010).

The results of the analysis show that in order to systematize solutions related to the creation of closed loops of the supply chain, in accordance with the transformation towards a circular economy, criteria should be proposed that will enable enterprises to verify activities in terms of a new economic approach, especially in the field of expanding cooperation with external entities and with development of the service sphere (Tundys, 2015). Including e.g., a website in the chain or cooperation with local enterprises as part of sharing or joint educational and marketing activities, even to a small extent, will be profitable both financially and in terms of promotion for entities participating in the project.

In the literature, you can find many searches for the best indicators for verifying actions towards circular economy, also, and maybe in particular, for actions taken towards the transformation of supply chains (Kulczycka, 2020; Tundys, 2015; Dendera-Gruszka et al., 2017; Kronenberg, Bergier, 2010; Mohamoumgonbadi et al., 2021). The best means the most comparable, reliable, but also easy to use. Tundys (Tundys, 2015) proposes to assess the adaptation of supply chains on the basis of descriptive indicators developed on the basis of the EC Communication (COM 2014) [17], Kronenberg, Bergier (Kronenberg, Bergier, 2010) in turn - based on the guidelines for eco-design (Table 3).

The effects of activities undertaken by enterprises towards circular transformation must take into account the entire value chain. Only then will they allow the circuit to be fully closed. The most important stage of transformation is product design, which requires close cooperation of everyone involved at every stage of the supply chain (Metta, Badurdeen, 2012). A systemic

approach to creating new business models is a necessity. It is also necessary to use the results of the product life cycle analysis in their creation as the most reliable tool that comprehensively covers the entire supply chain (Kulczycka, 2020). LCA analysis (Kulczycka, Góralczyk, 2007), not very common so far due to the cost and time-consuming nature of the analysis, will become a commonly used method with time. It is already known today that it is the only method that allows the company to be assessed from the perspective of the entire supply chain. Here, the key is not only that the company implements the assumptions of circular economy, but also that those cooperating with a given enterprise are also assessed in terms of the implementation of circular economy assumptions.

Three indicators can be used to assess the efficiency of the supply chain in a company: the level of total logistics costs, the level of inventory costs and the effectiveness of financing the logistics system (Dendera-Gruszka, 2017).

- The level of total logistics costs can be determined by the formula:
  $W_{KL} = K_L \times 100 / P$ [PLN] (1)
  where:
  K_L - logistics cost,
  P - company's turnover.
- The level of inventory costs is:
  $WKZ = KZ \times 100 / MZ$ [PLN] (2)
  where:
  K_Z - inventory cost,
  M_Z - Inventory Value.
- Effectiveness of financing the logistics system:
  EPSL = EKM + EKT + Ei + EP [PLN] (3)
  where:
  E_{KM} - effects obtained due to the reduction of the costs of the movement of goods,
  E_{KT} - effects achieved as a result of reducing inventory costs,
  E_i - results obtained from reducing the costs of IT processes,
  E_P - other effects.

Effectiveness assessment also begins with examining the flow of information and relationships within the supply chain. Then, if necessary, the information flow should be improved, first of all eliminating all disturbances. If the flow of information between the supply chain partners is at least at an acceptable level, the analysis and evaluation of other components of the supply chain can be undertaken (Klein, Rai, 2009).

In order to fully measure the effectiveness of the supply chain, it is also necessary to calculate the efficiency of transport, storage, material flow processes, and the spread of innovation. Calculations should be made for the processes before and after the implementation of the changes to compare the performance indicators. Considering the need to conduct an analysis towards implementations enabling the transformation of the supply chain towards

circular economy, all indicators should be analyzed in terms of the intensity of their impact on the adaptation of the company to the circular model.

In their publication (Kulczycka, 2020), the authors look for indicators that will be the most universal and pay attention to the need to complement each other. The search for a universal tool is still ongoing, unfortunately, no ideal solution has been proposed yet. More and more companies in their reports on the climate footprint pay a lot of attention to the analysis of the supply chain, but it is still not a common activity (Qiang Du, Jiajie Zhou, 2022).

4. Conclusions

The analyzed enterprises, by implementing the Cleaner Production strategy, made a step towards the implementation of the circular economy assumptions. Some of them carry out CP Projects on a continuous basis, perfecting their approach and achieving very specific benefits. Some of them are only just starting activities aimed at organizing the environmental policy.

The results of the analysis confirm that the indicators most frequently reported by enterprises in the field of circular economy in Poland are those in the area of waste, concerning CO_2 and water emissions (Kulczycka, 2020). The publications contain many examples of companies that are created from scratch and function perfectly in the circular economy model based on new business models. Unfortunately for companies that have been operating on the market for many years, it is very difficult to change the business profile or even just expand it without comprehensive support for such a transformation. And this requires not only financial support, but above all interference in the organizational culture, and thus training and motivation to take non-routine activities.

Analysis conclusions:

1. The implementation of the Cleaner Production Project enables comprehensive actions to be taken by arranging them, hierarchizing them, and providing comprehensive advice and support from both the expert side and examples of implementations that can be used on the basis of benchmarking.
2. The review of activities undertaken by the 14^{th} cleaner production companies revealed as many as 12 activities in the area of reverse logistics and only 4 aimed at cooperation with other entities on the market or at the development of the service sphere (only 1), which would shorten the supply chain.
3. Observing the market needs it can be assumed that it would be necessary to provide enterprises with transformation know-how in this area.

4. Diagnosed by the authors, the least reported changes in the scope of delivery, regarding cooperation and development of the service sphere and eco-design, are also emphasized in the priority literature, but also the least reported in relation to the improvement of the economic effect of the company.

The conclusions of the analysis of the world literature report formulated in this way (Mohamoumgonbadi et al., 2021; Metta, Badurdeen 2012; Klein, Rai, 2009; Qiang Du, Jiajie Zhou, 2022), the development of a closed-loop study is widely analyzed. Numerous examples included that the benefits of using enterprise action are seen here that are involved in the supply chain, marginally analyzing the application and society aspects, which has also been confirmed in the inclusion based on some research. Beware of researchers for this analysis, which may not be due to the failure of the company to perform actions, but due to the fact that, firstly, the priority classical treatment, economic factors, are included in the exact inputs and take into account the rates of return, and the lack of norms that would arise in based on good practices as benchmarks. Companies probably do not see the role of social aspects in the regionalization of supply chains, which deserves more attention as a trend for the future, especially after the experience of the COVID pandemic and the current problems on the global market due to Russia's aggression against Ukraine. It is also necessary to support the companies in the supply chains transformation towards developing and implementing tools that improve the connection and flow of information, not only in the field of equipment but also by personnel.

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References

1. Bachorz, M. (2017). *Polska droga do gospodarki o obiegu zamkniętym.* IGOZ.
2. Biała Księga. *Plan utworzenia jednolitego europejskiego obszaru transportu – dążenie do osiągnięcia konkurencyjnego i zasobooszczędnego systemu transportu.* Bruksela, 28.3.2011, KOM (2011) 144 wersja ostateczna. Retrieved from: https://eur-lex.europa.eu, 5.05.2023.
3. Dendera-Gruszka, M., Kulińska, E., Masłowski, D. (2017). Efektywność łańcucha dostaw. *Gospodarka Materiałowa i Logistyka, 11*, pp. 12-25.
4. Doniec, A. (ed.) (2011). *Symbiozy i parki przemysłowe.* Warszawa: Wolters Kluwer.

5. Doniec, A. (ed.) (2019). *Powiązania symbiotyczne między przedsiębiorstwami*. Łódź: Wydawnictwo Politechniki Łódzkiej,.
6. Hordyńska, M. (2018). *Ekologistyka i zagospodarowanie odpadów*. Gliwice: Wydawnictwo Politechniki Śląskiej.
7. https://kampania17celow.pl/17-celow-dla-biznesu/, 20.12.2021.
8. https://przemyslprzyszlosci.gov.pl/sposoby-na-neutralnosc-klimatyczna-czyli-o-co-chodzi-w-zielonym-ladzie, 20.12.2021.
9. https://www.cp.org.pl, 20.12.2021.
10. Karwacka, M., Łuba, P. (eds.) (2016). *W kierunku gospodarki obiegu zamkniętego*. Warszawa: Koalicja na rzecz Gospodarki Obiegu Zamkniętego Reconomy.
11. KE (Komunikat Komisji do Parlamentu Europejskiego, Rady, Europejskiego Komitetu Ekonomiczno-Społecznego i Komitetu Regionów, *Ku gospodarce o obiegu zamkniętym: program zero odpadów dla Europy*. Bruksela, 2.07.2014, COM (2014) 398 final). Retrieved from: https://www.europarl.europa.eu/, 5.05.2023.
12. Kisperska-Moroń, D., Niestrój, K., Świtała, M. (2017). *Budowanie łańcuchów dostaw jutra w świetle teorii i wyników badań*. Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
13. Klein, R., Rai, A. (2009). *Interfirm Strategic Information Flows in Logistics Supply Chain Relationships*. MIS Quarterly. Vol. 33, No. 4 (Dec. 2009), pp. 735-762 (28 pages), Management Information Systems Research Center, University of Minnesota. Retrieved from https://doi.org/10.2307/20650325, 05.05.2023.
14. Kronenberg, J., Bergier, T. (eds.) (2010). *Wyzwania zrównoważonego rozwoju w Polsce*. Kraków: Fundacja Sendzimira.
15. Kulczycka, J. (ed.) (2020). *Wskaźniki monitorowania gospodarki o obiegu zamkniętym*. Kraków: Wydawnictwo Instytutu Gospodarki Surowcami Mineralnymi i Energią PAN.
16. Kulczycka, J., Góralczyk, M. (2007). *Ekologiczna ocena cyklu życia procesów wytwórczych (LCA)*. Warszawa: PWN.
17. *Mapa drogowa transformacji w kierunku gospodarki o obiegu zamkniętym* [*Roadmap towards the Transition to Circular Economy*], załącznik do uchwały Rady Min. (2019). Retrieved from: https://www.gov.pl/web, 5.05.2023.
18. Metta, H., Badurdeen, F. (2012). Integrating Sustainable Product and Supply Chain Design: Modeling Issues and Challenges. *IEEE Transactions on Engineering Management, Vol, 60, Iss. 2, May 2013),* 438-446, DOI: 10.1109/TEM.2012.2206392.
19. Mohamoumgonbadi, A., Genovese, A., Sgalambro, A. (2021). Closed-loop supply chain design for the transition towards a circular economy: A systematic literature review of methods, applications, and current gaps. *Journal of Cleaner Production, 323(2-3),* 129101, DOI:10.1016/j.jclepro.2021.129101.

20. Qiang Du, Jiajie Zhou (2022). Companies' climate footprint reports pay a lot of attention to supply chain analysis. *International Journal of Environmental Research and Public Health, 19(23),* 15541. Retrieved from: https://doi.org/10.3390/ijerph192315541, 5.05.2023.
21. Tundys, B. (2015). Zielony łańcuch dostaw w gospodarce o okrężnym obiegu – założenia, relacje, implikacje. In: J. Witkowski, A. Skowrońska (eds.), *Prace naukowe UE we Wrocławiu: Ekonomiczne, społeczne i środowiskowe uwarunkowania logistyki*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, pp. 288-301.

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THE CURRENT EPIDEMIOLOGICAL ANALYSIS AND MEASURES TAKEN BY THE REPUBLIC OF POLAND TO COMBAT DEADLY INFECTIOUS CORONA VIRUS DISEASE

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Purpose: This article aims to provide an overview of the current situation of COVID-19 in the Republic of Poland, including the measures taken by the government to combat and prevent the virus epidemic.
Methodology: The authors conducted a review of available literature and data sources related to the COVID-19 situation in Poland. Information was gathered from official government websites, academic journals, news articles, and other relevant sources.
Findings: Poland is actively taking steps to combat the COVID-19 pandemic, including enhancing testing facilities, increasing the budget for infectious hospitalization, initiating a national immunization program, and implementing strict regulatory measures against SARS-CoV-2. However, despite these efforts, the country is currently facing a surge in cases due to the emergence of the Omicron variant.
Practical implications: The information presented in this article can be useful for policymakers, healthcare professionals, and the general public in understanding the current COVID-19 situation in Poland and the measures being taken to combat the virus. This knowledge can help inform decisions related to public health policies and individual behaviors to prevent the spread of COVID-19.
Originality: While there are many articles available on the COVID-19 pandemic, this article specifically focuses on the situation in the Republic of Poland, providing a detailed overview of the measures being taken by the government and the available facilities to the public. This article also highlights the impact of the Omicron variant on Poland, which is a current and rapidly evolving situation

Keywords: Corona Virus, Pandemic, Preventing Measures, Republic of Poland, Current updates.

1. Introduction

The abrupt increase of severe pneumonia cases reported by health official in city Wuhan province Hubei, that leads to global pandemic in late December 2019 (Dietz et al., 2020). The Chinese Centre for Disease Control and Prevention (CDC) immediately sent researcher squad to Wuhan and also informed world health organization (WHO) (Wu et al., 2020). In the first week of January this infection was identified as novel corona virus of 2019 (nCovid-19) and closely related to severe acute respiratory syndrome (SARS-CoV) and middle east respiratory syndrome (MERS-CoV) (SSMJ Team, 2021). The WHO announced another sixth Public Health Emergency on 30 January 2020 and a global pandemic on 11 March 2020. According to the report by Johns Hopkins university (JHU) Covid-19 Dashboard Centre for system science and engineering (CSSE) on 21 January 2022, 346M (+3.88M) cases of covid infection and more than 5.59M (+10,163) deaths have been reported yet to WHO (CSSE 2022). According to WHO Coronavirus (COVID-19) dashboard the global mortalities are going to be robust due to covid 19 variants. In Americas 2,460897, Europe 1,735,102, South-East Asia 729,368, Eastern Mediterranean 319,005, Western pacific 163,903 and in Africa 161,875 deaths are reported weakly. Figure 1 indicates that America and Europe have the highest mortalities rate in the world from December 2019 to January 2022 (WHO Covid dashboard, 2023).

On 24rth January 2020 France was the first European union country that identified three cases of ncovid-19 in Paris and one in Bordeaux (Stoecklin, S. B 2020). The First case in Poland "Pierwszy przypadek koronawirusa w Polsce" Ministry of Health in Poland become alert, made a strict rules for entering in Poland. Lubusz Voivodeship on 4rth March 2020 confirmed the first case of ncovid-19 in his hospital Zielona Góra later Prof. Łukasz Szumowski, the health minister re-confirmed in his Press conference (Polish Ministry of Health, 2023). Inside about fourteen days of the first laboratory‐confirmed COVID-19 case, Poland had carried out numerous far‐reaching general steps, such as public awareness, prevention, mediations to moderate the early spread of nCoV-19, including shutting borders, forbidding mass occasions, limiting trade exchange, closing educational departments, introducing several health relief (Pinkas, 2020). The polish government announced the lock down on 31 March 2020 and made regulations to control the pandemic transmission. Every possible measures were taken to stop public gathering (Rozporządzenie Rady Ministrów…, 2020). The Polish Border Guards Head Quarter (HQ) monitoring every passenger travelling to Poland within European and non-European continents and providing special forms and app for registering to locate the person, during the current outbreak of corona virus. The polish embassies around the world and polish border guard marinating strict rules to entry to Poland and staying in the territory of the republic of Poland (Polish Boarder HQ, 2022).

The present study presents an early and current epidemiological investigation of COVID-19 epidemic and measures taken to control the pandemic in the republic of Poland.

2. The current status of Covid-19 pandemic in Poland

This investigation was in view of information from epidemiological reports composed between 4, March 2020 to 21 January 2022, by the Chief Sanitary Inspector of polish government from 16 provinces.

According to the Polish Ministry of Health, republic of Poland, there are total of 4,443,217 cases of corona virus reported, in which 103,626 cases of death, and 3,823,409 number of patients recovered from this disease. Table 1 data was calculated from the day, when the first case reported in Poland 4rth, March 2020 to 21, January, 2022 (Polish Ministry of health news, 2022). According to the global change data lab (The Oxford Martin programme on Global development), The current fatalities rate is 3.33%, the effective reproduction rate is 1.39, the omicron variant share is 37.15% in Poland. The comparison of new infection rate and mortalities rate between Poland, Europe and world has been recorded in the Figure 2. It shows that rate of daily new cases are robust, then comparison to world-wide cases. The rate of positive infections in Poland are low as compared to other European union countries. The death rate of daily death among covid patient is higher in Poland than world-wide and other European countries. The second and third graph it can be seen polish population is highly effected in the early variant wave of covid during march 2020, the current wave is not vigorous due to prevention measurements in the country. In the fourth of graph, it was revealed that new cases of infection and positive test rate of omicron variant, and reproduction rate of previous variants are continuously increasing in Poland (Our World in Data, 2022).

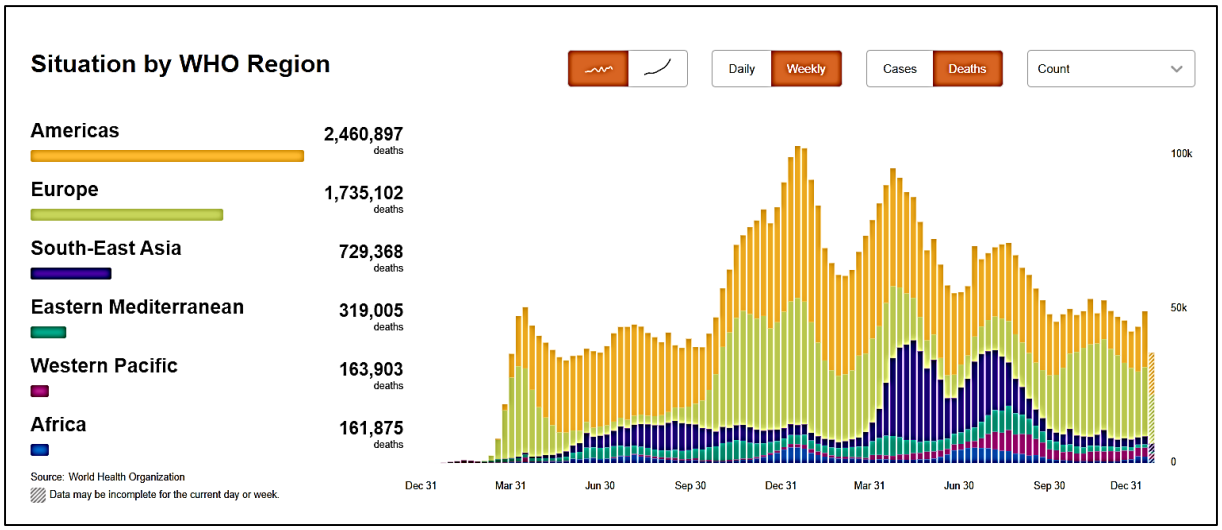

Figure 1. The current Mortalities rate in the world.

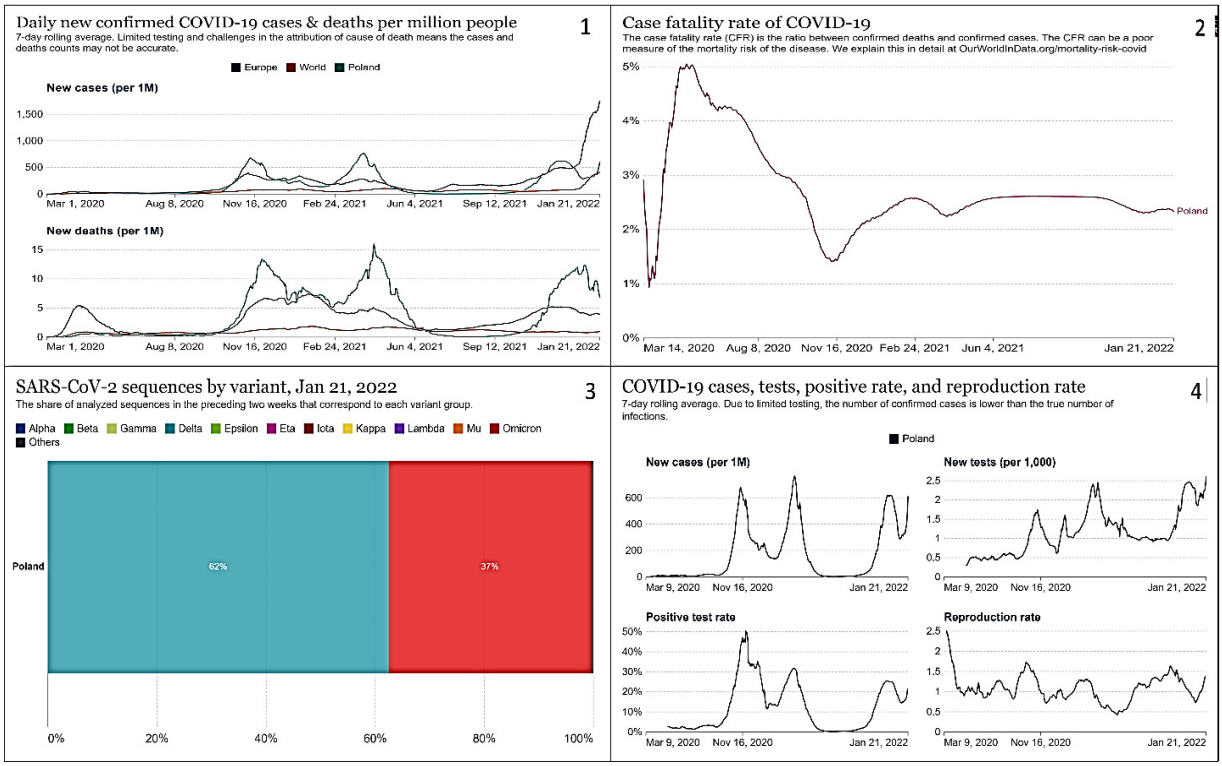

Figure 2. The comparison on Infection and fatalities among Poland, Europe, World, and the effects of covid-19 on republic of Poland.

Table 1.
The overall Coronavirus infection report (SARS-CoV-2) in Poland

People Infected	Fatal Cases	Recovered
4,443,217	103,626	3,823,409

Table 2.
The Daily Statistic of Coronavirus infection (SARS-CoV-2) in Poland

Infected Persons	36,665
Recovered Persons	17,493
Fatal Person	248
Solely because of COVID-19	67
Comorbidities with COVID-19	181
People in quarantine	747,290
Tests performed	135,321
Tests with positive result	42,424
Orders for POZ tests	46,437

Table 3.
The Daily statistic of Coronavirus infection (SARS-CoV-2) in voivodships

Name of voivodships	Population	Daily Confirmed	Daily Fatal
Opole	986,506	699	12
Swiętokrzyskie	1,241,546	715	9
Kuyavian-Pomeranian	2,077,775	1,158	10
Masovian	5,403,412	6,227*	37*
Pomeranian	2,333,523	2,251	4
Silesian	4,533,565	5,923	19

Cont. table 3.

Warmian-Masurian	1,428,983	1,138	12
The West Pomeranian	1,701,030	1,410	14
Lower Silesian	2,901,225	3,203	13
Greater Poland Voivodeship	3,493,969	2,587	23
Lodz	2,466,322	1,765	22
Podlaskie	1,181,533	585	7
Lesser Poland Voivodeship	3,400,577	4,207	27
Lubusz Voivodeship	1,014,548	514	9
Podkarpackie	2,129,015	2,403	20
Lublin	2,117,619	1,697	10

The data calculated in Table 2 and Table 3 bases on the latest updates for January 21, 2022.The polish Ministry of the daily statistics of covid-19, shows that daily infected cases are 36,665. In which 67 confirmed deaths due to covid-19 and recovered persons are 17,493. Table 3 indicates, Masovian voivodships has highest number of daily confirmed new positive and death cases. The Masovian, Silesian, and Lesser Poland Voivodeship are effected more in omicron 5th wave, as confirmed cases are continuously increasing. Table 4 analyse the detailed view of the current omicron scenario in Poland. The confirmed deaths of 15 patients from Lesser Poland Voivodeship, 10 patients from Greater Poland Voivodeship, 9 patients from Masovian, while 7 patients from lower Silesian region have been reported. Masovian and Silesian region have 147,861, and 115,385, highest number of peoples in quarantine. The further parameters, daily tests performed in every voivodships, their results with positive and negative figures, special tests recommended by family doctors, number of test remaining and cases recovering from covid are mentioned in Table 4.

The above data was recorded until 21^{IST} January. 2022, 10:29 pm. The total infection were calculated from 4^{rth} March 2020. Here POZ tests indicates, test recommended by family doctors owing to mild and severe symptoms of covid 19. While calculating data the following methodology were take under-consideration (Public announcement, 2022).

Table 4.

The Detailed statistic of Coronavirus infection polish voivodships

Serial Number	Name of voivodships	Confirmed at 10,000 Resident	Fatalities due to Covid	Comorbidities with Covid-19	People in quarantine	Tests performed	Tests with positive result	Tests with Negative result	Orders for POZ tests	Number of Test Remaining	Number of Convalescence
1.	**O**	7.13	3	9	21,052	2,659	827	1,798	1,190	34	459
2.	**S**	5.81	1	8	9,862	2,870	839	1,986	906	45	369
3.	**KP**	5.6	1	9	18,039	5,392	1,382	3,946	1,963	64	664
4.	**M**	11.47	9	28	147,861	24,228	7,117	16,637	6,591	474	2,821
5.	**P**	9.59	0	4	63,524	8,334	2,635	5,474	3,321	225	1,126
6.	**S**	13.14	3	16	115,385	17,280	6,867	10,133	7,936	280	2,127
7.	**WM**	8.01	6	6	25,698	5,343	1,362	3,923	1,621	58	510

Cont. table 4.

8.	**TWP**	8.33	0	14	29,846	6,186	1,665	4,435	2,173	86	725
9.	**LS**	11.05	7	6	63,288	9,990	3,643	6,134	3,629	213	1,529
10.	**GPV**	7.39	10	13	44,547	9,372	2,964	6,297	3,354	111	1,417
11.	**L**	7.21	2	20	46,259	8,174	2,084	6,005	2,800	85	785
12.	**P**	4.97	1	6	16,809	2,994	704	2,265	1,127	25	309
13.	**LPV**	12.32	15*	12	53,131	12,389	4,808	7,301	3,859	280	2,467
14.	**LV**	5.09	6	3	9,571	2,444	586	1,820	821	38	345
15.	**P**	11.3	1	19	48,052	7,793	2,787	4,986	2,559	20	1,013
16.	**L**	8.07	2	8	34,206	7,366	1,955	5,373	2,522	38	765

1. Opole, 2. Swiętokrzyskie, 3. Kuyavian-Pomeranian, 4. Masovian, 5. Pomeranian, 6. Silesian, 7. Warmian-Masurian, 8. The West Pomeranian, 9. Lower Silesian, 10. Greater Poland Voivodeship, 11. Lodz, 12. Podlaskie, 13. Lesser Poland Voivodeship, 14. Lubusz Voivodeship, 15. Podkarpackie, 16. Lublin.

Methodology while recording data

1. Daily number of infected = number of people with positive results reported by laboratories to the EWP system during the last day (people with a unique PESEL number) EWP is electronic logging platform for health care.
2. Corrections - in the reporting system, in individual cases, the results may change retroactively as a result of the introduced corrections. Corrections may also apply to address data or personal data. Therefore, the global number of cases will be recalculated for each day, and the change in this value in a specific time period may not be equal to the sum of all new cases reported on each day of that period.
3. Positive results of antigen and commercial tests are included in the presented data on an ongoing basis.
4. The deaths take into account both the death of an individual from COVID-19 alone and the coexistence of COVID-19 with other diseases. In individual cases, after medical verification or re-reporting, the cause of death of a given person may be changed.
5. In the daily reports, there are cases of reporting a positive result without being assigned to a specific voivodeship and powiat, due to the lack of the patient's address on the laboratory side. The indicated patients will be assigned to voivodships and powiats by sanitary and epidemiological stations.

3. Services Provided by republic of Poland

The republic of Poland, taking every measure to control the pandemic, from the first day, when first case was reported in Poland. The government started easy steps for covid testing. Presently, there are 91 infectious hospitals (List of Infectious hospitals, 2022), 831 social welfare homes for corona relief (Social welfare homes, 2022), and 221 laboratories list of laboratories in Poland, (2022), that are working on daily bases for testing within the country. These formation of these special laboratories in overall Poland was completed on 26th October,

2020. The detail numbers are presented in the Table 5, while the further details are mentioned in the reference.

National Health Foundation (NFZ), has started telephone patient consultation in every province, and provided special hotline number 24/7 helpline (NFZ News, 2022). Thanks to the program, people over the age of 70 will get the help they need in a pandemic without leaving home. All you need to do is contact a dedicated hotline. Support in the form of e.g. necessary products will be delivered to the retirement home. It is solidarity corps for supporting senior, with slogan "Together we will defeat the corona-virus" (Solidarity corps, 2022).

Government of Poland started two mobile applications, home quarantine (App quarantine, 2022) and stop covid - ProteGo Safe (ProteGO Safe, 2022). The first one is an application that facilitates and streamlines the performance of mandatory home quarantine. The second is our attitude determines how quickly we return to normal life. By using this application polish people can speed it up with slogan Let's act together. To protect the mental health of patient, a psychological service was started to help the mental health in quarantine, mental health protection of children and adolescents, and people experiencing mental disorders or addictions (Ministry of Health and the National Health Fund: News Section, 2021, 2022).

Government started national immunization program in the Poland. The main objective for the programme safe and effective, accessible supply of vaccine to public. The person can get vaccine by electronic referral from doctor, or registering himself for voluntary vaccination (Immunization program, 2022). Presently, 57.10% polish population are fully vaccinated against covid (Legal Act, 2022).

4. The current rules in the republic of Poland

The government announced new restriction for public safety, which includes, social distancing 1.5 meter distance for pedestrian, wearing mask in public, 7 days compulsory quarantine, Covid digital Eu certificate with negative PT-PCR test requirement for all of those crossing European or non-European boarder while entering in Poland territory. There is strict regulation in culture and entertainment, care and education, international boarder and movements, services, trades, sports and recreation, sanatoriums, health resorts, rehabilitation public transport and religious celebrations. In the meanwhile government is allowing these activities for a maximum of 30%. occupancy. But if anyone is vaccinated against covid or recovered from covid or having Eu digital covid certificate this occupancy limit is not applicable on those gatherings (Ministry of Health and the National Health Fund: News Section, 2021).

Table 5.
The Current Number of laboratories, and hospital in provinces

Name of voivodships	Number of Covid Laboratories	Infectious Hospitals
Opole	5	3
Swiętokrzyskie	10	5
Kuyavian-Pomeranian	13	4
Masovian	31	10
Pomeranian	14	5
Silesian	24	7
Warmian-Masurian	10	5
The West Pomeranian	10	3
Lower Silesian	16	4
Greater Poland Voivodeship	24	5
Lodz	13	5
Podlaskie	8	8
Lesser Poland Voivodeship	16	10
Lubusz Voivodeship	3	2
Podkarpackie	10	7
Lublin	14	8

5. Latest Updates

On January 20, 2022, the polish health minister announced, free covid testing at public pharmacies, shorten the quarantine requirements to 7 days, special intensive aid for old citizens, enhanced the bed space in hospitals for covid, assign 95 medical emergency teams, and increase the budget for other expenditure or necessary tool to fight against covid (Polish ministry of health, 2022).

6. Conclusion and Discussion

The COVID-19 pandemic has generated a vast amount of new knowledge in several fields, including virology, epidemiology, public health, and healthcare. Some of the key lessons learned from the COVID-19 pandemic are:

Importance of preparedness: The pandemic has highlighted the importance of preparedness in the face of emerging infectious diseases. Countries need to be better prepared with adequate healthcare infrastructure, equipment, and medical supplies to manage future pandemics.

Need for effective communication: The COVID-19 pandemic has emphasized the importance of effective communication in controlling outbreaks. Clear and concise messaging

can help people understand the risks, and motivate them to take the necessary precautions to prevent the spread of the virus.

Importance of public health measures: The pandemic has demonstrated that public health measures such as hand hygiene, social distancing, and the use of masks can be effective in controlling the spread of the virus.

Importance of global collaboration: The pandemic has highlighted the need for global collaboration in managing emerging infectious diseases. Countries need to work together to share information, resources, and expertise to control the spread of the virus.

Need for equitable vaccine distribution: The COVID-19 pandemic has brought to light the importance of equitable distribution of vaccines, particularly in low-income countries. Ensuring that everyone has access to vaccines is critical in controlling the spread of the virus and ending the pandemic.

Long-term effects of COVID-19: The pandemic has also highlighted the potential long-term effects of COVID-19, including the development of long COVID, a condition where people experience persistent symptoms long after the initial infection. Overall, the COVID-19 pandemic has underscored the importance of global collaboration, preparedness, effective communication, and the need for equitable access to healthcare resources, including vaccines. These lessons learned can help us better prepare for future pandemics and address ongoing health challenges.

The COVID-19 pandemic has had a significant impact on Poland, with over 3 million confirmed cases and more than 70,000 deaths. In response, the Polish government has implemented several measures to slow the spread of the virus. These measures include mandatory mask-wearing in public spaces, social distancing requirements, and restrictions on public gatherings. Furthermore, the government has launched a national vaccination campaign to immunize the population against COVID-19. As of March 2023, over 70% of the Polish population has received at least one dose of the vaccine. The government's efforts have resulted in a decline in new cases and deaths. However, the situation remains fluid, and the government continues to monitor the situation closely and adapt its measures accordingly.

6.1. Importance of the research

This communication highlights the measures taken by the Polish government to control the spread of COVID-19 in the country. This information is crucial in understanding the effectiveness of various public health interventions in controlling the pandemic.

Furthermore, this short communication provides insight into the impact of vaccination campaigns in reducing the number of COVID-19 cases and deaths. This information can be used to inform and guide vaccination strategies in other countries facing similar challenges. Overall, the current study will contributes to the growing body of knowledge on COVID-19, and it highlights the importance of evidence-based public health interventions in controlling the spread of the virus.

6.2. Further use of the obtained information

The information obtained from the current studies can be further used to guide policy decisions and public health interventions in Poland and other countries facing similar challenges. The insights on the impact of vaccination campaigns, for instance, can be used to inform vaccine distribution strategies and optimize vaccine uptake. Additionally, this short communication can serve as a reference for researchers and policymakers seeking to understand the effectiveness of various public health interventions in controlling the spread of COVID-19. The information can also be used to develop and refine models for predicting the spread of the virus and identifying potential intervention strategies.

Author credit statement

Ayesha Amjad: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. Formal analysis, Methodology.

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References

1. Chief Sanitary Inspectorate. About the inspection (2022). https://gis.gov.pl/en/homepage/, 21, January, 2022.
2. Clinical psychiatrist help (2022). https://pacjent.gov.pl/internetowe-konto-pacjenta/erecepta, 21, January, 2022.
3. Corona virus and recommendations, legal Acts (2022). https://www.gov.pl/web/koronawirus/podstawa-prawna, 21, January, 2021.
4. Corona virus information and recommendations (2022). https://www.gov.pl/web/koronawirus/wykaz-zarazen-koronawirusem-sars-cov-2, 21, January, 2022.
5. Corona Virus: The List of Infectious hospitals (2022). https://www.gov.pl/web/koronawirus/lista-szpitali, 21, January, 2022.

6. Corona Virus: The list of laboratories in Poland (2022). https://www.gov.pl/web/koronawirus/lista-laboratoriow-covid, 21, January, 2022.
7. Corona Virus: The social welfare homes (2022). https://www.gov.pl/web/koronawirus/dps, 21, January, 2022.
8. COVID Epidemia koronawirusa – szczególne zasady wjazdu i pobytu na terytorium RP (2022). https://www.strazgraniczna.pl/pl/cudzoziemcy/covid-epidemia-koronawi/8578, Outbreak-of-coronavirus-rules-of-entry-and-stay-on-the-territory-of-the-Republic.html, 21, January, 2022.
9. Covid-19 Dashboard Centre for system science and engineering (CSSE) (2022). https://coronavirus.jhu.edu/map.html, 21, January, 2022.
10. Dietz, L., Horve, P.F., Coil, D., Fretz, M., Eisen, J., Van Den Wymelenberg, K. (2020). *2019 Novel Coronavirus (COVID-19) Outbreak: A Review of the Current Literature and Built Environment (BE) Considerations to Reduce Transmission*.
11. Home quarantine (2022). https://play.google.com/store/apps/details?id=pl.nask.droid.kwarantannadomowa&hl=en&gl=US, 21, January, 2022.
12. Live covid Vaccination tracker (2022). https://covidvax.live/location/pol, 21, January, 2022.
13. Mental Health Centre in your area (2022). https://czp.org.pl/index.php/o-czp/, 21, January, 2022.
14. National Health Foundation (NFZ), Telephone consultation 24/7 Helpline number (2022). https://www.nfz.gov.pl/aktualnosci/aktualnosci-centrali/telefoniczna-informacja-pacjenta-tu-uzyskasz-informacje-o-postepowaniu-w-sytuacji-podejrzenia-zakazenia-koronawirusem,7597.html, 21, January, 2022.
15. National Health Fund (2022). https://www.nfz.gov.pl/o-nfz/informator-o-zawartych-umowach/, 21, January, 2022.
16. National immunization program (2022). https://www.gov.pl/web/szczepimysie/narodowy-program-szczepien-przeciw-covid-19, 21, January, 2022.
17. Our World in Data, Statistical analysis of covid 19 pandemic (2022). https://ourworldindata.org/, 21, January, 2022.
18. Pinkas, J., Jankowski, M., Szumowski, Ł., Lusawa, A., Zgliczyński, W.S., Raciborski, F., Gujski, M. (2020). Public health interventions to mitigate early spread of SARS-CoV-2 in Poland. *Medical science monitor: international medical journal of experimental and clinical research*, *26*, e924730-1.
19. Regulation by the Cabinet on 31 March 2020 to limit the public gathering (2022). http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20200000566/O/D20200566.pdf, 21, January, 2022.
20. Solidarity corps for supporting senior (2022). https://wspierajseniora.pl/, 21, January, 2022.
21. SSMJ Team (2021). What do we know about breastfeeding and COVID-19? *South Sudan Medical Journal*, *14*(2), pp. 55-59.

22. Stoecklin, S.B., Rolland, P., Silue, Y., Mailles, A., Campese, C., Simondon, A., Levy-Bruhl, D. (2020). First cases of coronavirus disease 2019 (COVID-19) in France: surveillance, investigations and control measures, January 2020. *Eurosurveillance*, *25*(6), 2000094.
23. STOP COVID - ProteGO Safe (2022). https://play.google.com/store/apps/details?id=pl.gov.mc.protegosafe, 21, January, 2022.
24. Strategy to combat the COVID-19 pandemic, legal Acts (2022). https://www.gov.pl/web/zdrowie/strategia-walki-z-pandemia-covid19, 21, January, 2022.
25. The First case in Poland [Pierwszy przypadek koronawirusa w Polsce] (2023). Ministerstwo Zdrowia. Portal Gov.pl, www.gov.pl, 5, May, 2023.
26. WHO Coronavirus (COVID-19) Dashboard (2023). https://covid19.who.int/, 5, May, 2023.
27. Wu, P., Hao, X., Lau, E.H., Wong, J.Y., Leung, K.S., Wu, J.T., Leung, G.M. (2020). Real-time tentative assessment of the epidemiological characteristics of novel coronavirus infections in Wuhan, China, as at 22 January 2020. *Eurosurveillance*, *25*(3), 2000044.

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IMPACT OF THE COVID-19 PANDEMIC ON THE CHOICE OF INVESTMENT STRATEGIES AND INVESTORS' BEHAVIOR ON THE WARSAW STOCK EXCHANGE – 2017-2020 RESEARCH FINDINGS

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Purpose: This paper attempts to reveal the potential differences between the portfolios of dividend-paying companies with growth or value potential and the same portfolios fortified with the financial instruments replicating precious metals or real estate price behavior in a turbulent global economy.
Design/methodology/approach: The research objective of this paper is accomplished by means of a thorough literature analysis. Moreover, the authors employ comparative analysis methods to explore the features of stock portfolios held by dividend-paying companies with value or growth potential and portfolios of the companies that are fortified with financial instruments replicating the price behavior of precious metals or real estate and uncover the similarities and differences. Research of the characteristics of financial instrument portfolio variants and comparison between them is conducted by means of standard deviation of the rate of return, coefficient of variation, the Pearson correlation coefficient and the Spearman's rank correlation coefficient. It was also assessed whether the estimated correlation coefficients were statistically significant through the use of a non-parametric correlation coefficient significance test.
Findings: The results of the empirical analyses conducted here reveal that the average annual return of portfolios held by dividend-paying companies with value and growth potential is lower than ETFs replicating precious metals. Furthermore, during the turbulent economy of 2020, the inclusion of precious metal assets boosted the rates of return of the Polish dividend-paying companies portfolios.
Research limitations/implications: The research was carried out on a limited number of the analyzed companies. Therefore, it could be biased, due to the deterministic stock sampling method.
Practical implications: Knowledge of the similarities and differences between dividend-paying companies with value or growth potential and the risk diversification of such companies' stock portfolios by means of instruments replicating the price behavior of precious metals or real estate is of great importance to both the investors and investment funds' boards. Consequently, one can make better investment decisions.

Social implications: Among the paper's social implications, the most important appears to be a possible change in the investors' attitude towards dividend-paying companies with value potential and financial instruments replicating the price behavior of precious metals or real estate. Ultimately, investors' needs could be better addressed.
Originality/value: What is new in the paper is the stock comparison of dividend-paying companies' with value and growth potential with precious metals and real estate-based instruments. The paper also attempts to compare efficiency of investing in the portfolio variants, capturing the effect of the SARS-CoV-2 pandemic, thereby filling our knowledge gap.

Keywords: COVID-19 pandemic, precious metals, ETFs, Spearman rank correlation coefficient.

Category of the paper: Research paper.

1. Introduction

The stock portfolios' rates of return are determined by the possible profit from the sale of stocks and a possible income from dividends distributed over the stock ownership period. In the long term, it is becoming particularly important to invest in the stocks of issuers that maintain a dividend policy and distribute dividends on a regular basis, generating steady income for the investor. However, ever since the publication of a paper by F. Modigliani and M. Miller (Miller, Modigliani, 1961) proving that there is no impact of dividend policy on the stock prices, this matter has proved to be the topic of extensive research and consideration in many scientific publications (Al-Malkawi, Rafferty, Pillai, 2010). In particular, it was considered a key issue to determine whether investing in dividend companies makes it possible to achieve above-average income (McQueen, Shields, Thorley, 1997). M. Lichtenfeld (Lichtenfeld, 2015, p. 63) states that for the 2001–2011 period, the average annual rate of return of the S&P Dividend Aristocrats Index was 7.1% compared to 2.9% average annual rate of return of the S&P 500 Index. A. Williams and M. Miller (Williams, Miller, 2013, pp. 58-69), however, based on the research conducted, found that during the financial crisis in the USA (especially 2008), the rates of return of companies that paid dividends on a regular basis (dividend aristocrats) were characterized by higher rate of return than the S&P 500 index. Together with the issue of dividend policy and dividend payments, the issue of the market ratios of these companies (P/E and P/BV) and how the level of these ratios actually determines the choice of dividend-paying companies' stocks is often cited. R.A. Haugen has conducted a research using both ratios, showing that companies with high P/BV ratio are characterized by the highest risk and the lowest rate of return (Haugen, 1999, pp. 2-10). However, R. Banz (1981) proved that this rate is even higher for companies with lower market capitalization. J. Czekaj, M. Woś and J. Żarnowski (2001) came to the analogous conclusions but pertaining to the Polish stock market and P/BV ratio. They proved that companies featuring low P/BV ratios have brought statistically significant above-average rates of return, as opposed to the companies with high P/BV ratio values.

This paper attempts to reveal the potential differences between the portfolios of dividend-paying companies with growth or value potential and the same portfolios fortified with the financial instruments replicating precious metals or real estate price behavior in a turbulent global economy.

The scope of the research covers investment strategies that include dividend-paying companies with value and growth potential and financial instruments replicating precious metals and real estate price behavior. According to the literature of the subject (Haugen, 1999, pp. 2-10), based on the P/BV parameter indications, dividend-paying companies are assigned to two groups – companies with growth potential and companies with value potential. Companies with a high P/BV indicator, i.e. above 1, were assigned to the first group, and those with a low P/BV indicator, i.e. below 1, were assigned to the second group.

It should be noted that there are studies on the attitudes and behavior of investors in the capital market, also including their investment strategies (among others, G.C. Selden, O.K. Burrel, W.S. Bauman, S. Benartzi, R.H. Thaler, J.R. Nofsinger, S.E.G. Lea, R.M. Tarpy, P. Webley, R.A. Haugen, H. DeAngelo, L. DeAngelo and R.M. Stulz). These studies, however, do not address the division into dividend-paying companies with growth and value potential. Similarly, they fail to address the development and implementation of investment strategies in a turbulent global economy and incorporation of instruments regarded as "safe harbors" like precious metals (namely monetary metals such as gold and silver) and real estate.

2. Literature review and research hypotheses development

The perception of a group as a psychological, rather than physical phenomenon has been confirmed by researchers like G. Le Bon, S. Freud, C. Jung or A. Koestler (Le Bon, 1986 after Plummer, 1995, p. 11). Le Bon's observations suggest that the group displays specific characteristics such as a collective mind and an influence on the behavior of an individual, provided that such an individual becomes a member of the group. The group's influence on an individual is powerful enough to change one's existing beliefs (Koestler, 1978; Talbot, 1981 after Plummer, 1995, pp. 16-19). Group affiliation alters the individual's perception of personal responsibility and the population implements its objectives in an emotional and often irrational manner. This could explain financial instruments price change mechanism in the financial markets, as the co-existence of two groups with different perception of the future market trends and future valuation of an instrument results in different investment decisions. Notwithstanding the correctness of decisions made, an individual will seek validation and acceptance of their views within the group. Therefore, an individual identifies himself with other investors that belong to a group with similar investment philosophy. A rational investor always acts to maximize the profits, is not driven by emotions or pressure from the group of other gamblers,

and only follows information based on the reliable financial analyses (known as fundamental data) (Zaleśkiewicz, 2003, pp. 9-10). G.C. Selden, O.K. Burrell and W.S. Bauman are among the first to outline the application of the field of psychology to the capital market (Razek, 2011, p. 8). The authors indicate a new field of benefits that can arise from combining quantitative investment models with behavioral finance (Olsen, 1998, p. 10). *EMH – Efficient Market Hypothesis* was published in 1965 by E.F. Fama (Fama, 1995, pp. 75-80). According to the theory, the capital market is operated by the rational investors who are able to utilize public information to anticipate stock price changes. Meanwhile, an efficient market is a place with a huge number of rational and return-maximizing investors and information flow is free and unlimited for any investor. In 1970, P.A. Samuelson proved that information flowing into the capital market is quickly and appropriately interpreted by the investors (Samuelson et al., 1995, p. 445). However, the paradox of market efficiency is that if a hypothetical situation occurs, and all investors believe it exists and accept the required conditions, the market will instantly cease to be efficient. The reality, however, is that markets are neither efficient nor inefficient, so efficiency can only take different shades (Dembny, 2005, pp. 79-80). According to A. Timmermann and C.W.J. Granger, the efficient markets hypothesis is, however simple, hard to empirically verify. Identifying at least one accurate forecast constitutes an evidence against the efficient markets hypothesis, if uncertainty as to the choice of the best forecasting model is ignored. Otherwise, such proof can only be accepted if the optimal model selection methodology allows investors to identify the correct ex ante model (Timmermann et al., 2004, pp. 15-27). Also, the research by R.H. Thaler, J.R. Nofsinger and S.E.G. Lea, R.M. Tarpy, P. Webley (Thaler, 1999; Nofsinger, 2001; Lea et al., 1987) reveals that most investors tend to make financial choices hot-headed because they hope for fast profit. Investors are too hot-headed, lack self-control and struggle to defer financial gratification. Research by S. Benartzi, R.H. Thaler, however, indicates that investors revise their portfolios far too often. They no longer consider investing as a long-term process in favor of swift decisions of short-term importance. The authors believe that mental accounting and loss aversion play a significant role here (Benartzi et al., 1995, pp. 73-92). Investment principles indicate that all the revenue obtained should be considered collectively – for an economically reasonable investor it is not important whether they profit from the payment of dividends or the sale and acquisition of stocks[1]. According to the research, investors distribute their income as if dividends and profit on sale constituted two separate incomes, and their purpose is also different. This is because collecting dividends is mainly related to a short-term consumption goal, while the profit on the disposal of stocks is associated with a long-term goal. H.M. Shefrin and M. Statman also conclude that those investors, who need cash for their current expenses, will look for stocks that provide them with regular dividend payments (Shefrin et al., 1984, pp. 253-282;

[1] It is also based on the estimation of the stock's income value, which recognizes stock price fluctuations (profit or loss) and dividends collected.

Zaleśkiewicz, 2003, pp. 134-136). Considering the prospect of investment, according to R.A. Haugen, the relationship between stock rate of return and P/E and dividend values becomes relevant when the period over which the relationship is considered extends (Haugen, 1999, pp. 69-94). This indicates that short-term market behavior does not correspond to what happens in the long term. It is particularly important when investors are creating their portfolios in the long term (see more: Zaleśkiewicz, 2003, p. 88). Therefore, investing in stocks of companies, whose issuer pays regular dividends becomes particularly important for the investor. Research conducted by K.P. Fuller and M.A. Goldstein (Fuller, Goldstein, 2011, pp. 457-473), H. Rubin and C. Spaht II (Rubin, Spaht II, 2011, pp. 11-19) and P. Asquith and D.W. Mullins Jr. (Asquit, Mullins, 1983, pp. 77-96) confirm that stock price behavior variations in favor of dividend-paying companies can be observed, especially during a bull market. E. Fama and K. French (Fama, French, 1992) carried out research of all stocks listed on the New York Stock Exchange, the American Stock Exchange and the over-the-counter market (Nasdaq) for the 1963-1990 period, taking into account the relationship between the book value of equity and the stock's market value. The correspondence of these values was analyzed by the authors of research by investigating behavior of the companies' P/BV parameter. The authors attributed a low P/BV parameter to companies being entities with value potential, while stocks of companies characterized by a high level of this parameter were considered to have growth potential. The research results indicate that an average annual rate of return for the companies with value potential was 24.4%, and for the companies with growth potential it was only 8%. R.A. Haugen has reached similar conclusions, by using the P/BV indicator to describe companies with growth and value potential (Haugen, 1999, pp. 2-10). By contrast, H. DeAngelo, L. DeAngelo and R.M. Stulz (DeAngelo, DeAngelo and Stulz, 2006) connected P/BV values to the dividend payments by companies. The authors believe that the higher the P/BV value of a company in the preceding year, the higher the possible dividend in the reference year. Meanwhile, research conducted by M. Baker and J. Wurgler (Baker, Wurgler, 2004, pp. 271-288) indicates that companies with higher P/BV values are paying dividends more often than those with low values of this parameter. During the periods of elevated inflation, stocks of the dividend-paying companies could be seen as attractive to the investors because dividend income is a real variable and investors collect dividends that are generally inflation-adjusted (Lee, 2000, p. 192).

The research and analysis presented, despite the broad time span and inclusion of various stock exchanges, does not cover the research on how the inclusion of assets regarded as “safe harbors”, i.e. precious metals (monetary metals such as gold and silver) and real estate, affects rates of return and investment risk in dividend-paying companies portfolios. They also do not cover as to whether the division of dividend-paying companies into value and growth potential companies is important to the investor and how the characteristics of these portfolios evolve in a turbulent global economy.

Based on the literature review and the identified research gaps, the following research hypotheses were defined:

H_1: The average annual rate of return of dividend-paying companies portfolios with value and growth potential is higher than ETFs replicating precious metals.

H_2: During the turbulent 2020 economy, the inclusion of precious metals assets or REITs has improved the Polish dividend portfolios' rates of return.

H_3: The portfolios of dividend-paying companies with growth and value potential behave much like a portfolio made of companies replicating the real estate market.

3. Sample selection and methodology

In order to fulfill this paper's objectives, companies listed on the Warsaw Stock Exchange in Poland, which have been regularly paying dividends in the 2017-2020 period and their dividend payment policy dates back to at least 2006 (10 years of uninterrupted dividend payments), were covered by the research. 52 WSE listed companies were analyzed, namely: Asseco Business Solutions (ABS), ACAutogaz (ACG), Asseco Poland (ACP), Ambra (AMB), Aplisens (APN), Apator (APT), Aqua (AQU), Asseco South Eastern Europe (ASE), Atende (ATD), ATM Grupa (ATG), Budimex (BDX), Bank Handlowy w Warszawie (BHW), CCC (CCC), CEZ (CEZ), Firma Oponiarska Dębica (DBC), Dektra (DKR), Dom Development (DOM), ED Invest (EDI), Korporacja Gospodarcza Efekt (EFK), Elektrotim (ELT), Eurocash (EUR), Eurotel (ETL), Euro-Tax.pl (ETX), Ferro (FRO), Fabryka Sprzętu i Narzędzi Górniczych Fasing (FSG), Giełda Papierów Wartościowych w Warszawie (GPW), Przedsiębiorstwo Hydrauliki Siłowej Hydrotor (HDR), IFIRMA (IFI), Introl (INL), KGHM (KGH), KRKA (KRK), Zakłady Tłuszczowe Kruszwica (KSW), Grupa Kęty (KTY), Lena Lighting (LEN), LPP (LPP), Neuca (NEU), Oponeo.pl (OPN), Bank Polska Kasa Opieki (PEO), PGS Software (PSW), Powszechny Zakład Ubezpieczeń (PZU), Fabryka Obrabiarek Rafamet (RAF), Silvano Fashion Group (SFG), Fabryka Farb i Lakierów Śnieżka (SKA), Sanok Rubber Company (SNK), Sonel (SON), Stalprofil (STF), Talex (TLX), Unibep (UNI), Wawel (WWL), WODKAN Przedsiębiorstwo Wodociągów i Kanalizacji (WOD), Grupa Azoty Zakłady Azotowe Puławy (ZAP), Grupa Żywiec (ZWC). The authors of this paper indicate that the research included particularly unusual year 2020, which was dominated by the worldwide SARS-CoV-2 pandemic and its impact on the individual companies' operation and dividend payments, and on the investment decisions made by investors.

Additionally, the research included, from the perspective of managed assets value, the largest dollar-settled ETFs replicating the prices of precious metals (gold and silver) and the real estate market. Two ETFs (namely ETC, or Exchange Traded Commodity) replicating gold (iShares Physical Gold ETC and Invesco Physical Gold ETC) and silver (WisdomTree

Physical Silver ETC and iShares Physical Silver ETC) market, which invest funds in physical precious metals, were selected for this analysis. The research also included two of the largest ETFs investing in REITs (hereafter ETF REIT), owning real estate located across the globe (Vanguard Real Estate ETF – office buildings, hotels, other real estates and iShares Developed Markets Property Yield UCITS ETF – broadly understood real estate market excluding the Greek market). Including ETFs investing in global REITs in the research is motivated by the need for a well-diversified real estate portfolio. Global coverage of the assets in their portfolios eliminates the risk that the real estate location and the REITs listing location will influence stock prices, which is the case for precious metals listings, are not determined by the asset location risk.

The research was carried out in the following stages:

1. Stage one – to identify companies with value and growth potential and make comparisons in terms of rates of return and risk among the WSE listed companies that have been paying dividends continuously in the 2017-2020 period.
2. Stage two – to analyze stock price movements of the Polish dividend-paying companies with value potential during the turbulent economy of 2020 and portfolio variants that include financial instruments replicating precious metals and real estate price behavior.

4. Investment strategy and investor behavior analysis – research findings for the 2017-2020 period

To select companies with value (portfolio 1), and growth (portfolio 2) potential, a P/BV ratio analysis of WSE listed, dividend-paying companies was conducted. It was assumed that low P/BV companies, i.e. below 1, will be included in Portfolio 1. High P/BV companies, i.e. above 1, in contrast, will be allocated to portfolio 2. Both portfolios were compared in terms of the rate of return obtained over the considered period. Each portfolio featured 10 companies with the best P/BV ratios in the considered group. In this research, portfolios were kept for one year (early January to the end of December), then, the annual rates of return were calculated for each portfolio and afterwards the procedure was repeated in a similar manner. Investment portfolio compositions and the rates of return of individual constituent companies over the past 4 years are presented in table 1.

Table 1.
Compositions of portfolios 1 and 2 and the rates of return [%] of the respective companies in 2016-2020 – WSE listed issuers in Poland

Number of companies	1	2	3	4	5	6	7	8	9	10
Portfolio 1_{2017}	WOD	CEZ	EFK	EDI	FSG	RAF	AQU	ACP	ZAP	ASE
Rate of return$_{2017}$	0.53	16.81	-11.52	4.19	18.73	-28.90	-9.94	-19.11	-11.63	42.86
Portfolio 2_{2017}	ZWC	PSW	SFG	CCC	LPP	BDX	ETX	KRK	SKA	ACG
Rate of return$_{2017}$	7.27	12.41	-16.94	35.06	61.97	5.37	-0.71	-5.65	24.58	-1.42
Portfolio 1_{2018}	WOD	CEZ	EFK	ZAP	FSG	EDI	RAF	STF	AQU	TLX
Rate of return$_{2018}$	-11.86	8.73	-7.56	-57.75	-1.19	-12.39	-19.84	-40.00	-1.24	-39.47
Portfolio 2_{2018}	ZWC	SFG	PSW	CCC	ETX	KRK	LPP	BDX	ACG	SKA
Rate of return$_{2018}$	-2.12	-13.39	-39.60	-33.48	-9.09	5.13	-14.25	-43.76	5.12	-0.64
Portfolio 1_{2019}	EFK	CEZ	WOD	FSG	RAF	STF	ZAP	INL	AQU	EDI
Rate of return$_{2019}$	-50.23	-5.84	21.90	-8.02	-7.29	-16.94	33.13	-23.07	1.28	26.70
Portfolio 2_{2019}	ZWC	SFG	ETX	KRK	PSW	BDX	LPP	CCC	ACG	SKA
Rate of return$_{2019}$	6.06	-14.59	4.74	24.70	21.11	50.33	11.08	-43.88	7.83	5.81
Portfolio 1_{2020}	CEZ	FSG	WOD	EFK	STF	ZAP	AQU	TLX	BHW	PEO
Rate of return$_{2020}$	5.26	-29.19	44.36	11.81	-4.68	-8.92	-3.16	-7.26	-33.55	-40.10
Portfolio 2_{2020}	ZWC	CCC	SFG	ETX	KRK	BDX	PSW	LPP	IFI	SKA
Rate of return$_{2020}$	-2.81	-24.49	-31.43	-28.57	39.29	72.94	16.73	-6.33	68.57	9.20

Source: Own study.

Over the past 4 years, among dividend-paying companies on the Polish stock exchange, it was found that the higher average rates of return were generated by the companies with growth potential rather than value potential. For portfolio 2, made of 10 companies with the highest P/BV ratios, the average annual rate of return was 4.05% (see table 2).

Table 2.
Average annual rate of return generated by portfolios 1 and 2 made of 10 companies – Polish stock exchange

Portfolio variants	2017	2018	2019	2020	Average rate of return	Standard deviation of return
Portfolio 1 (companies with value potential)	0.20%	-18.26%	-2.84%	-6.54%	-6.86%	8.08%
Portfolio 2 (companies with growth potential)	12.19%	-14.61%	7.32%	11.31%	4.05%	12.62%

Source: Own study.

The 2020 analysis, however, as the world struggled with the SARS-CoV-2 pandemic and major turbulence, panic and consequent steep stock price declines developed in the financial markets, the average annual rate of return was higher for companies with growth potential at 11.31%, compared to -6.54% for companies with value potential (table 2). Polish dividend-paying companies with value potential in a turbulent 2020 economy were characterized by a considerably lower risk level (portfolio 1 standard deviation of σ_{P1_GPW}=8.08 p.p.) than dividend-paying companies with growth potential (σ_{P2_GPW}=12.62 p.p.).

In order to conduct the second stage of analyses, the listings of selected ETFs replicating gold and silver price movements in USD and PLN for the 2016–2020 period (rates of return for the 2017-2020 period) were presented in tables 3÷4.

Table 3.
Pricing of ETFs replicating gold price movements for the 2016-2020 period

	Items/Year	2016	2017	2018	2019	2020
Price (USD)	**iShares Physical Gold ETC**	22.8425	25.5075	25.1725	29.775	36.9675
	Invesco Physical Gold ETC	113.41	126.5	124.85	147.735	183.45
	Gold (1 Oz)	1150.91	1303.33	1282.56	1517.31	1898.71
Price (PLN)	**iShares Physical Gold ETC**	95.61	88.78	94.17	112.96	138.06
	Invesco Physical Gold ETC	474.67	440.26	467.07	560.48	685.11
	Gold (1 Oz)	4817.10	4536.04	4798.12	5756.37	7090.92
USD (PLN)		4.19	3.48	3.74	3.79	3.73

Source: Own study.

Table 4.
Pricing of ETFs replicating silver price movements for the 2016-2020 period

	Items/Year	2016	2017	2018	2019	2020
Price (USD)	**WisdomTree Physical Silver ETC**	15.46	16.01	14.6025	16.9675	24.745
	iShares Physical Silver ETC	15.8475	16.4313	14.9913	17.4425	25.44
	Silver (1 Oz)	15.95	16.95	15.49	17.85	26.39
Price (PLN)	**WisdomTree Physical Silver ETC**	64.71	55.72	54.63	64.37	92.41
	iShares Physical Silver ETC	66.33	57.19	56.08	66.17	95.01
	Silver (1 Oz)	66.76	59.01	57.96	67.73	98.55
USD (PLN)		4.19	3.48	3.74	3.79	3.73

Source: Own study.

Tables 5÷6, respectively, present the annual rates of return of the selected ETFs replicating gold and silver price movements in USD and PLN for the 2016-2020 period (rates of return for the 2017-2020 period).

Table 5.
Annual rates of return of the ETFs replicating gold price movements for the 2017-2020 period

	Items/Year	2017	2018	2019	2020
Price (USD)	**iShares Physical Gold ETC**	11.67%	-1.31%	18.28%	24.16%
	Invesco Physical Gold ETC	11.54%	-1.30%	18.33%	24.18%
	Gold (1 Oz)	13.24%	-1.59%	18.30%	25.14%
Price (PLN)	**iShares Physical Gold ETC**	-7.15%	6.08%	19.95%	22.22%
	Invesco Physical Gold ETC	-7.25%	6.09%	20.00%	22.24%
	Gold (1 Oz)	-5.83%	5.78%	19.97%	23.18%

Source: Own study.

Table 6.
Annual rates of return of the ETFs replicating silver price movements for the 2017-2020 period

	Items/Year	2017	2018	2019	2020
Price (USD)	**WisdomTree Physical Silver ETC**	3.56%	-8.79%	16.20%	45.84%
	iShares Physical Silver ETC	3.68%	-8.76%	16.35%	45.85%
	Silver (1 Oz)	6.30%	-8.62%	15.23%	47.81%

Cont. table 6.

Price (PLN)	**WisdomTree Physical Silver ETC**	-13.89%	-1.96%	17.83%	43.56%
	iShares Physical Silver ETC	-13.78%	-1.93%	17.99%	43.57%
	Silver (1 Oz)	-11.61%	-1.77%	16.85%	45.51%

Source: Own study.

Tables 5 and 6 demonstrate substantial differences in the rates of return of precious metals and ETFs depending on whether ETF listing prices are quoted in USD or PLN. The differences are particularly apparent in the years 2017–2018. Including the PLN listings, however, makes perfect sense as portfolios comprise of stocks from dividend-paying companies listed on the Warsaw Stock Exchange and therefore listed in PLN. Selected ETFs replicating silver and gold prices are perfectly reflecting precious metal price movements – the Pearson's linear correlation coefficient of the funds' and precious metals' rates of return for both USD and PLN listings is at 1.

Tables 7 and 8 present the listings, the rates of return and dividend rates of the selected REIT ETFs replicating stock price movements for REITs with portfolios composed of real estates all over the world. Data for the 2016-2020 period is presented in a similar manner as the precious metals market, in USD and PLN.

Table 7.
Vanguard Real Estate ETF parameters in USD and PLN

	Items/Year	**2016**	**2017**	**2018**	**2019**	**2020**
Data for USD	**Vanguard Real Estate ETF**	67.72	71.04	66.76	86.06	82.09
	Dividends	2.31	2.96	3.11	2.88	3.18
	Rate of return		9.25%	-1.65%	33.23%	-0.91%
	Dividend rate		4.16%	4.66%	3.35%	3.87%
Data for PLN	**Vanguard Real Estate ETF**	283.46	247.23	249.73	326.48	306.58
	Dividends	9.67	10.29	11.63	10.93	11.87
	Rate of return		-9.15%	5.72%	35.11%	-2.46%
	Dividend rate		4.16%	4.66%	3.35%	3.87%
USD (PLN)		4.19	3.48	3.74	3.79	3.73

Source: Own study.

Table 8.
iShares Developed Markets Property Yield UCITS ETF parameters in USD and PLN

	Items/Year	**2016**	**2017**	**2018**	**2019**	**2020**
Data for USD	**iShares Developed Markets Property Yield UCITS ETF**	20.77	23.09	21.83	26.46	23.94
	Dividends	0.80	0.77	0.94	0.81	0.72
	Rate of return		14.86%	-1.37%	24.93%	-6.80%
	Dividend rate		3.32%	4.32%	3.07%	3.01%
Data for PLN	**iShares Developed Markets Property Yield UCITS ETF**	86.93	80.36	81.67	100.38	89.41
	Dividends	3.33	2.66	3.53	3.09	2.69
	Rate of return		-4.49%	6.02%	26.70%	-8.26%
	Dividend rate		3.32%	4.32%	3.07%	3.01%
USD (PLN)		4.19	3.48	3.74	3.79	3.73

Source: Own study.

Unlike ETFs replicating precious metals market, for REIT ETFs, the investor's rate of return is contingent not only on the fund's price movements but also on the dividends received, distributed by REITs to their investors. The average dividend rate for the Vanguard Real Estate ETF was 4.01%, and for the iShares Developed Markets Property Yield UCITS ETF was 3.43%. For the entire analyzed period, the dividend rate of both funds was still above 3%.

Table 9 presents the average ETF rates of return for each group, i.e. replicating gold, silver and REIT prices and risk measures. Data presented in the table was estimated for the prices expressed in PLN. The application of each average in further analyses aims to eliminate potential differences in the ETFs' listings within their respective groups.

Table 9.
Average rates of return and risk measures of the ETFs groups

ETFs groups averages	2017	2018	2019	2020	Average annual rate of return	Standard deviation of return	Coefficient of variation
Average ETF Gold	-7.20%	6.08%	19.98%	22.23%	10.27%	13.66%	1.33
Average ETF Silver	-13.84%	-1.94%	17.91%	43.57%	11.43%	25.11%	2.20
Average ETF Reit	-6.82%	5.87%	30.90%	-5.36%	6.15%	17.45%	2.84

Source: Own study.

The highest average annual rate of return can be found in the silver market (11.43%), with the highest standard deviation of (25.11 p.p.). The lowest average annual rate of return, in contrast, was generated by the REIT ETFs portfolio (6.15%), at a risk that was 3.79 p.p. higher than that of the gold market. It is worth noting that, in this case, higher risk levels didn't correlate with higher average annual rate of return (figure 1).

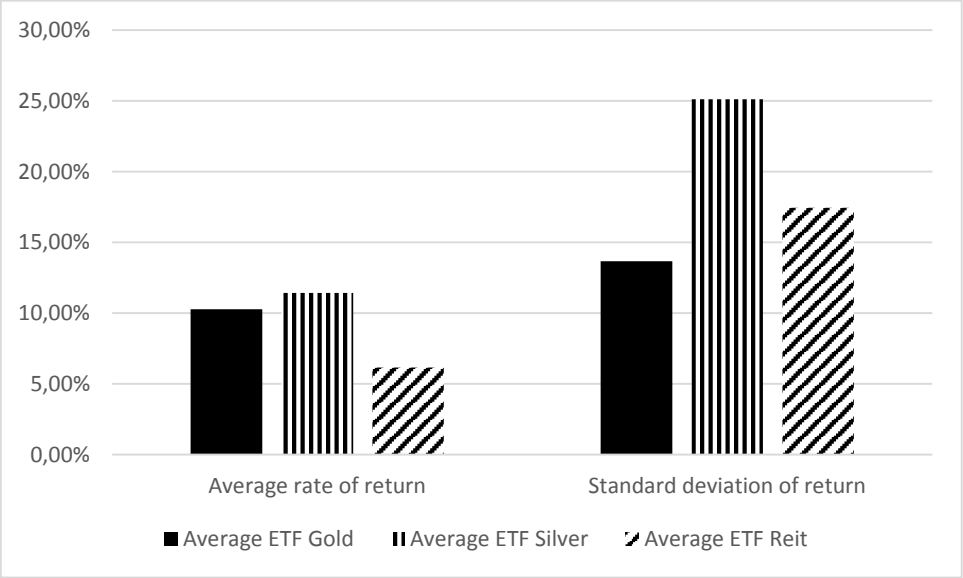

Figure 1. Parameters of the analyzed ETFs for the 2017-2020 period.

Source: Own study.

Among the asset groups analyzed, gold market has the lowest risk-return ratio (coefficient of variation at 1.33) and the highest – the REIT market (coefficient of variation at 2.84). The coefficients of variation presented for the ETF groups support the postulate of a well-balanced investor, who seeks to minimize risk and maximize return. Given the diversity of individual groups of ETFs, all of them will be included in the research concerning variants of portfolios made of dividend-paying companies with value potential (portfolio 1) and with growth potential represented by portfolio 2 (figure 2).

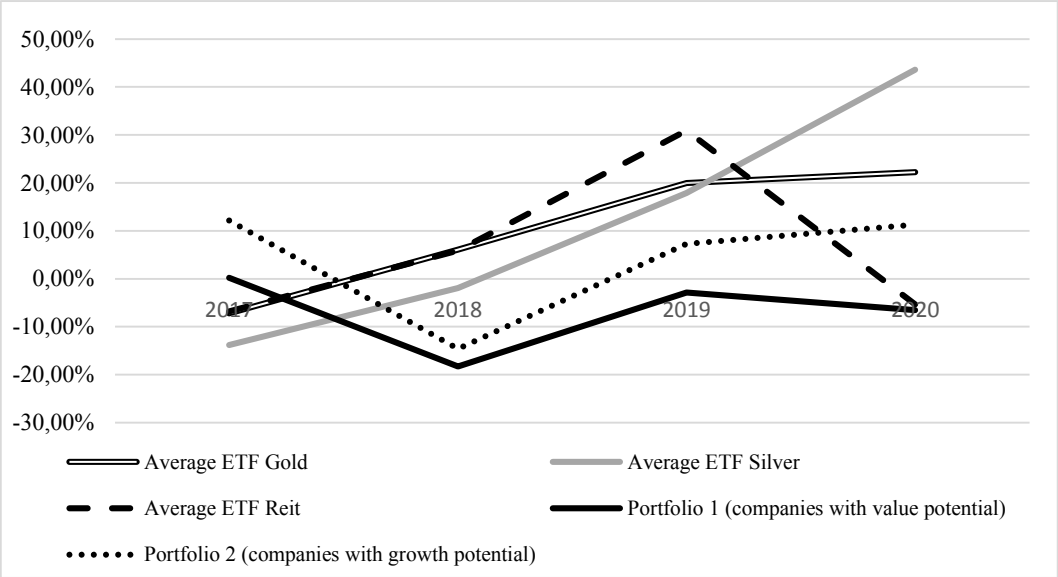

Figure 2. Returns of the analyzed portfolios and ETFs for the 2017-2020 period.

Source: Own study.

Table 10 presents portfolio variants that include dividend-paying companies with value (portfolio 1) and growth (portfolio 2) potential, along with ETFs representing gold and silver markets, and REITs. Equal participation of the individual portfolio components was assumed in the portfolio variants.

Table 10.

Average rates of return and risk measures of the portfolio variants

Portfolio variants	2017	2018	2019	2020	Average annual rate of return	Standard deviation of return	Coefficient of variation
Portfolio 1	0.20%	-18.26%	-2.84%	-6.54%	-6.86%	8.08%	-1.18
Portfolio 1/Etf Gold	-3.50%	-6.09%	8.57%	7.84%	1.71%	7.58%	4.45
Portfolio 1/Etf Silver	-6.82%	-10.10%	7.54%	18.51%	2.28%	13.26%	5.81
Portfolio 1/Etf Reit	-3.31%	-6.20%	14.03%	-5.95%	-0.36%	9.68%	-27.16
Portfolio 2	12.19%	-14.61%	7.32%	11.31%	4.05%	12.62%	3.11
Portfolio 2/Etf Gold	2.50%	-4.26%	13.65%	16.77%	7.16%	9.78%	1.36
Portfolio 2/Etf Silver	-0.82%	-8.28%	12.62%	27.44%	7.74%	15.72%	2.03
Portfolio 2/Etf Reit	2.68%	-4.37%	19.11%	2.98%	5.10%	9.94%	1.95

Source: Own study.

The investor could eliminate negative average annual rate of return of the companies with value potential by considering only precious metals assets in his portfolio (Portfolio 1/Etf Gold = 1.71% and Portfolio 1/Etf Silver = 2.28%). A portfolio of companies with growth potential, in contrast, saw an average annual rate of return increase in every case. The investor gained the highest annual average rate of return increase from Portfolio 1 and Portfolio 2, by incorporating ETF Silver funds By including the gold market in both dividend-paying companies portfolios, the investor reduced the portfolios' risk (the standard deviation of the rates of return for portfolio 1 was reduced from 8.08 p.p. to 7.58 p.p., while portfolio 2 was reduced from 12.62 p.p. to 9.78 p.p.). Among the portfolio variants analyzed, dividend-paying companies with growth potential diversified by the gold market (Portfolio 2/Etf Gold) present the lowest risk-return ratio and dividend-paying companies with value potential diversified by the silver market (Portfolio 2/Etf Silver) present the highest risk-return ratio. Adding ETFs that replicate REITs to portfolio 1 and portfolio 2 improved the average annual rate of return to a lesser extent compared to the inclusion of precious metals. The diversification of all asset groups analyzed with ETFs reduced the coefficient of variation only for portfolio 2. Negative coefficient of variation values (Portfolio 1 and Portfolio 1/Etf Reit) are not to be interpreted.

The 2020 analysis, when panic and stock price declines impacted financial markets, diversification of portfolios with ETFs was a sensible solution by using precious metals (figure 3).

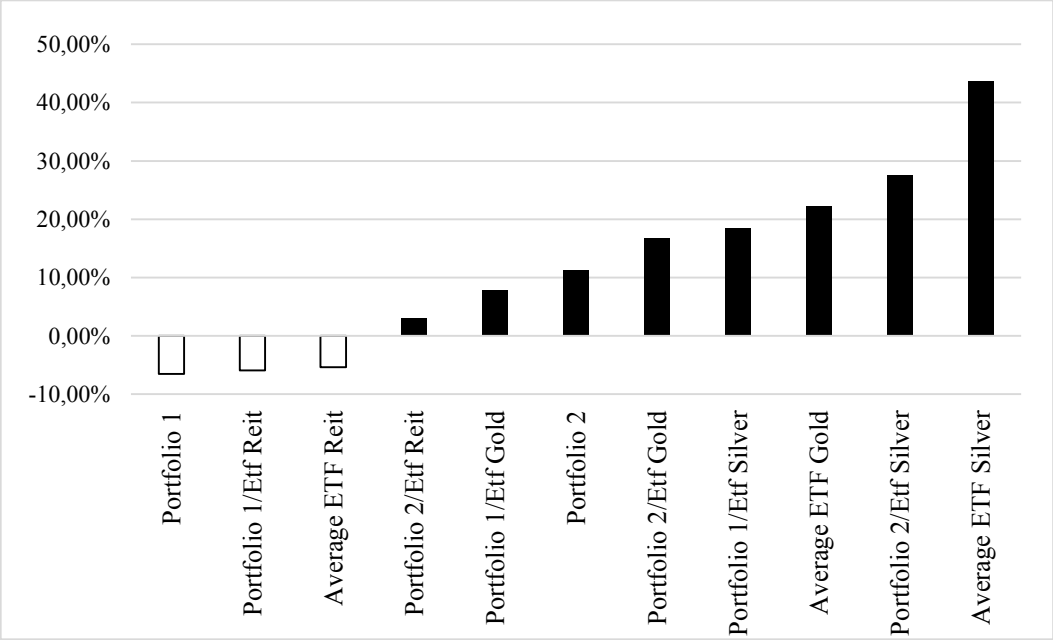

Figure 3. Ranked portfolio variants rates of return in 2020.

Source: Own study.

The highest rate of return in 2020 was generated by portfolios diversified by ETFs replicating silver and gold price movements. By including ETF Silver group assets, the profitability of portfolio 1 increased from -6.54% to 18.51% and portfolio 2 increased from 11.31% to 27.44%. Following the diversification of both dividend-paying companies' portfolios

with gold, their profitability also increased, but to a lesser degree (Portfolio 1 saw an increase from -6.54% to 7.84% and Portfolio 2 from 11.31% to 16.77%). Including ETFs replicating REITs in the composition of portfolios proved to be a sensible solution only for portfolio 1 (increase in average annual rate of return from -6.54% to -5.95%).

Additional analyses were conducted to analyze the relationship between portfolios made of dividend-paying companies (Portfolio 1 and 2) and portfolios of ETFs (replicating gold, silver and REIT prices). Pearson's linear correlation coefficient and Spearman's rank correlation coefficient were chosen as measures of relationship. It was also assessed whether the estimated correlation coefficients were statistically significant through the use of a non-parametric correlation coefficient significance test. A nonparametric *t* test was conducted to determine whether the estimated correlation was statistically significant. The closer the value of correlation coefficient is to 0, the weaker the relationship between the analyzed characteristics. Therefore, the following hypotheses were adopted:

H_0: rho = 0 (this is no relationship between the two characteristics in the sample),

H_1: rho ≠ 0 (this is a relationship between the two characteristics in the sample).

Next, p-value calculated by a test statistic was compared with significance level of α (assumed α value=0.05), thus:

- if p-value > α, there are no grounds to reject H_0,
- if p-value ≤ α, H_0 should be rejected by assuming H_1 (the correlation is significant).

The research reveals (see tables 11 and 12) that a moderate degree of Pearson's linear correlation ($_{Pearson's}$rho = 0.3137) was observed only between portfolio 2 (portfolio with growth potential companies) and portfolio made of ETFs replicating silver prices. There are no grounds to reject H_0 hypothesis claiming that the variables are independent (p-value = 0.6863). In other cases, it can be concluded that there is no linear relationship between the analyzed variables. The results are somewhat different in the case of Spearman's rank correlation. A moderate correlation ($_{Spearman's}$rho = 0.4) was observed between portfolio 1 (portfolio with value potential companies) and all the ETFs analyzed, and again there are no grounds to reject the H_0 hypothesis. A very high, negative correlation ($_{Spearman's}$rho = -0.8), and therefore the most interesting relationship, emerged between portfolio 2 and the ETFs REIT companies portfolio, with p-value = 0.3333. It can be concluded that during the considered period, the portfolio of dividend-paying companies with growth potential performed to a large extent like the portfolio of companies replicating real estate market (but with an opposite sign). For the other two portfolios, however, the Spearman rank correlation was also slightly negative ($_{Spearman's}$rho = -0.2; p-value = 0.9167), meaning that there was no relationship between the analyzed portfolios.

Table 11.
Pearson's linear correlation coefficient, Spearman's rank correlation coefficient and p-value levels – Portfolio 1

2017-2020Correlation	P1 and ETF gold		P1 and ETF silver		P1 and ETF Reit	
	rho	p-value	rho	p-value	rho	p-value
Pearson	-0.0987	0.9013	0.0170	0.983	0.0176	0.9824
Spearman	-0.4	0.75	-0.4	0.75	-0.4	0.75

Source: Own study in the R-CRAN statistical analysis package.

Table 12.
Pearson's linear correlation coefficient, Spearman's rank correlation coefficient and p-value levels – Portfolio 2

2017–2020Correlation	P2 and ETF gold		P2 and ETF silver		P2 and ETF Reit	
	rho	p-value	rho	p-value	rho	p-value
Pearson	0.1055	0.8945	0.3137	0.6863	-0.1559	0.8441
Spearman	-0.2	0.9167	-0.2	0.9167	-0.8	0.3333

Source: Own study in the R-CRAN statistical analysis package.

5. Discussion and conclusions

A research, concerning the portfolio variants of the Polish dividend-paying companies diversified with ETFs replicating price changes of gold, silver or REITs in the years 2017-2020, was conducted, which revealed rates of return and risk differences, especially when the analysis is related to the financial market crisis and stock price declines. Most importantly, it should be demonstrated that the selected ETFs faithfully reflected the sentiment of the assets prevailing in a given group. The higher average annual rate of return of precious metals ETFs was accompanied by a higher risk and vice versa, which was proven by the coefficient of variation (average gold ETF of 1.33 and average silver ETF of 2.20). In light of the aim of the research and the hypotheses adopted, an analysis of the results obtained in 2020, as the world struggled with the COVID-19 pandemic, becomes important. By including precious metals assets in the portfolio, not only did the average annual rate of return of the Polish dividend-paying companies stocks increase, but it also had a positive impact on the annual rate of return in 2020 (with silver included, Portfolio 1 saw a rise from -6.54% to 18.51% and Portfolio 2 from 11.31% to 27.44%; with gold included, Portfolio 1 saw a rise from -6.54% to 7.84% and Portfolio 2 from 11.31% to 16.77%). Coefficient of variation applicable to the Polish dividend-paying companies stocks has also been reduced through the use of precious metals ETFs. Inclusion of ETFs replicating REITs in the investors' portfolios no longer show such positive developments, despite the fact that dividend payments from these companies were also included. Moreover, during the considered period, a portfolio made of dividend-paying companies with growth

potential was characterized by a high negative correlation with the portfolio of companies that replicate real estate market.

Based on the conducted research, the adopted research hypotheses were verified, and on this basis, it was concluded that:

H_1: The average annual rate of return of dividend-paying companies portfolios with value and growth potential is not higher, but instead it is lower than ETFs replicating precious metals. This hypothesis was verified negatively.

H_2: During the turbulent economy of 2020, the inclusion of precious metal assets boosted the rates of return of the Polish dividend-paying companies' portfolios. In the case of ETFs including REITs, no increase in the rate of return of the Polish dividend-paying companies' portfolios was observed. This hypothesis was verified negatively in part.

H_3: During the considered period, a portfolio made of dividend-paying companies with growth potential was the only one to be characterized by a strong negative correlation with a portfolio of companies that replicate real estate market. This hypothesis was verified negatively in part.

Based on the comparisons carried out, concerning variants of portfolios made of dividend-paying companies, further divided into companies with value potential and with growth potential, including the precious metals market and REITs, recommendations for capital market investors can be indicated. Irrespective of the variants of the Polish dividend-paying companies' portfolios, their average annual rates of return were significantly elevated, when the precious metals ETFs were included. Those investors, who expect higher rates of return, should include precious metals in a physical form or the ETFs replicating fiduciary metal behavior in their portfolios.

References

1. Al-Malkawi, H.-A.N., Rafferty, M., Pillai, R. (2010). Dividend policy: A review of theories and empirical evidence. *International Bulletin of Business Administration*, *Vol. 9, No. 1,* pp. 171-200.
2. Asquith, P., Mullins, D.W. Jr (1983). The Impact of Initiating Dividend Payment on Shareholders' Wealth. *Journal of Business, Vol. 56(1),* 77-96.
3. Baker, M., Wurgler, J. (2004). Appearing and disappearing dividends: The link to catering Incentives. *Journal of Financial Economics*, *vol. 73.*
4. Benartzi, S.B., Thaler, R.H. (1995). Myopic loss aversion and the equity premium puzzle. *The Quarterly Journal of Economics.* University of Southern California.
5. Czekaj, J., Woś, M., Żarnowski, J. (2001). *Efektywność giełdowego rynku akcji w Polsce.* Warszawa: PWN.

6. DeAngelo, H., DeAngelo, L., Stulz, R.M. (2006). Dividend policy and the earned/contributed capital mix: a test of the life-cycle theory. *Journal of Financial Economics*, *vol. 81*.
7. Fama, E.F., French, K.R. (2001*).* Disappearing Dividends: Changing Firm Characteristics or Lower Propensity to Pay? *Journal of Financial Economics, vol. 60*.
8. Fama, E.F. (1995). Random Walks in Stock Market Proces. *Financial Analysts Journal*, *vol. 51, no. 1*.
9. Fuller, K.P., Goldstein, M.A. (2011). Do Dividends Matter More in Declining Markets? *Journal of Corporate Finance*, *vol. 17, No. 3*, pp. 457-473.
10. Haugen, R.A. (1999). *Nowa nauka o finansach. Przeciw efektywności rynku*. Warszawa: WIG-Press.
11. Koestler, A. (1978). *Janus: a Suming Up.* Londyn: Hutchinson.
12. Lea, S.E.G., Tarpy, R.M., Webley, P. (1987). *The individual in the economy*. Cambridge: Cambridge University Press.
13. Lee, T. (2000). *Ekonomia dla inwestorów giełdowych*. Warszawa: Wig-Press.
14. Le Bon, G. (1986). *Psychologia tłumu*. Warszawa: PWN.
15. Lichtenfeld, M. (2015). *Get Rich with Dividends.* New Jersey: John Wiley & Sons, Inc.
16. McQueen, G., Shields, K., Thorley, S.R. (1997). Does the 'Dow-10 Investment Strategy' Beat the Dow Statistically and Economically? *Financial Analysts Journal*, *Vol. 53, No. 4,* pp. 66-72.
17. Miller, M.H., Modigliani, F. (1961). Dividend policy, growth, and the valuation of shares. *The Journal of Business*, *Vol. 34, No. 4*, pp. 411-433.
18. Nofsinger, J.R. (2001). *Investment madness. How psychology affects your investing…And What To Do About It.* London: Prentice Hall.
19. Olsen, R.A. (1998). Behavioral Finance and Its Implications for Stock-Price Volatility. *Financial Analyst Journal, vol. 54, no. 2*.
20. Plummer, T. (1995). *Psychologia rynków finansowych*. Warszawa: WIG-Press.
21. Razek, Y.H.A. (2011). An Overview of Behavioral Finance and Revitising the Behavioral Life Cycle Hypothesis. *IUP Journal of Behavioral Finance*, *vol. VIII, no. 3*.
22. Rubin, H., Spaht, C. II (2011). Financial Independence Through Dollar Cost Averaging and Dividends Reinvestment. *Journal of Applied Business and Economics. No. 4*, pp. 11-19.
23. Samuelson, P.A., Nordhaus, W.D. (1995). *Ekonomia, T. 1*. Warszawa: PWN.
24. Shefrin, H.M., Statman, M. (1984). Explaining investor preferences for cash dividends. *Journal of Financial Economics*, *vol. 13*.
25. Talbot, M. (1981). *Mysticism and the New Physics*. Londyn: Routledge and Kegan Paul.
26. Thaler, R.H. (1999). The end of behavioral finance. *Financial Analysts Journal*, *vol. 55*, *no. 6*.
27. Timmermann, A., Granger, C.W.J. (2004). Efficient market hypothesis and forecasting. *International Journal of Forecasting, vol. 20*.

28. Williams, A., Miller, M. (2013). Do Stocks with Dividends Outperform the Market during Recession. *Journal of Accounting and Finance*, *vol. 13, No. 1*, pp. 58-69.
29. Zaleśkiewicz, T. (2003). *Psychologia inwestora giełdowego. Wprowadzenie do behawioralnych finansów*. Gdańsk: Gdańskie Wydawnictwo Psychologiczne.

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ATTRIBUTES OF THE COMMERCIAL OFFER OF THE PETROL STATION NETWORK ADDRESSED TO MICRO AND SMALL ROAD TRANSPORT ENTERPRISES IN THE PODKARPACKIE VOIVODESHIP

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Purpose: The aim of the research will be to identify the structure of the petrol stations network in the Podkarpackie Voivodeship and to indicate the attributes of their commercial offer to the extent necessary to support the decision-making process aimed at selecting the appropriate supplier of transport fuels for the needs of micro and small road transport enterprises. The essence of the research problem will aim at answering questions about the subjective structure of the retail market of petrol stations in the Podkarpackie Voivodship. In addition, its geographical, material and functional structure. Object of the research is the retail market of transport fuels in the Podkarpackie Voivodship, and the subject of the research is the petrol station network operating there. The area of research are the attributes of the commercial offer of the petrol station network addressed to micro and small road transport enterprises.
Design/methodology/approach: The research procedure will run through the following stages: 1) indicating the topic, purpose and scope of the research; 2) determination and definition of evaluation criteria; 3) selection of the test sample; 4) measurement; 5) interpretation of the obtained results; 6) final conclusions; 7) dissemination of research results. The research method used is a critical review of the literature and databases, as well as a direct interview. Three criteria were used to evaluate the comercial offer, i.e. economic and financial, organizational and technical, and security. In addition, an interview form was developed.
Findings: The implementation of the topic and purpose of the research allowed to indicate the attributes of the commercial offer of the petrol station network addressed to micro and small road transport enterprises in the Podkarpackie Voivodeship. It should be emphasized that the presented research is preliminary. They are the first stage of the main research topic. The purpose of these researches is to indicate the scope and form of cooperation between a retail supplier of liquid fuels and a micro and small enterprise of road transport in the Podkarpackie Voivodeship. The stages of its implementation include: determining the attributes of the commercial offer of the petrol station network in the analyzed region; an indication of the determinants of the choice of a supplier of liquid fuels by the surveyed enterprises; determination of the extent to which the commercial offer of the petrol station network addressed to micro and small road transport enterprises in the Podkarpackie Voivodship reflects the real needs of the market.

Originality/value: In this article, the actions taken to achieve the progress of scientific knowledge led to the expansion of knowledge in the discipline of management and quality science in the area of trade systems, their organization and management. The research focused on the areas that have and will have an impact on improving the competitive position of road transport enterprise.

Keywords: supplier, liquid fuels, transport.

Category of the paper: Research paper.

1. Introduction

The adopted topic is a response to the identified needs reported by transport enterprises located in the Podkarpackie Voivodeship in relation to the current state of knowledge. In the analyzed region, the share of road transport in the transport of goods and passengers remains at a very high level. In the past period, the number of motor vehicles increased in the Podkarpackie Voivodship. In their structure, the vast majority were vehicles powered by petroleum fuels. Due to the high level of prices of fuels used in transport on the domestic market, an increase in the share of their purchase costs in the cost structure of global enterprises was recorded. It should be noted that the domestic fuel market is very strongly determined by current events in the world. In addition, the climate and energy policy of the European Union has a large impact on transport and fuel economy.

The retail market of transport fuels in the Podkarpackie Voivodship was characterized by high flexibility. Strong competition from domestic and foreign entities translated into the price offer and non-price conditions. In Poland, fuel prices were not regulated. They were determined on an arm's length basis, on the basis of import parity (price of crude oil and finished fuels, USD exchange rate and the level of domestic taxes). The structure contained fixed elements, i.e. excise duty, fuel surcharge and emission fee, as well as variable elements, i.e. VAT, margin and net price. In addition, their final level was affected by the size of local needs and the scale of competition between suppliers (Frączek, Kaliski, Siemek, 2013).

In response to the above issues, it was assumed that the purpose of the research would be to identify the structure of the network of petrol stations in the Podkarpackie Voivodeship and to indicate the attributes of their commercial offer to the extent necessary to support the decision-making process aimed at selecting the appropriate supplier of transport fuels for the needs of micro and small road transport enterprises.

Its implementation will take place through: establishing the current state of knowledge in the field of the discussed issues; description of the test method; measurement; presentation of final conclusions. The research method used is a critical review of the literature and databases, as well as a direct interview.

It should be emphasized that the presented research is preliminary. They are the first stage of the main research topic. The purpose of these researches is to indicate the scope and form of cooperation between a retail supplier of liquid fuels and a micro and small enterprise of road transport in the Podkarpackie Voivodeship. The stages of its implementation include: determining the attributes of the commercial offer of the petrol station network in the analyzed region; an indication of the determinants of the choice of a supplier of liquid fuels by the surveyed enterprises; determination of the extent to which the commercial offer of the petrol station network addressed to micro and small road transport enterprises in the Podkarpackie Voivodship reflects the real needs of the market.

2. Theoretical basis

The concept of a transport enterprise can be considered from the point of view of representatives of various scientific disciplines (Koźlak, 2018; Wall, 2002). In subjective terms, it is an organizational unit consisting of a network of related and cooperating functional and task departments as well as human work. In material terms, an enterprise is defined on the basis of the means of production at its disposal. The means of production include both the object of labor and the means of labour. Means of work include buildings and structures, means of transport, other technical devices and materials used in their operation (including fuels and energy). In functional terms, a transport enterprise is a set of tasks related to the preparation of the transport process, its implementation, control and settlement (Mendyk, 2009; Koźlak, 2008; Grzywacz et al., 1989; Tarski 1974).

In practice, assuming the criterion of employment and annual revenues, a transport enterprise can be divided into four groups, i.e. micro, small, medium and large. A micro-enterprise is an economic unit that employs less than 10 employees, a small enterprise employs less than 50 (Dz.U. 2004, Nr 173, poz. 1807). In the literature on the subject, a further division of enterprises takes into account, above all, the phases of material goods flow, the degree of specialization, the geographical scope of the business, capital structure, ownership sector, type of ownership, forms of ownership, legal forms or the degree of resources involved (Jedynak, 2022; Budzyński, 2013; Krawczyk, 2011; Dz.U. z 2007 r. nr 251, poz. 185).

Within the organization of a transport enterprise, the basic (transport) and auxiliary (support) subsystems are commonly indicated. One of the areas of support for transport processes is the fuel and energy subsystem. In the literature on the subject, the system of fuels and energy is presented in two ways (Orecchini et al., 2012). In a narrow sense, at the enterprise level. It includes the supply and consumption subsystem. The entity structure of the supply subsystem consists of the department and positions responsible for the purchase and supply of individual energy carriers and their suppliers. The consumption subsystem includes

a department and position responsible for the consumption of energy carriers (Jedynak, 2022). In a broader sense, the fuel and energy system is a separate part of the national economy (Górzyński, 2017; Łucki et al., 2011; Rechul, 2010). Taking into account the phases of flow of streams of material goods, people and information in the economy, this subsystem will include supply, production and distribution as well as waste management (Jedynak, 2022).

The supplier is an organizational unit that offers and delivers to the recipients, independently or by commissioning an external entity, appropriate tangible goods and services being the subject of their manufacturing or commercial activity, in accordance with previously agreed purchase conditions (commercial offer) (Dubisz, 2003). In the literature on the subject, various criteria for dividing the supplier are presented. The criterion of the type of market served, the reliability and security of supplies, the supplier's share in the company's overall purchases, the current and future capabilities of the supplier or the pace of their development are commonly taken into account. Other criteria also play an important role in establishing cooperation with suppliers, i.e. the location of the supplier, the size of the supplier and their position on the market, period of operation or financial stability. In addition, the level of prices, the breadth and depth of the commercial offer, its comprehensiveness or the quality of the material goods and services provided (Jedynak, 2022; Budzyński, 2016; Krawczyk, 2011; Bendkowski et al., 2011; Dworecki et al., 2005; Górski, 2004).

In the literature on the subject, a supplier's commercial offer means his offer to sell goods and/or services aimed at concluding a binding contract. According to the legal provisions, a commercial offer is a way of concluding a contract consisting in the presentation of conditions by the offeror and acceptance by the offeree (Dz.U. 1964, nr 16, poz. 93). It should be emphasized that the rules set out in it cannot be changed. They can be fully accepted or rejected. The content of the offer includes the terms and methods of commercial transaction accepted by the supplier. The offer may be presented in various forms and scope. It can be submitted both orally and in writing in paper or electronic form. It can be addressed to a single person or to a larger group. It can be public or restricted. In the literature on the subject, the following are indicated as the basic attributes of a commercial offer: fit, availability, transparency and timeliness.

3. Methodology

Subject of research: Attributes of the commercial offer of a network of petrol stations addressed to micro and small road transport enterprises in the Podkarpackie Voivodship.

Its main goal will be to identify the structure of the fuel stations network in the Podkarpackie Voivodeship and to indicate the attributes of their commercial offer to the extent necessary to support the decision-making process aimed at selecting the appropriate supplier of transport

fuels for the needs of micro and small road transport enterprises. The essence of the research problem will aim at answering questions about the subjective structure of the retail market of petrol stations in the Podkarpackie Voivodship. In addition, its geographical, subject and functional structures. Therefore, the subject of study is the retail market of transport fuels in the Podkarpackie Voivodship, and the subject of the research is the petrol station network operating there. The area of research are the attributes of the commercial offer of the petrol station network addressed to micro and small road transport enterprises.

In terms of the state of knowledge, taking into account the achievements and experience of the researcher, the following research hypothesis was formulated, i.e. the commercial offer of the petrol station network addressed to micro and small road transport enterprises goes far beyond the sale of fuels. The offer includes facilities for recipients supporting their process of purchasing and using transport fuels. They are designed to add additional value by integrating dispersed activities carried out as part of handling the transport process.

The stages of the research procedure include: 1) indicating the topic, purpose and scope of the research; 2) determination and definition of evaluation criteria; 3) selection of the test sample; 4) measurement; 5) interpretation of the obtained results; 6) final conclusions; 7) dissemination of research results.

The research method used is a critical review of available databases (such as: electronic databases (For business, Orlen, 2022; Products..., 2022; Business…, 2022; Customer…, 2022; For business, Moya, 2022; Drive…, 2022; Petrol…, 2022; Oil…, 2021) and applicable regulations of cooperation (Ogólne…, 2022; Regulamin sprzedaży…, 2022; Wzór…, 2022; Regulamin program…, 2022; Regulamin użytkowania … mikrofirma, 2022; Regulamin użytkowania …, 2022; Regulamin promocji…, 2022; Załącznik… kart flotowych…, 2022; Załącznik… kart Prepaid…, 2022) and direct interview. An interview form was developed for the research. In addition, three criteria for assessing the service station network were adopted, i.e. economic and financial, organizational and technical, and security. The assumed areas were defined by parameters. The form for measuring the commercial offer of the surveyed suppliers of transport fuels and its description are presented in Table 1.

Table 1.
Tested parameters for evaluating the petrol station network

GROUP NAME	SYMBOL	TESTED PARAMETER		UNIT OF MEASURE
Economic and financial	A.1.1	Average unit price at selected petrol stations	- Motor gasoline	PLN/liter
	A.1.2		- Diesel	PLN/liter
	A.1.3		- LPG	PLN/liter
	A.2	Value/quantity discounts (fuel offer)		–
	A.3	Value/quantity discounts (non-fuel offer)		–
	A.4	Form of payment as part of the established cooperation		–
	A.5	Form of payment security		–
	A.6	Electronic invoices		–
	A.7	Summary invoice for a given period		–

Cont. table 1.

Organizational and technical	B.1	Remote form of concluding a cooperation agreement		–
	B.2	Duration of the agreement		–
	B.3	Availability of a fuel card in the offer (including the form of payment)		–
	B.4.1	Fuel card access	- Assigning the card to the vehicle	–
	B.4.2		- Assigning the card to the driver	–
	B.4.3		- Assigning cards to the company	–
	B.4.4		- Bearer card	–
	B.5	Other supported fleet cards		–
	B.6.1	Electronic platform and its functionality	- Access to fuel transactions and beyond fuel	–
	B.6.2		- Access to e-invoice	–
	B.6.3		- Possibility to personalize the card and purchase limits	–
	B.6.4		- Fast payment	–
	B.6.5		- Road and parking fees	–
	B.6.6		- Access to navigation and maps	–
	B.7	Mobile application		–
	B.8	Loyalty program		–
	B.9.1	Additional services	- Shop	–
	B.9.2		-Parking	–
	B.9.3		- Catering services	–
	B.9.4		- Hotel services	–
	B.9.5		- Car repair	–
	B.9.6		- Car wash	–
	B.9.7		- Postal services	–
	B.9.8		- Infrastructure for servicing trucks and buses	–
	B.9.9		- Others	–
	B.10	Number of petrol stations located in the serviced area		pcs
	B.11	Geographic/demographic indicator		pcs/km^2 pcs100 thou. people
	B.12	Access to infrastructure		h/day
	B.13.1	Main location	- City	–
	B.13.2		- Highway and expressway	–
	B.13.3		- National roads	–
	B.13.4		- Other road categories	–
	B.14	Geographical scope of the commercial offer		–
Security	C.1.1	Type of fuel	- Motor gasoline	–
	C.1.2		- Motor gasoline (Premium)	–
	C.1.3		- Diesel	–
	C.1.4		- Diesel (pPremium)	–
	C.1.5		- Diesel TIR	
	C.1.6		- LPG	–
	C.1.7		- Electricity	–
	C.2	Fuel quality assessment (according to the President of the Office of Competition and Consumer Protection		–
	C.3	Length of the supplier's existence on the market		–
	C.4	Enterprise size		–
	C.5	Specialization in the service provided		–
	C.6	Supplier's position in the market		–
	C.7	Opinion about the supplier from buyers (concerns the Rzeszow poviat and the city of Rzeszow)		–

Source: own study.

4. Empirical Results and Discussion

Based on the analysis of the structure of the petrol stations network located in the Podkarpackie Voivodship, the following enterprises were selected for the study: PKN Orlen SA (Orlen), BP Europa SE Spółka europejska Branch in Poland (BP), Shell Polska Sp. z o.o. (Shell), Circle K Polska Sp. z o.o. (Circle K), Anwim SA (Moya station network), Slovnaft Polska SA (Slovnaft Partner), Watkem Sp. z o.o. (Thread). These enterprises included both dependent and independent networks (i.e. Moya, Slovnaft, Watkem). In the case of other operators operating in the Podkarpackie Voivodship, due to the limited number of filling stations, it was assumed that they are of secondary (local) nature. The research does not include the network of stations belonging to Grupa Lotos SA, part of which as of August 1, 2022, as a result of consolidation, became part of PKN Orlen SA. The research took into account the offer dedicated to micro and small transport enterprises operating in the country and abroad. The measurement was made at the turn of 2022/2023.

The measurement results in the economic and financial area are presented in Table 2.

Table 2.
Measurement results in the economic and financial area

PARAMETER	PETROL STATION NETWORK						
	Orlen	**BP**	**Shell**	**Circle K**	**Moya**	**Slovnaft**	**Watkem**
A.1.1	6,64	6,61	6,62	6,60	6,60	6,65	6,62
A.1.2	7,80	7,81	7,83	7,81	7,80	7,81	7,79
A.1.3	3,21	3,20	3,19	3,20	3,19	3,19	3,17
A.2	yes (program Biznestank)	yes (program BP Komfort Prepaid, Program BP Plus)	yes (program Shell Card, Shell Fleet App)	yes (the fuel card can be registered as a loyalty card)	yes	no data	yes (individual arrange-ments, coopera-tion on permanent contracts)
A.3	yes (program Biznestank: automatic car wash, vacuum cleaner)	yes (program BP Komfort Prepaid: car wash, oils and washer fluids; BP Plus: car wash, AdBlue)	no data	yes (program Circle K Extra: car wash, shopping in the store for selected products)	no	no data	yes (individual arrange-ments, coopera-tion on permanent contracts)

Cont. table 2.

A.4	cash, cashless	cashless	cashless	cashless	cash, cashless	no data	cash, cashless
A.5	bank guarantee, insurance, deposit	deposit, trade credit, blocking of funds on a bank account, guarantee by another company	credit limit (no data on the form of collateral)	deposit (program Circle K Easy Card)	promissory note, deposit	no data	individual arrange-ments, coopera-tion on permanent contracts
A.6	yes	yes	yes	yes	yes	no data	yes
A.7	yes (program Mikroflota: 2/month)	yes (program BP Komfort Prepaid 1/month; BP Aral, BP Plus: individual arrangemen ts)	yes	yes (program Circle K Easy Card: 1/month)	yes (program Moya Mikrofirma : 5, 2, 1/month)	no data	yes (2/month)

Source: own study.

The measurement of the prices of individual fuels was carried out at selected stations located within a radius of approximately 5 km in the voivodeship city of Rzeszów. Of which four stations, i.e. Orlen, Moya, Slovnaft, Watkem, were located at ul. Sikorskiego (the main street leading towards Insurgents of Warsaw Street and Rejtana Street). In the case of Circle K at Rejtana Street. The others were located at Insurgents of Warsaw Street. The measurement was carried out on January 7-11, 2023. In the analyzed period, fuel prices remained at an even level. Minor differences were noted in prices.

Depending on the size of the car fleet at the disposal of enterprises or the monthly fuel consumption at stations, discounts were granted on fuels and on selected non-fuel products or services. Most of the proposed forms of cooperation were based on a non-cash transaction. As a consequence, there were various forms of payment security. As part of the ongoing cooperation, electronic invoices and a collective invoice for a given period were offered.

The measurement results in the organizational and technical area are presented in Table 3.

Table 3.
Measurement results in the organizational and technical area

PARAMETER	PETROL STATION NETWORK						
	Orlen	**BP**	**Shell**	**Circle K**	**Moya**	**Slovnaft**	**Watkem**
B.1	yes	yes	yes	yes	yes	no data	no
B.2	contract for an indefinite period	contract for an indefinite period, (program BP Komfort Prepaid: without a contract)	contract for an indefinite period	contract for an indefinite period	contract for an indefinite period	no data	contract for an indefinite period
B.3	Mikroflota (cashless) Biznestank (cash)	BP Komfort Prepaid, BP+Aral, BP Pus (cashless) BP Super Card (Gift card)	Shell Fleet App, Shell Card (cashless)	Circle K Easy Card Circle K Pro Card Circle K Routex Card (cashless)	Moya Mikrofirma (cash) Moya Firma, TFC powered by MOYA (cashless)	no	no
B.4.1	yes (program Mikroflota, Biznestank)	yes	yes	yes (program Circle K Easy Card)	yes	no	no
B.4.2	no	yes	no	no	yes	no	no
B.4.3	yes (program Mikroflota)	no	no	yes (program Circle K Easy Card)	yes	no	no
B.4.4	no	yes	yes (assigning a card yourself)	no	no	no	no
B.5	FLOTA, UTA, DKV, Open Drive, E100, LOGPAY, Big family card	UTA	UTA, DKV	UTA, DKV, Routex	UTA, DKV, Eurowag, iQ, Diesel24, CRT Partner, E100	no data	Big family card
B.6.1	yes	yes	yes	yes	yes	no	no
B.6.2	yes	yes	yes	yes	yes	no	no
B.6.3	yes	yes	yes	yes	yes	no	no
B.6.4	yes	yes	yes	yes	yes	no	no

Cont. table 3.

B.6.5	yes	yes	yes	yes	x (program TFC powered by Moya)	no	no
B.6.6	no	no	yes	no	x (station map Moya)	no	no
B.7	yes	yes	yes	yes	yes	no data	no
B.8	Orlen Vitay	Payback	Shell Club Smart	Circle K Extra	Moya VIP	no	no
B.9.1	yes	yes	yes	yes	yes	yes	yes
B.9.2	yes	yes	yes	yes	yes	yes	yes
B.9.3	yes	yes	yes	yes	yes	no	no
B.9.4	no	no	no	no	tak (station: Tryńcza 281)	no	yes
B.9.5	yes	yes (program BP + Aral: 24/7 roadside assistance)	yes (program Shell Card: 24/7 roadside assistance)	yes (program Circle K Routex Card: 24/7 roadside assistance)	yes (car repair shop – stations: Leżajsk 279, Radymno 94, Dynów 277)	no	yes (vehicle control station)
B.9.6	yes	yes	yes	yes	yes	yes	yes
B.9.7	yes	no	no	no	yes	no	no
B.9.8	yes	yes	yes	yes	yes	no	yes
B.9.9	direct service, fees at the distributor	BP Toll Box, fees at the distributor	ETTS box, fees at the distributor	fees at the distributor	fees at the distributor, automatic fleet station: Krościenko Wyżne 457)	no	no
B.10	82	23	13	23	21	12	10
B.11	218/29	776/92	1373/164	776/92	850/101	1478/177	1785/213
B.12	24h	24h	24h	24h	10/21	4/12	7/10
B.13	dispersion	dispersion	dispersion	dispersion	dispersion	dispersion	concentration
B.13.1	yes	yes	yes	yes	yes	no	yes
B.13.2	yes	yes	yes	no	no	no	no
B.13.3	yes	yes	yes	yes	yes	no	no
B.13.4	no	no	no	yes	yes	yes	no
B.14	continental (program Mikroflota: Poland, Czech Republic, Lithuania, Germany; Biznestank: Polska; DKV ORLEN: 42 countries in Europe)	global (program BP + Aral: Europe; BP Plus: Poland, stations BP i Circle K; BP Komfort Prepaid: Poland stations BP)	global (program Shell Fleet App: Polska stacje Lotos i Lotos Optima; Shell Card: Europe 22 thou. Shell stations + 16,000 partner stations)	continental (program Circle K Routex Card 29 countries, 18 thou. station; Circle K Easy Card, Circle K Pro Card: national)	continental (program Moya Mikrofirma, Moya Firma: Poland; TFC Card Moya)	national	regional

Source: own study.

One of the forms of establishing permanent cooperation was the remote form. The contracts were mainly concluded for an indefinite period.

Fuel cards were available as part of the commercial offer. They were mainly based on non-cash transactions. Their type depended on the size of the company, vehicle fleet or annual fuel consumption. Sometimes they were dedicated to micro and small enterprises. In this case, the geographical scope of the commercial offer was usually limited to the area of the country. This did not mean that such enterprises could not take advantage of other offers. Fuel cards were issued to a vehicle, person or company. A bearer option was also available. Fleet cards of other companies were also accepted at petrol stations.

Access to the transactions carried out from the enterprise level was possible via the internet platform and the mobile application. Most often, their functionality meant a review of transaction history, ongoing access to invoices, the ability to personalize cards and purchase limits, or road and parking fees. In the case of two independent operators, cooperation was not based on fuel cards. There was also no internet platform or mobile application in their offer.

Apart from fuel sales, the surveyed stations also offered other services. Commonly a shop, gastronomy, car wash or public parking lot. Depending on the purpose of the station and its location, the stations were equipped with infrastructure for servicing trucks and buses. In addition, selected domestic operators provided postal services (own or external). Hotel services were provided primarily by independent operators. In addition, the offer of the Moya station included car repair shops. However, in the case of Watkem, vehicle inspection stations. In other cases, the stations offered 24-hour roadside assistance. In the past period, the payment service at the dispenser or, in the case of some enterprises, direct service at the dispenser has become popular.

From the point of view of the number of petrol stations in the Podkarpackie Voivodship, stations operating under the Orlen brand were dominant. Their share in the total number of entities surveyed was 45.1% (excluding Grupa LOTOS SA stations). On the other hand, when analyzing the structure of service stations in the city of Rzeszów and the Rzeszów poviat, the share of stations operating under the Orlen brand in Rzeszów in the total number of stations was 16.2% (excluding Grupa LOTOS SA stations), in the Rzeszów poviat it was 16.1% (excluding Grupa LOTOS SA stations) . For BP, the share was 5.4% and 3.6%, Shell 10.8% and 1.8%, Circel K 5.4% and 1.8%, Moya 5.4% and 5.3%, Slovnaft 0 .0% and 7.1% or Watkem 13.5% and 3.6%.

The location of the stations of individual enterprises was most often dispersed throughout the Podkarpackie Voivodeship. Their location is mainly in the city. In the case of the network of dependent stations, their points were most often located on motorways, expressways and national roads.

The measurement results in the economic and financial area are presented in Table 4.

Table 4.
Measurement results in the security area

PARAMETER	PETROL STATION NETWORK						
	Orlen	**BP**	**Shell**	**Circle K**	**Moya**	**Slovnaft**	**Watkem**
C.1.1	yes (95 efecta)	yes (Euro Super 95)	yes (FuelSave 95)	yes (95 miles)	yes	yes (SUPER 95)	yes
C.1.2	yes (98 verva)	yes (98 Ulitmate)	yes (V-Power 95)	yes (98 miles PLUS)	no	yes (BA 98)	no
C.1.3	yes (Diesel efecta)	yes (BP Diesel)	yes (FuelSave Diesel)	yes (miles Diesel)	yes	yes	yes
C.1.4	yes (Disel verva)	yes (ON Ulitmate)	yes (V-Power Diesel, V-Power Racing)	tak (miles Plus Diesel)	yes (ON Moya Power)	yes (Drive)	no
C.1.5	yes	yes	yes	yes	yes	no data	yes
C.1.6	yes	yes	yes	yes	yes	yes	yes
C.1.7	yes (stations: Paszczyna 4496, Rzeszów 291, Rzeszów 4224)	no	no	no	yes (stations: Przemyśl 387, Rzeszów 317, 452)	no	no
C.2	lack	lack	lack	lack	lack	lack	lack
C.3	above 5	above 5	above 5	above 5	above 5	above 5	above 5
C.4	large	large	large	large	large	large	medium
C.5	specialized	specialized	specialized	specialized	specialized	specialized	specialized
C.6	basic	basic	basic	basic	basic	secondary	secondary
C.7	4,0	4,2	4,0	4,4	4,3	2,8	4,0

Source: own study.

The commercial offer of the subsidiaries included standard and premium fuels as well as TIR diesel oil (depending on the purpose of the filling stations). However, in the case of independent operators, the situation was different. Access to electricity distributors at network fuel stations in the Podkarpackie Province was very limited (only at selected Orlen and Moya stations). In the analyzed period, according to the information of the President of the Office of Competition and Consumer Protection, no deviations from the applicable fuel quality standards were found at the examined petrol stations (Fuel quality, 2022, Dz.U. 2015, poz. 1680).

Petrol station chains belonged to large and experienced enterprises. These were units associated with domestic and foreign capital. Their activities were specialized. The geographical scope of the commercial offer varied from global, through continental and national, to regional. The position on the market due to the potential they had and the location of individual points was of a basic nature. In the case of the Watkem station, due to the number

of points in the country, the geographical range or concentration of station locations were of secondary importance.

According to the assessment of service station users, the average rating was above 4.0 (on a scale of 5.0-2.0). The ratings were determined on the basis of anonymous customer reviews posted on GoogleMaps.pl. They concerned petrol stations located in the city of Rzeszów and the Rzeszów poviat.

5. Conclusions

The implementation of the topic and purpose of the research allowed to indicate the following attributes of the commercial offer of the petrol station network addressed to micro and small road transport enterprises in the Podkarpackie Voivodship:

- Personalization of the offer. The commercial offer of the petrol station network addressed to road transport enterprises is a package consisting of available goods and services, as well as terms and conditions for handling purchase and sale transactions. The offer addressed only to micro and small enterprises is carried out on generally accepted terms. In the event that the needs go beyond it, there is a possibility of establishing cooperation under other convenient forms. In this case, the terms of cooperation are determined individually (under the applicable cooperation models) depending on the amount of fuel used, the size of the vehicle fleet or geographical criteria.
- Limited access to the terms of cooperation. Most enterprises have limited access to data on the terms of cooperation. No published regulations or contract forms. The data is made available after sending an application for cooperation to the supplier.
- A wide range of offers. Petrol stations have turned into shopping and service centers. In addition to the possibility of refueling there, the sale of fresh, food and industrial goods is also available to a certain extent, and catering services are provided. In addition, services related to the operation of the vehicle fleet, i.e. parking, car wash and repairs.
- Offer availability. The vast majority of petrol stations network provide their services 24 hours a day.
- Integration of the transport process. Cooperation between the operator and the enterprise is remote via a mobile application and an internet platform. There is a wide range of services that can be used in the field of fleet management. They allow for the integration of various tasks performed as part of handling the entire transport process.

- Personalization of tasks. The available internet application gives you the ability to manage the fleet and the driver's work. Shared services allow you to control them and give you the opportunity to personalize access to purchases and services and to set their limits.
- The speed of establishing cooperation. A remote form of communication is made available and accepted in order to establish permanent cooperation with a given operator.
- Distributed location. Most of the locations of petrol stations are dispersed throughout the Podkarpackie Voivodeship. They are located mainly in large and medium-sized towns and along main communication routes. On the other hand, small towns or roads of secondary importance are dominated by local independent operators.
- Extra-regional significance. The geographical range of the service station network's commercial offer extends beyond the Podkarpackie Voivodeship. The offer is mostly continental. It involves the use of both own and partner stations.

In conclusion, the adopted research hypothesis was confirmed.

References

1. Bendkowski, J., Radziejowska, G. (2011). *Logistyka zaopatrzenia w przedsiębiorstwie*. Gliwice: Wydawnictwo Politechniki Śląskiej.
2. Budzyński, I. (Ed.) (2013). *Zmiany strukturalne grup podmiotów gospodarki narodowej w rejestrze Regon, 2012 r.* Warszawa: GUS.
3. Budzyński W. (2016). *Zakupy w przedsiębiorstwie – negocjacje, procedury i umowy z dostawcami*. Warszawa: Poltext.
4. *Business customers*. Shell. https://www.shell.pl, 2022.
5. *Customer service area*. Circel K. https://www.circlek.pl, December 2022.
6. *Drive with us*. Slovnaft. https://slovnaft.pl, December 2022.
7. Dubisz, S. (Ed.) (2003). *Uniwersalny słownik języka polskiego – tom 1*. Warszawa: PWN.
8. Dworecki, S.E., Berny, J. (2005). *Zarządzanie procesami logistycznymi – wybrane zagadnienia*. Radom: Reprograf.
9. *For business*. Moya. https://moyastacja.pl, December 2022.
10. *For business*. Orlen. https://www.orlen.pl, December 2022.
11. Frączek, P., Kaliski, M., Siemek, P. (2013). The modernization of the energy sector in Poland vs. Poland's energy security. Archives of Mining Sciences, 58(2), pp. 301-316.
12. *Fuel quality.* Office of Competition and Consumer Protection. https://uokik.gov.pl, December 2022.

13. Górski, J. (2000). Logistyka, czyli … ludzie. *Midwest: Business Sales, Nr 4*.
14. Górzyński, J. (2017). *Efektywność energetyczna w działalności gospodarczej*. Warszawa: PWN.
15. Grzywacz, W., Burnewicz, J. (1989). *Ekonomika transportu*. Warszawa: Wydawnictwo Komunikacji i Łączności.
16. Jedynak, Z. (2022). *Nośniki energii i wybór ich dostawcy w przedsiębiorstwach handlu detalicznego wielkopowierzchniowego*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
17. Koźlak, A. (2008). *Ekonomika transportu: teoria i praktyka gospodarcza*. Gdańsk: Wydanie Uniwersytetu Gdańskiego.
18. Koźlak, A. (2018). The Assessment of the Changes in the Road and Railway Accessibility to the Voivodeship Cities of Poland in the Years 2010-2016. *Springer Proceedings in Business and Economics*, pp. 110-121.
19. Krawczyk, S. (Ed.) (2011). *Logistyka – teoria i praktyka*, *tom 1-2*. Warszawa: Difin.
20. Łucki, Z., Misiak, W. (2011). *Energetyka a społeczeństwo.* Warszawa: PWN.
21. Mendyk, E. (2009). *Ekonomika transportu*. Poznań: Wyższa Szkoła Logistyki.
22. *Ogólne warunki sprzedaży i używania kart paliwowych przedpłaconych (Kart TANKBANK) z dnia 24 maja 2018 roku*. Orlen. https://www.orlen.pl, December 2022.
23. *Oil industry and trade 2020 – annual repor.* Warsaw: POPiHN (2021).
24. Orecchini, F., Naso, V. (2012). *Energy Systems in the Era of Energy Vectors*. Springer.
25. *Petrol stations*. Watkem. https://watkem.pl, December 2022.
26. *Products and services*. British Petroleum. https://www.bp.com, December 2022.
27. Rechul, H. (2010). System energetyczny jako kategoria teoretyczna. *Energetyka, Maj*.
28. *Regulamin Programu BIZNESTANK PKN Orlen SA z dnia 29.04.2022 r*. Orlen. https://www.orlen.pl, December 2022.
29. *Regulamin promocji -10 gr/l realizowanej na stacjach MOYA w terminie 12.09-31.12.2022*. Moya. https://moyastacja.pl, December 2022.
30. *Regulamin sprzedaży i używania kart MIKROFLOTA PKN Orlen SA z dnia 20 października 2021 r. (dalej zwany Regulaminem)*. Orlen. https://www.orlen.pl, December 2022.
31. *Regulamin użytkowania gotówkowych kart flotowych Moya – mikrofirma*. Moya. https://moyastacja.pl, December 2022.
32. *Regulamin użytkowania gotówkowych kart flotowych Moya*. Moya. https://moyastacja.pl, December 2022.
33. Rozporządzenie Ministra Gospodarki z dnia 9 października 2015 r. *w sprawie wymagań jakościowych dla paliw ciekłych*, Dz.U. 2015, poz. 1680.
34. Rozporządzenie Rady Ministrów z dnia 24.12.2007 r. *w sprawie Polskiej Klasyfikacji Działalności (PKD)*, Dz.U. z 2007 r. nr 251, poz. 1885.

35. Tarski, I. (1973). *Ekonomika i organizacja transportu międzynarodowego*. Warszawa: PWE.
36. Ustawa z dnia 18 maja 1964 r. *Kodeks cywilny.* Dz.U. 1964, nr 16, poz. 93.
37. Ustawa z dnia 4 lipca 2004 r. *o swobodzie gospodarczej.* Dz.U. 2004, Nr 173, poz. 1807.
38. Wall, G. (2002). Conditions and tools in the design of energy conversion and management systems of a sustainable society. *Energy Conversion and Management, Vol. 43, Iss. 9-12, June-August,* pp. 1235-1248.
39. *Wzór umowy o wydanie i używanie Kart MIKROFLOTA*. Orlen. https://www.orlen.pl, December 2022.
40. *Załącznik 2 do Umowy z dn. ... r. o użytkowanie Kart flotowych Moya. Regulamin użytkowania kart (bezgotówkowych)*. Moya. https://moyastacja.pl, December 2022.
41. *Załącznik 2 do Umowy z dn. ... r. o użytkowanie Kart Prepaid Moya firma. Regulamin użytkowania kart*. Moya. https://moyastacja.pl, December 2022.

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IMPACT OF EU ALLOWANCES COST ON THE FINANCIAL RESULTS OF POLISH POWER COMPANIES

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Purpose: The aim of the article is to estimate the impact of the EU Allowances price increase on the financial results and return on investment in the portfolio of shares of four listed power companies, i.e., Enea S.A., Energa S.A., PGE Polska Grupa Energetyczna S.A., and TAURON Polska Energia S.A.
Design/methodology/approach: Financial analysis of energy groups. Statistical analysis, a linear regression model with 6 independent variables and the dependent variable, i.e., the return on investment in the portfolio of shares of the analyzed companies. The studies cover the years 2016-2021.
Findings: The results of the financial analysis show that the analyzed energy groups did not always could include increased operating costs in the price of energy sold in 2016-2021?
The linear regression analysis did not indicate that the decrease in the profitability of investments in the shares of the surveyed companies can be explained by the increase in the prices of EU Allowances.
Research limitation/implications: The inability to determine the unequivocal impact of the EU Allowances price increase on the financial results and share prices of the considered companies can be explained by the number of operating segments in the energy groups, the outbreak of the COVID pandemic and negative GDP in 2020, and the "upward rebound" of the economy after the pandemic and high GDP in 2021**.**
Practical implications: The analysis is useful for shareholders of electricity companies and politicians who create regulations concerning the Polish energy policy. The results of the study are useful to all stakeholders of electricity companies.
Social influence: The high costs of EU Allowances affect electricity prices for the Polish society and prove very high CO_2 emissions when producing electricity in Poland.
Originality/value: The conducted financial analysis and regression analysis are one of the first attempts to indicate the impact of the increase in the cost of CO_2 emission allowances on the financial results and share prices of Polish energy companies. The article contributes to reducing the research gap existing in Polish literature in this area.

Keywords: power companies, EU Emissions Trading System, EU Allowances (EUA), regression analysis.

Category of the paper: research paper.

1. Introduction

Reducing greenhouse gas emissions has become a particularly important goal of the European Union. The main tool stimulating individual member states and companies operating in the EU energy, industrial, and aviation market to reduce greenhouse gas emissions, including CO_2, is the EU Emissions Trading System (EU ETS) established in 2005 (Directive 2003/87/EC, 2003). Currently, the EU ETS system covers all EU member states and three countries belonging to the European Free Trade Association (EFTA): Iceland, Liechtenstein, and Norway. Participation in the EU ETS is mandatory for companies in certain sectors, including the power sector, but in some sectors, such as heat generators, only plants of a certain size are considered. Every year, participants in the EU ETS system have to account for their actual emissions by redeeming an appropriate number of EU Allowances. Article 3(a) of Directive 2003/87/EC (the EU ETS Directive) defines the emission allowance as being *an allowance to emit one tonne of carbon dioxide equivalent during a specified period, which shall be valid only for the purposes of meeting the requirements of this Directive and shall be transferable in accordance with the provisions of this Directive*. If a company reduces emissions, it can keep some of its allowances to cover future needs or sell them to another company that does not have enough allowances.

The functioning of the EU Emissions Trading System (EU ETS) can be divided into four phases. The phase I covered the years 2005-2007, the II phase - years 2008-2012, the phase III - years 2013-2020, and in 2021 the fourth phase began, which will last until the end of 2030. Each subsequent phase is associated with an increasingly restrictive approach to pollutant emissions, including CO_2. This applies to the maximum amount of CO_2 that can be emitted in the European Union, the so-called "cap" and increasing the number of industries and gases covered by the EU ETS. For example, in the phase I (2005-2007), the EU Emission Trading Scheme (EU ETS) covered only CO_2 emissions of electricity producers and producers of energy-intensive industries, and all EU Allowances were allocated free of charge. The penalty for not redeeming EU Allowances was € 40 t/CO_2. In the phase II, the EU ETS also covered nitrous oxide emission, and the penalty for not redeeming EU Allowances increased to €100 t/CO_2. About 90% of EU Allowances were allocated free of charge. The plan for this period assumed a lower limit of EUA, i.e., about 6.5% less than in 2005 (European Commission, 30.09.2022). Since 2012, the aviation sector has also been included in the EU ETS.

In 2013, i.e., at the beginning of phase III, the so-called the "cap", i.e., the maximum amount of greenhouse gases that entities belonging to the EU ETS could emit in the European Union, amounted to 2,084,301,856 tonnes per year, and an obligation was introduced (Directive 2009/29/EC, 2009) to reduce this level by 1.74% per year (linear), i.e., by 38,264,246 tonnes (European Commission 31.10.2022).

For aviation, the maximum level of EU Aviation Allowances (EUAA) was set at 210,349,264 tonnes per year throughout the phase III (European Commission, 2015). From 2021 to 2030 (the phase IV), the maximum limit of EU Allowances, the so-called "cap", in the EU ETS is reduced by 2.2% (Directive (EU) 2018/410, 2018) per year (linearly). In December 2020, European Union leaders agreed to increase the reduction of greenhouse gas emissions from 40% to 55% by 2030 compared to 1990 levels. (FORSAL.PL, 2021). According to experts, achieving this result will be possible with a further reduction of the maximum level of EU Allowances from the current 2.2% to 3.8% annually, i.e., by 83 million tonnes, which will have a significant impact on future prices of EU Allowances (KOBiZE, 2019).

From 2013 (the phase III), electricity producers are not entitled to free EU Allowances, except in cases related to the so-called derogations. Pursuant to Article 10c of Directive 2003/87/EC, installations in certain Member States, including Poland, generating electricity that meet the modernization criteria may be temporarily allocated free EU Allowances (the number of free EU Allowances for a given country then decreases).

In 2021 in the European Union, 37% of electricity production came from fossil fuels, while in 2005 it was 52.8%, which is as much as 29.5% less (Figure 1). A similar downward trend was observed in the production of electricity from nuclear power plants, the share of which decreased from 31.7% in 2005 to 25.5% in 2021 (a decrease of 19.6%).

The reduction in electricity production from nuclear fuel and fossil fuels has been replaced by production from renewable energy sources (RES). Its share in electricity production in 2021 was 37.2%, while in 2005 it was 15.4% (an increase of 141.6%). The Polish energy mix in 2005 was based on fossil fuels at 97.5% and 83.3% in 2021 (a decrease of 14.5%). The share of electricity from renewable energy sources (RES), amounting to 2.5% in 2005, increased to 16.6% in 2021 (an increase of 568%). The Polish electricity production mix resulted from the production mix of Polish electricity companies. This means that the share of fossil fuels in the production of electricity in the largest Polish electricity companies was about 90%.

The analysis concerns 4 Polish power companies, the majority or dominant shareholder of which is the State Treasury, and whose total share in electricity production in Poland in 2021 was 65% (Figure 2). At the end of 2021, the State Treasury was the majority shareholder in 2 out of 4 examined companies, i.e., PGE Polska Grupa Energetyczna S.A. - 57.39% of shares and Enea S.A. - 51.50% of shares and a significant shareholder in TAURON Polska Energia S.A. - held directly 30.06% of the shares and indirectly, through KGHM Polska Miedź S.A., 10.0% of the shares (Bankier.pl, 31.07.2022).

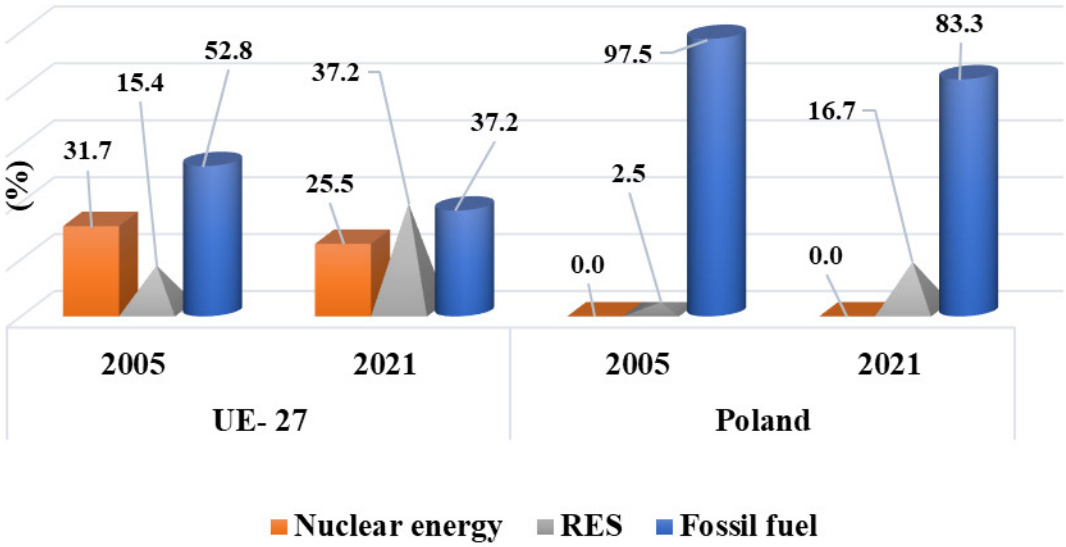

Figure 1. Electricity production by energy source in 2005 and 2021, (%).

Source: (Moore, 2022).

Until April 2020, the State Treasury was also the majority shareholder in Energa S.A. - 51.50% of shares and 64.09% of votes. In April 2020, PKN Orlen S.A. because of a tender offer for the purchase of Energa S.A. shares acquired 80% of the shares of this company, including all Treasury shares in Energa S.A. Thus, the State Treasury, which was the dominant shareholder in PKN Orlen S.A. (18.79% of shares and the same number of votes) indirectly holds over 80% of shares in Energa S.A. (Bankier.pl, 2022).

The aim of the article is to estimate the impact of the EU Allowances price increase on the financial results and return on investment in the portfolio of shares of four listed power companies, i.e., Enea S.A., Energa S.A., PGE Polska Grupa Energetyczna S.A., and TAURON Polska Energia S.A.

It can be assumed that such large increases in the prices of EU Allowances had a negative impact on the financial results and share prices of Polish power companies. This assumption results from the fact that the share of fossil fuels in the production of electricity in the surveyed companies is over 90% and they emit about 100 million tonnes of CO_2 annually (their average CO_2 emissions in 2016-2021 amounted to 100.4 million tonnes of CO_2 (Figure 3).

The analysis covers the years 2016-2021. At the end of 2015, the price of EU Allowances was EUR 8.22/t CO_2, and at the end of December 2021, it was already EUR 80.65/t CO_2, more than 881% (Table 5).

In the studied period, i.e., from the end of 2015 to the end of 2021, the quotations of the companies share prices on the Warsaw Stock Exchange decreased respectively for: PGE Polska Grupa Energetyczna S.A. by 36.1%, Energa S.A. by 39.5%, Enea S.A. by 24.3%, TAURON Polska Energia S.A. by 7.2%. The share portfolio of these 4 companies fell by 31.7%.

In order to achieve the aim of this article, two research hypotheses were put forward:

H1 - the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the aggregated financial results of the surveyed four power companies.

H2 - the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four energy companies.

To test the validity of hypothesis H1, a financial analysis of the four energy groups and their operating segments was performed. Then, in order to examine the validity of hypothesis H2, a statistical analysis was carried out using a linear regression model to assess the impact of changes in the EU Allowances prices and other independent variables on the return on investment in the portfolio of shares of four energy groups. The selection of variables other than the price of EU Allowances that could affect the return on investment in the portfolio of shares of the surveyed companies was the result of the studies of the available literature on this subject, described later in the article.

2. The costs of EU Allowances and their impact on the aggregated financial results of the surveyed companies

The average net electricity production of the surveyed companies in the years 2016-2021 amounted to 102 TWh, which, with the average national production in these years of 163 TWh, accounted for 62.4%. The share of these companies in the production of electricity from fossil fuels (average annual 95 TWh) in domestic production (average annual 146 TWh) was 65.0%. In turn, their share in the production of electricity from RES (average annual 7 TWh) in domestic production (average annual 17 TWh) was 40.8% (Figure 2).

The high share of electricity from fossil fuels in total production resulted in the emission of a large amount of CO_2. In 2016-2021, the surveyed companies emitted an average of 100.4 million tonnes of CO_2, which meant the need to purchase such a a quantity of EU Allowances.

However, since these companies received part of the EU Allowances for free (because of the derogation and as the heat generators), the actual amount of EU Allowances that they had to buy on the market was lower than the amount of CO_2 emitted by approx. 14.5% (Figure 3).

Thus, the companies had to buy an average of 85.9 million tonnes of EU Allowances on the market in 2016-2021. In 2020-21, the allocation of free EU Allowances was negligible, and companies had to buy EU Allowances in amounts corresponding to their CO_2 emissions.

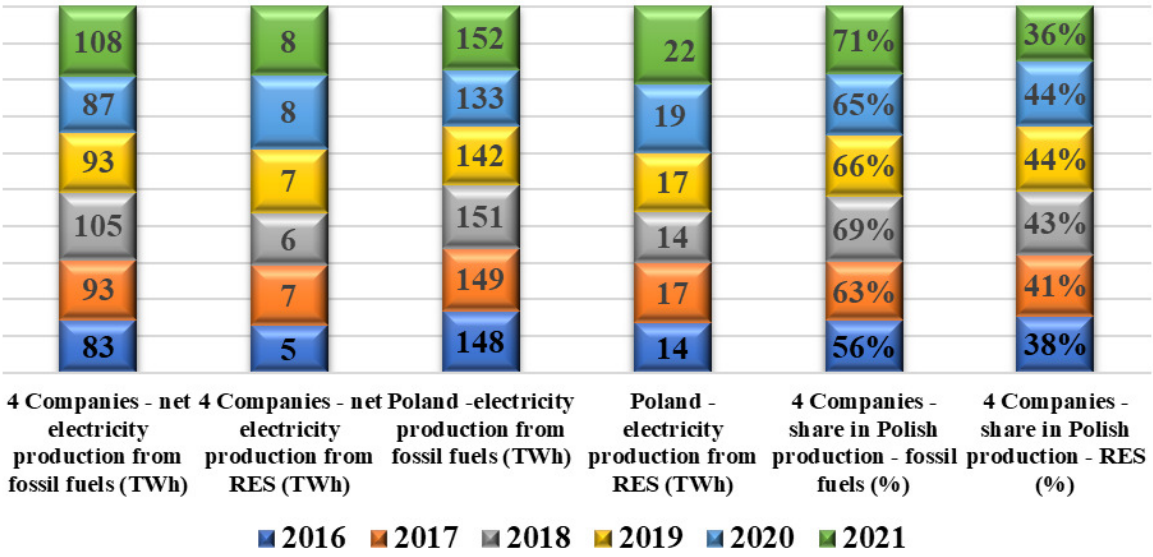

Figure 2. Electricity production in 2016-2021.

Source: (Financial statements, 2016-2022; Moore, 2022, own calculations).

The reduction in the number of free EU Allowances and the increase in their prices meant that the surveyed companies paid more for the purchase of EU Allowances from year to year. In 2016, they paid PLN 1.69 billion for EU Allowances, and in 2021 it was already PLN 13.51 billion (Figure 3). The increase in prices of EU Allowances in 2016-2021 resulted in an increase in the costs of generating MW of electricity from fossil fuels. The exact costs of EU Allowances for a given year are not known until the end of April of the following year, i.e., the date of redemption of EU Allowances. In this analysis, the costs of EU Allowances for a given year are the costs of redeemed EU Allowances reported by these companies in the following year.

The cost of EU Allowances at the unit cost of 1 MWh of electricity from fossil fuels amounted to: PLN 20.5/MWh in 2016; PLN 28.8/MWh in 2017; PLN 29.8/MWh in 2018; PLN 60.6/MWh in 2019; PLN 116.1/MWh in 2020 and PLN 125.0/MWh in 2021. Thus, the cost of electricity production per MW, due to higher prices of EU Allowances, increased in 2021 by PLN 104.5 compared to 2016 (an increase of 510%).

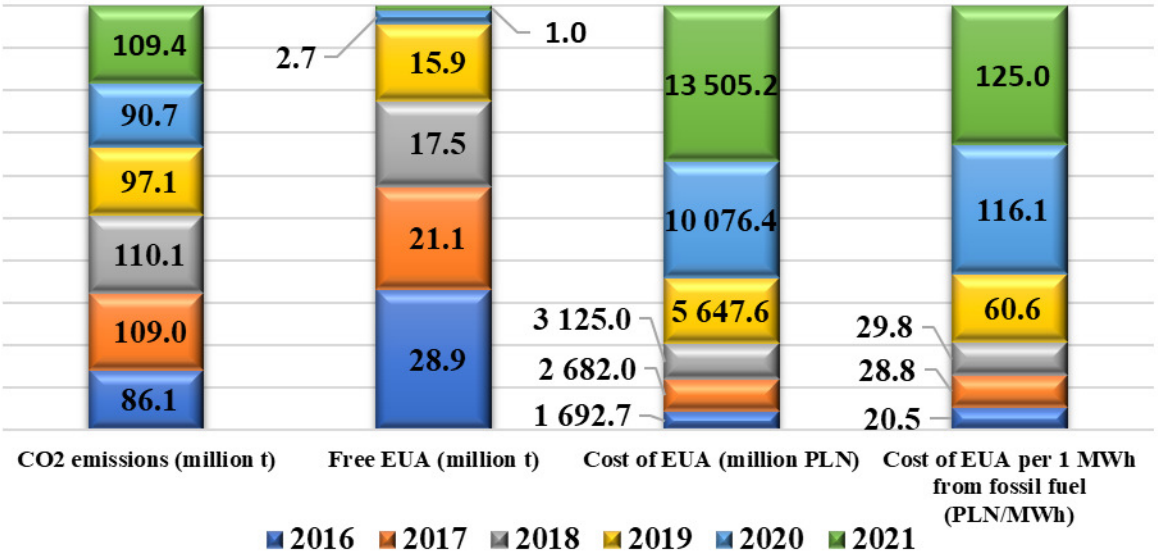

Figure 3. The 4 analyzed companies – CO_2 emission and its cost in 2016-2021.

Source: (Financial statements, 2016-2022; own calculations).

The considered power companies are among the largest Polish companies in terms of revenues. The total sales revenues of these four energy groups increased from PLN 67.2 billion in 2016 to PLN 113.6 billion in 2021 (an increase of 69%). Unfortunately, such a dynamic increase in sales revenues did not "contribute" to the improvement of their financial results. In 2019 and 2020, the companies recorded net losses of PLN 4.4 billion and PLN 4.7 billion. While, in 2016-2018, the companies' net profit amounted to: PLN 3.9 billion in 2016; PLN 6.0 billion in 2017; PLN 3.2 billion in 2018. In the last of the examined years, in 2021, the companies recorded a huge improvement in their financial results, and their total net profit amounted to PLN 7.1 billion (Figure 4).

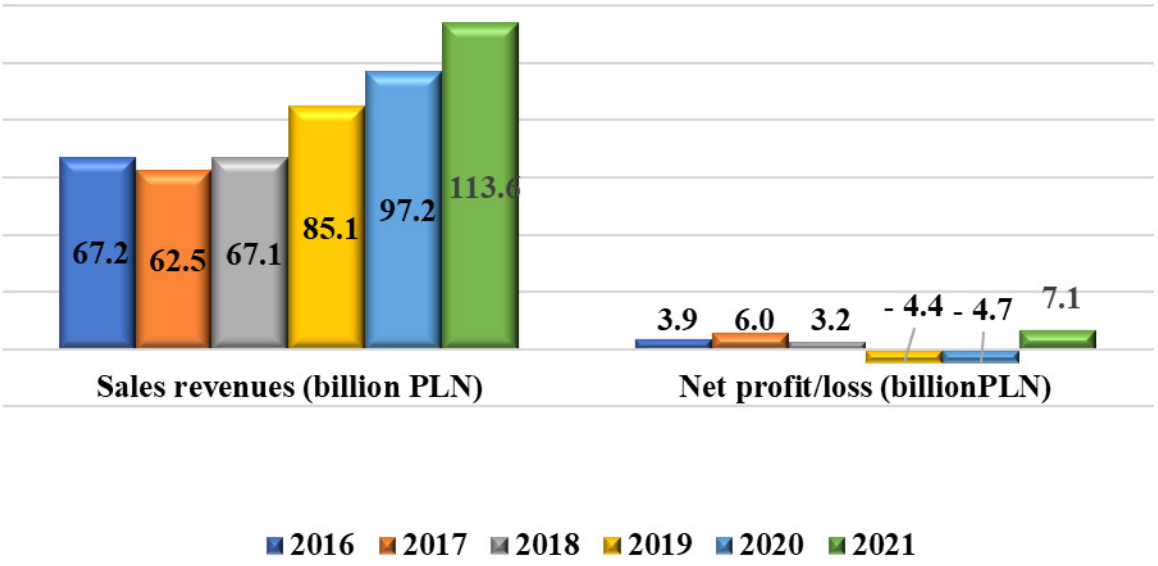

Figure 4. The 4 Analyzed companies - sales revenues and net profit/loss in 2016-2021.

Source: (Financial statements, 2016-2022).

The share of individual companies in the net profit in the examined years is shown in Figure 5. The largest share in the net profit of the 4 surveyed companies, amounting to 62% (average for 6 years), was held by PGE Polska Grupa Energetyczna S.A. The following places were taken by: Enea Group (26%), Energa Group (11%) and TAURON (1%). The greatest impact on the value of net profit reported by individual companies had the amount of sales revenues and the share of individual operating segments in revenues and EBIT in a given energy group (Tables 1 and 2).

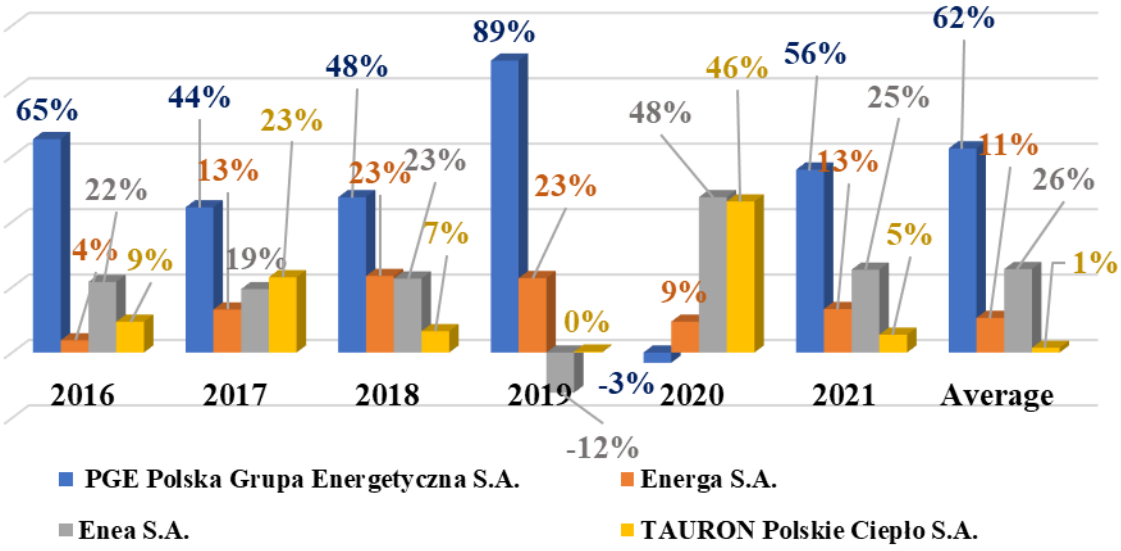

Figure 5. The share of individual companies in the net profit of all 4 companies in 2016-2021.
Source: (Financial statements, 2016-2022; own calculations).

The surveyed companies are energy groups consisting of several operating segments. Each of them consists of the following operating segments: Distribution, Conventional Power Generation, Sales or Trade, and Other activities. The Enea and Tauron Groups also have an operating segment Mining. From 2018, the PGE Group has a segment Heat Generation, separated from the operating segment Conventional Generation. The TAURON and PGE Groups also have an operating segment Renewables Power Generation. The Energa Group and the Enea Group do not have a separate Renewables Power Generation operating segment, and all electricity produced is reported in the Power generation operating segments.

The need to isolate an operating segment and report selected financial data of such a segment by listed companies results from the Accounting Act (Accounting Act, 1994, Article 55). Pursuant to the Act, listed companies obliged to prepare consolidated financial statements must apply the International Accounting Standards. In accordance with the International Financial Reporting Standard 8 Operating Segments, selected entities, mainly listed companies, must separate and disclose information about their operating segments.

Selected financial data for individual operating segments of the surveyed power groups in 2016-2021 are presented in Tables 1 and 2. Table 1 presents the sales revenues of individual operating segments of the surveyed energy groups and their shares in the total revenues of these

groups. The share of Conventional Generation and Heat Generation operating segments in total revenues (excluding other revenues and consolidation adjustments) ranged from 31% in 2016 to 50% in 2021.

Table 1.
Revenues of the 4 surveyed power companies, broken down into operating segments - 2016-2021

Operating segments	REVENUES (PLN m)					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Conventional Generation and Heat Generation	20 544	23 330	30 886	38 359	44 310	57 037
Renewables Generation (RES)	717	724	839	1 039	1 707	2 333
Sales	42 835	40 522	42 949	46 966	63 765	81 068
Distribution	19 455	20 692	18 792	16 437	20 805	21 301
Mining	3 097	3 322	3 023	2 503	2 874	3 830
Other activities and consolidation adjustments	-19 473	-26 126	-29 391	-20 240	-36 356	-52 337
Total	**67 175**	**62 464**	**67 098**	**85 065**	**97 105**	**113 231**
Operating segments	**REVENUES (%)**					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Conventional Generation and Heat Generation	31%	37%	46%	45%	46%	50%
Renewables Generation (RES)	1%	1%	1%	1%	2%	2%
Sales	64%	65%	64%	55%	66%	72%
Distribution	29%	33%	28%	19%	21%	19%
Mining	5%	5%	5%	3%	3%	3%
Other activities and consolidation adjustments	-29%	-42%	-44%	-24%	-37%	-46%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: (Financial statements, 2019-2021; own calculations).

In 2019-2020, Conventional Generation and Heat Generation operating segments had negative EBIT values of PLN 6.3 and PLN 6.0 billion respectively. In 2016-2018, the total EBIT was positive and amounted to: PLN 1.7 billion in 2016; PLN 2.4 billion in 2017 and PLN 1.7 billion in 2018. However, the average price of EU Allowances (the sum of the prices at the end of each month divided by 12) was: EUR 5.32/t CO_2 in 2016; EUR 6.35/t CO_2 in 2017; EUR 18.11/t CO_2 in 2018; EUR 25.85/t CO_2 in 2019, EUR 25.67/t CO_2 in 2020, and EUR 55.37/t CO_2 in 2021 (Table 5). Therefore, the average prices of EU Allowances in 2021 were 904% higher than in 2016.

This may indicate that the increase in prices of EU Allowances had an impact on these values. The increase in the prices of other production factors did not have a significant impact on the costs of Conventional Generation and Heat Generation operating segments. For example, coal prices in the discussed period increased by only 12%. Gas prices at the end of 2021 were higher by 543% compared to December 2015 (Table 5), but the production of electricity from gas in the surveyed enterprises was very low or equal to zero. It follows that the increase in gas prices had no impact on the costs of electricity production in the surveyed companies. In turn, the financial results of Conventional Generation and Heat Generation operating segments in 20021 was positive and amounted to PLN 3.127 billion. The improvement in profits was possible due to higher electricity prices on the stock exchange (it is assumed that the increase in electricity prices on the stock exchange resulted in an increase in the prices of electricity sold by the surveyed companies).

Table 2.
EBIT of the 4 analyzed power companies, broken down into operating segments - 2016-2021

Operating segments	EBIT (PLN m)					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Conventional Generation and Heat Generation	1 676	2 418	1 700	-6 023	-6 320	3 127
Renewables Generation (RES)	-770	-36	205	657	551	910
Sales	1 103	1 831	331	781	1 307	394
Distribution	4 083	3 921	4 186	3 846	4 573	5 223
Mining	36	140	-948	-974	-760	-62
Other activities and consolidation adjustments	-154	-105	100	-348	-786	-128
Total	5 973	8 169	5 575	-2 060	-1 435	9 465

Source: (Financial statements, 2016-2021; own calculations).

At the end of 2016, electricity prices were 8.5% higher than in December 2015 (Table 5). At the end of 2017, the price of electricity was only 5% higher compared to the end of 2015. A year later, in December 2018, the price of electricity was 60% higher than in December 2015 while in December 2019, the price of electricity was 29% higher than in December 2015, i.e., 19% lower than in December 2018. At the end of 2020, electricity prices on the stock exchange were 78% higher than in December 2015. In December 2021, the price of electricity was 476.6% higher than in December 2015, i.e. 224.4% higher than in 2020.

Such a level of electricity prices on the stock exchange proves that it is not possible to "pass" higher electricity production costs onto customers in 2019-2020.

One of the reasons for the inability to increase the prices of electricity sold in 2020 was the outbreak of the COVID pandemic, which had a significant impact on the global economy in 2020. In Poland, Gross Domestic Product (GDP) in 2020 was negative and amounted to 2.7% In 2019 Polish GDP increased by 4.7% (GUS, 21.12.2022). Electricity production in Poland in 2020 decreased by 3.3% compared to 2019 (Figure 2). In 2021, the surveyed companies reported a total EBIT of PLN 3.127 billion from Conventional Generation and Heat Generation operating segments. The improvement in the result was significantly influenced by the increase in electricity prices, which increased by 260% compared to December 2019 and by 224.4% compared to December 2020. In 2021, Polish GDP increased by 6.8% (GUS, 2022), and electricity production increased by 12.4% compared to the previous year (Figure 3). The total EBIT value of the 4 surveyed groups in 2021 amounted to PLN 9.5 billion (in 2020, the total EBIT was PLN -6.3 billion, and in 2019 - PLN -6.0 billion).

Apart from 2021, Conventional Generation and Heat Generation operating segments had a low or negative return on assets (Table 3). This situation also applies to Mining operating segments. It can be stated that those companies that produced large amounts of electricity from fossil fuels and had Mining operating segments reported worse financial results.

Table 3.
EBIT/ASSETS of the 4 analyzed power companies, broken down into operating segments - 2016-2021

Operating segments	EBIT/ASSETS (%)					
	2016	2017	2018	2019	2020	2021
Conventional Generation and Heat Generation	6%	8%	5%	-18%	-27%	15%
Renewables Generation (RES)	-535%	-44%	199%	435%	17%	34%
Sales	17%	34%	5%	11%	18%	5%
Distribution	10%	10%	10%	9%	10%	11%
Mining	1%	3%	-21%	-23%	-18%	-2%
Other activities and consolidation adjustments	16%	-6%	6%	-21%	369%	-7%
Total	7%	10%	6%	-2%	-2%	11%

Source: (Financial statements, 2016-2021; own calculations).

The data in Table 4 shows that in 2019-2021, the change in sales revenues of the operating segments was higher than the change the in cost of EU Allowances. This could mean that the increase in costs of EU Allowances has been "passed on" to customers.

The increase in the cost of EU Allowances compared to the increase in sales revenues amounted to 36% in 2017; 6% in 2018; 34% in 2019; 74% in 2020 and 27% in 2021. It reduced the margins on the electricity sold and the need to make multi-billion write-offs of non-financial assets in these operating segments in 2019-2020.

Table 4.
Selected operation and financial data for the Portfolio of 4 surveyed power companies in 2019-2021 – "The Conventional generation and heat generation" operating segments

Data		2016	2017	2018	2019	2020	2021
EBIT	PLN m	1676	2418	1700	-6023	-6320	3127
Write-offs related to the impairment of non-financial assets	PLN m	-2172	936	62	6982	5678	884
EBIT after correction for write-offs	PLN m	-496	3354	1762	959	-642	4011
Cost of EU Allowances	PLN m	1693	2682	3125	5648	10076	13505
Revenue	PLN m	20544	23330	30886	38359	44310	57037
Change in revenues	PLN m	0	2786	7556	7473	5951	12727
Change in EU Allowances costs	PLN m	0	989	443	2523	4429	3429
Change in EUA costs/Change in revenues	%	0%	36%	6%	34%	74%	27%
Cost of EU Allowances as % of revenues	PLN m	8.2%	11.5%	10.1%	14.7%	22.7%	23.7%
Profitability of sales (EBIT after corrections/revenues)	%	-2.4%	14.4%	5.7%	2.5%	-1.4%	7.0%

Source: (Financial statements, 2016-2021; own calculations).

The change in the financial situation of the surveyed companies occurred only in 2021, which is indicated by the high electricity prices on the stock exchange (Table 5). The mere analysis of the electricity prices sold by the companies in question is of little use because the price of electricity sold includes electricity produced by a given energy group and electricity purchased from other entities.

Hypothesis H1 assumed that the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the financial results of the surveyed four energy companies. The financial analysis of the combined financial results of the four energy groups and their operating segments shows that the increase in the prices of EU Allowances had a negative impact on the financial results of Conventional Generation and Heat Generation

operating segments in 2019-2020 (Table 4). It can therefore be concluded that this impact was also negative on the consolidated financial results of these energy groups in 2019-2020.

In 2021 a greater increase in the prices of EU Allowances and other factors of production was "transferred" into higher electricity prices (Table 5). In 2021, Polish GDP increased by as much as 6.8% and electricity production by 12.4% (Figure 3) compared to the previous year. In conclusion, hypothesis H1 is true for 2019-2020 and not true for 2016-2018 and for 2021. In conclusion, hypothesis H1 cannot be rejected for 2019-2020 and can be rejected for 2016-2018 and 2021. The higher costs of EU Allowances in 2021 were paid by the whole of Polish society.

3. The costs of EU Allowances and their impact on the share portfolio price of surveyed companies

3.1. Literature review

A review of the literature shows that some authors analyzed the impact of the prices of several factors on the prices of EU Allowances while other authors studied the impact of EU Allowances and the prices of other factors on the stock prices of European energy companies.

In general, we can say that the factors that determine prices of EU Allowances, considered in the literature, are microeconomic and macroeconomic (characteristics of the energy sector, GDP, emissions growth, emission targets), energy factors (the price of energy sources, and energy substitutability possibilities) and climate factors (temperature and climatic conditions) (Bataller et al., 2006). According to some authors, energy prices are the key factors shaping the prices of EU Allowances in the short term due to the ability of electricity producers to switch the energy source from coal to gas and vice versa, which generates different demands for EU Allowances. Other factors influencing the prices of EU Allowances are regulations and extreme temperatures (Chevallier, 2010). Some authors define factors influencing the prices of EU Allowances and analyse the relationship between prices of EU Allowances, electricity prices, and electricity costs for industry (Reinaud, 2007).

The impact of free allocation of EU Allowances (the phase I, 2005-2007) on the electricity prices and the profitability of power generation companies was dealt with by Jos Sijm, Karsten Neuhoff, and Yihsu Chen (Sijm et al., 2006). Electricity prices are determined by the cost of fossil fuels, mainly coal and gas, costs of EU Allowances, the impact of climate policy, and climatic factors such as temperature and rainfall (Kiriat, Ahmanda, 2011). According to some authors, an increase in the number of extremely hot days may adversely affect the EU Allowances prices because on hot days more cooling is needed, which increases the demand for energy, and thus prices of EU Allowances (Rickels et al., 2010). In turn, the cost of EU Allowances depends on the efficiency of power units and the CO_2 emission rate per MWh of

electricity produced from individual energy sources (Schumacher et al, 2012). Benz and Trück (Benz E., Trück, 2009) analyzed the short-term EU Allowances spot price of the new EU-wide CO_2 emissions trading system (EU-ETS).

Other authors have not examined the factors influencing the prices of EU Allowances but have studied the effect of EU Allowances cost on the returns on shares of electricity producers.

The relationship between the prices of EU Allowances and the stock exchange quotations of energy companies has been the subject of research by many authors in terms of their impact on the various stages of the development of the EU Emissions Trading System (EU ETS).

U. Oberndorfer (2009) studied, among others, the impact of changes in EU Allowances prices on changes in the share price portfolio of 12 European energy companies from 6 EU countries in the period from August 4, 2005, to June 19, 2007, i.e., in the period covering the entire phase I (2005-2007). He assumed that the share prices of the companies under consideration, apart from prices of EU Allowances, were influenced the crude oil prices, gas prices, and electricity prices. His calculations showed that the increase in the prices of EU Allowances had a positive or negative impact on the share prices of the company, depending on which country it came from.

On the other hand, Veith, Werner, and Zimmermann (2009) examined the impact of EU Allowances return and other independent variables (including daily gas and oil return, market portfolio return, and exchange rate return) on daily return on the shares of 22 European electricity companies in the period from April 25, 2005, to August 31, 2007 (128 companies in the second step). The calculations showed that the share prices of the surveyed companies were positively correlated with the prices of EU Allowances. These results may indicate that these companies could easily pass on the increase in prices of EU Allowances to the electricity prices (Veith et al., 2009).

Tian Y., Akimov A., Roca E., and Wong V. (2016) examined the impact of changes of EU Allowances prices, gas prices, oil prices, electricity prices, and the Dow Jones Euro Utilities Index on changes of share prices of the portfolio of 12 European stocks included in this index in the period from November 21, 2005, to December 5, 2012. The adopted period covers the phases I and II. The stock energy volatility was largely driven in the same direction by EU Allowances market volatility (Tian et al., 2016).

The relationship between the change in EU Allowances returns and the change in shares returns of electricity companies from 6 EU Member States in the phase III (2013-2020) was analysed by Garcia, Garcia-Alvarez, and Moreno (Garcia et al., 2020). Estimated coefficients for the period from January 1, 2013, to July 22, 2018, indicated that the EU Allowances prices had a satisfactory positive impact on the share prices of the surveyed power companies.

In addition to the impact of EU Allowances price changes on the share prices of power companies, many authors have examined their impact on other sectors of the economy, such as steel, and cement (Branger et al., 2001; Moreno, Pereira da Silva, 2016) and aviation industries (Velzen et al., 2019). The strength of this impact depends on the EU Allowances prices (Rabe

et al., 2019). The expected high prices of EU Allowances will determine the profitability of replacing coal-fired units with new high-efficiency units, the scale of the RES share increase, as well as the competitiveness of renewable energy in general (Rabe et al., 2020).

Research by the above-mentioned authors shows that the rate of return on shares of a power company is influenced by returns on coal, electricity, EU Allowances, and gas. Other important factors that affect stock returns are market index returns and currency exchange returns.

3.2. Empirical analysis

The research hypothesis H2 assumes that there is a statistical correlation between returns on investment in the portfolio of shares of the surveyed companies (dependent variable) and returns on investments in coal, electricity, WIG index, gas, and investments in currencies (EURO). In other words, the research hypothesis H2 assumes that the prices of gas, coal, and electricity, the exchange rate, and the value of the WIG index explain the changes in the share prices of the surveyed companies. To confirm or reject the research hypothesis H2, a regression analysis was performed. Finally, the following data were entered as independent variables: EUA return, coal return (PSCMI 1), electricity return (DAM), gas return (TTF), and exchange rate return. The dependent variable is the return on the portfolio of shares of the 4 examined companies.

Thus, 72 monthly data (from January 2016 to December 2021) were used to estimate the parameters of the regression model, calculated on the basis of the data in Table 5.

The share prices of the surveyed companies listed on the Warsaw Stock Exchange, EU Allowances prices and ICE Dutch TTF Natural Gas Futures prices listed by ICE (Intercontinental Exchange, Inc., NYSE: ICE), exchange rates published by the National Bank of Poland (NBP) and values of the Warsaw Stock Exchange Index (WIG) are daily data from the last trading day of each month. Prices of electricity (DAM) and coal (PSCMI 1 index) on the Polish Power Exchange (TGE) are average prices from individual months.

It is assumed that the price of the stock portfolio is the average price of the shares of the 4 surveyed companies. The logarithmic rate of return was used to calculate the rate of return on investment in individual variables: $\ln (r_t / r_{t-1})$. The regression analysis was performed in the Gretl program based on the data in Table 5. The dependent variable, denoted by Y, is the return on the portfolio of shares of the surveyed companies, and the independent variables are: X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return and X6 - WIG index return. After introducing all 6 independent variables and one dependent variable into the regression model, it turned out that not all of the proposed independent variables are statistically significant (p-value less than 0.05) and should be included in the regression model. After excluding 5 statistically insignificant independent variables (Table 6), it turned out that only one independent variable remained in the regression model, i.e. X6 - the return from the WIG index.

Table 5.
Selected Monthly data for regression analysis – December 2015-December 2021

Date	EUA price - EUR/EUA	Gas price (TTF) - EUR/MWh	X 5 Exchange rate - EUR/PLN	X 1- EUA price - PLN/pcs.	X- 2 Coal price (PSCMI 1) - PLN/tonne	X 3 - Electricity price (DAM) - PLN/MWh	X 4 - Gas price (TTF) - PLN/MWh	X - WIG Index	PGE share price PLN/pcs.	ENERGA share price - PLN/pcs.	ENEA share price - PLN/pcs.	TAURON share price - PLN/pcs.	AVERAGE PRICE - PLN/pcs.
30.12.2015	8.22	14.61	4.2615	35.03	225.98	142.90	62.26	46 467	12.79	12.64	11.30	2.88	9.90
29.01.2016	6.04	13.38	4.4405	26.82	201.17	169.50	59.41	44 290	13.80	13.52	11.72	2.71	10.44
29.02.2016	4.99	12.19	4.3589	21.75	192.97	140.00	53.13	45 430	12.94	12.69	11.06	2.53	9.81
31.03.2016	5.20	11.94	4.2684	22.20	194.34	146.40	50.96	49 017	13.98	13.11	11.92	3.01	10.51
29.04.2016	6.17	12.78	4.4078	27.20	195.00	157.40	56.33	47 642	13.18	12.44	11.80	2.96	10.10
30.05.2016	6.08	13.91	4.3820	26.64	195.40	155.60	60.95	45 844	12.61	9.85	10.02	2.58	8.77
30.06.2016	4.46	14.38	4.4265	19.74	193.54	209.40	63.65	44 749	11.82	9.50	9.90	2.84	8.52
29.07.2016	4.41	14.46	4.3684	19.26	196.13	151.60	63.17	46 172	12.80	9.74	10.96	3.08	9.15
30.08.2016	4.46	11.54	4.3555	19.43	188.78	140.50	50.26	47 935	11.54	8.10	9.86	2.78	8.07
30.09.2016	4.96	15.35	4.3120	21.39	197.09	155.20	66.19	47 085	10.15	7.50	8.51	2.60	7.19
31.10.2016	5.90	17.79	4.3267	25.53	189.71	169.30	76.97	49 159	10.27	8.04	10.04	2.65	7.75
30.11.2016	4.58	18.21	4.4240	20.26	189.49	159.70	80.56	48 619	9.28	7.95	9.30	2.65	7.30
30.12.2016	6.54	19.54	4.4405	29.04	190.49	155.00	86.77	51 754	10.45	9.10	9.50	2.85	7.98
31.01.2017	5.69	20.75	4.3308	24.64	198.38	162.40	89.86	51 754	10.45	9.10	9.50	2.85	7.98
28.02.2017	5.57	16.90	4.3166	24.04	198.60	155.70	72.95	55 232	10.92	10.21	10.13	2.95	8.55
31.03.2017	5.04	15.80	4.2198	21.27	200.20	146.50	66.67	58 300	11.87	10.92	10.67	3.00	9.12
28.04.2017	4.94	16.18	4.2170	20.83	199.26	141.10	68.23	57 911	11.40	10.63	11.31	3.39	9.18
31.05.2017	5.35	15.29	4.1737	22.33	208.64	148.80	63.82	61 645	11.53	9.96	11.92	3.29	9.18
30.06.2017	5.42	14.84	4.2265	22.91	208.45	153.10	62.72	60 092	10.92	9.84	11.30	3.22	8.82
31.07.2017	5.73	14.97	4.2545	24.38	208.39	155.20	63.69	61 018	12.11	10.47	13.36	3.58	9.88
31.08.2017	6.54	16.45	4.2618	27.87	200.76	162.80	70.11	62 596	13.10	12.73	15.15	3.81	11.20
29.09.2017	7.59	17.38	4.3091	32.71	206.17	171.40	74.89	64 974	14.27	13.64	15.25	3.92	11.77
31.10.2017	7.81	18.21	4.2498	33.19	208.75	174.50	77.39	64 290	13.30	13.40	14.80	3.75	11.31
30.11.2017	7.97	20.30	4.2055	33.52	211.41	170.30	85.37	64 867	13.05	12.65	13.93	3.52	10.79
29.12.2017	8.60	19.63	4.1709	35.87	212.66	150.40	81.87	62 440	11.93	12.09	11.89	3.10	9.75
30.01.2018	9.85	17.95	4.1461	40.84	226.76	161.00	74.42	66 048	11.89	12.00	10.99	3.03	9.48
28.02.2018	10.73	19.18	4.1779	44.83	228.22	187.00	80.13	61 703	10.14	10.42	10.12	2.55	8.31
29.03.2018	14.04	18.39	4.2093	59.10	230.75	206.00	77.41	58 377	9.91	9.63	9.22	2.43	7.80
30.04.2018	14.60	20.25	4.2204	61.62	238.22	180.00	85.46	59 932	10.47	10.31	10.43	2.35	8.39
31.05.2018	16.16	22.60	4.3195	69.80	237.20	221.00	97.62	57 283	9.84	9.43	10.26	2.24	7.94
29.06.2018	16.51	21.87	4.3616	72.01	239.42	228.00	95.39	55 954	9.34	8.94	9.14	2.29	7.43
31.07.2018	19.34	22.11	4.2779	82.73	238.10	227.00	94.58	59 964	9.83	8.95	9.58	2.25	7.65
31.08.2018	23.20	26.13	4.2953	99.65	248.44	258.00	112.24	60 201	9.00	8.40	8.54	2.00	6.99
28.09.2018	24.63	27.33	4.2714	105.20	245.38	272.00	116.74	58 975	9.52	7.82	8.00	1.77	6.78
31.10.2018	18.49	23.87	4.3313	80.09	243.44	254.00	103.39	55 313	10.51	7.80	8.04	1.78	7.03
30.11.2018	22.70	24.69	4.2904	97.39	250.78	253.00	105.93	58 203	11.67	9.09	10.70	2.25	8.43
31.12.2018	27.06	48.99	4.3000	116.36	241.76	229.00	210.66	57 691	10.00	8.91	9.90	2.19	7.75

Cont. table 5.

Date	EUA price - EUR/EUA	Gas price (TTF) - EUR/MWh	X 5 Exchange rate - EUR/PLN	X 1- EUA price - PLN/pcs.	X- 2 Coal price (PSCMI 1) - PLN/tonne	X 3 - Electricity price (DAM) - PLN/MWh	X 4 - Gas price (TTF) - PLN/MWh	X - WIG Index	PGE share price PLN/pcs.	ENERGA share price - PLN/pcs.	ENEA share price - PLN/pcs.	TAURON share price - PLN/pcs.	AVERAGE PRICE - PLN/pcs.
31.01.2019	23.90	19.85	4.2802	102.30	254.77	246.00	84.96	60 367	11.86	10.14	10.73	2.37	8.78
28.02.2019	23.13	17.89	4.3120	99.74	255.97	213.00	77.14	59 904	11.60	9.80	10.08	2.33	8.45
29.03.2019	22.82	14.43	4.3013	98.16	258.14	199.00	62.07	59 668	9.94	8.63	8.75	2.02	7.34
30.04.2019	27.43	14.53	4.2911	117.70	260.91	227.00	62.35	60 146	9.52	7.50	7.65	1.73	6.60
31.05.2019	25.45	11.21	4.2916	109.22	256.52	243.00	48.11	57 910	9.23	7.74	8.41	1.59	6.74
28.06.2019	27.50	9.62	4.2520	116.93	263.75	256.00	40.90	60 187	9.59	7.80	9.34	1.71	7.11
31.07.2019	29.38	11.00	4.2911	126.07	260.00	243.00	47.20	59 671	8.89	7.33	8.25	1.58	6.51
30.08.2019	27.37	10.72	4.3844	120.00	258.89	266.00	47.00	56 740	7.71	6.62	8.68	1.50	6.12
30.09.2019	25.76	16.39	4.3736	112.66	263.36	243.00	71.68	57 320	7.99	6.40	8.60	1.55	6.13
31.10.2019	26.35	16.13	4.2617	112.30	266.03	226.00	68.74	57 783	8.19	6.15	8.45	1.65	6.11
29.11.2019	25.94	15.65	4.3236	112.15	266.35	218.00	67.66	57 502	8.72	6.89	8.95	1.78	6.58
31.12.2019	25.18	12.29	4.2585	107.23	265.23	185.00	52.34	57 833	7.96	7.08	7.92	1.64	6.15
31.01.2020	24.31	9.78	4.3010	104.56	268.32	190.00	42.06	56 681	6.86	7.18	7.17	1.49	5.67
28.02.2020	24.02	8.87	4.3355	104.14	261.84	176.00	38.46	49 277	4.47	7.02	5.60	1.10	4.55
31.03.2020	18.42	6.90	4.5523	83.85	262.49	165.00	31.41	41 625	3.81	6.90	4.73	1.12	4.14
30.04.2020	20.39	6.22	4.5424	92.62	263.94	151.00	28.25	46 117	4.12	7.78	5.54	1.13	4.64
29.05.2020	22.18	4.38	4.4503	98.71	267.21	173.00	19.49	48 128	4.84	7.90	5.86	1.24	4.96
30.06.2020	27.68	6.16	4.4660	123.62	267.39	217.00	27.51	49 569	6.87	8.14	7.16	2.36	6.13
31.07.2020	27.22	6.02	4.4072	119.96	263.10	222.00	26.53	50 468	6.62	7.80	7.13	2.60	6.04
31.08.2020	29.53	11.24	4.3969	129.84	263.94	231.00	49.42	51 629	6.04	8.10	6.65	2.53	5.83
30.09.2020	27.50	12.35	4.5268	124.49	260.69	242.00	55.91	49 412	6.42	8.30	5.70	2.20	5.65
30.10.2020	24.19	14.22	4.6188	111.73	262.06	240.00	65.68	44 098	4.51	8.31	4.52	1.74	4.77
30.11.2020	29.60	15.14	4.4779	132.55	256.99	244.00	67.80	52 639	5.76	7.44	5.44	2.13	5.19
31.12.2020	32.94	19.12	4.6148	152.01	254.80	254.00	88.23	57 026	6.50	7.88	6.54	2.72	5.91
29.01.2021	33.18	20.91	4.5385	150.59	255.97	253.00	94.90	56 979	6.54	7.82	6.86	2.81	6.01
26.02.2021	37.60	15.69	4.5175	169.86	253.82	265.00	70.88	56 970	6.65	7.78	6.52	2.56	5.88
31.03.2021	42.89	18.99	4.6603	199.88	252.24	273.00	88.50	58 082	6.85	7.79	6.48	2.75	5.97
30.04.2021	49.31	23.29	4.5654	225.12	247.43	274.00	106.33	60 811	10.22	8.03	8.43	3.35	7.51
31.05.2021	52.24	25.12	4.4805	234.06	242.94	297.00	112.55	66 285	9.94	8.22	8.76	3.40	7.58
30.06.2021	56.78	34.62	4.5208	256.69	249.69	344.00	156.51	66 067	9.30	7.90	8.40	3.39	7.25
30.07.2021	53.69	40.76	4.5731	245.53	246.03	375.00	186.40	67 638	8.80	7.83	8.61	3.21	7.11
31.08.2021	61.07	49.68	4.5374	277.10	248.52	374.00	225.42	70 930	10.00	7.85	9.85	3.63	7.83
30.09.2021	62.16	97.78	4.6329	287.98	245.17	463.00	453.00	70 341	9.02	8.16	9.38	3.36	7.48
29.10.2021	59.08	64.86	4.6208	273.00	246.37	480.00	299.71	73 586	9.92	8.12	10.08	3.29	7.85
30.11.2021	75.73	93.15	4.6834	354.67	237.41	545.00	436.26	67 815	8.69	7.86	9.50	2.97	7.25
31.12.2021	80.65	87.03	4.5994	370.94	253.47	824.00	400.29	69 296	8.17	7.65	8.55	2.67	6.76

Source: (National Bank of Poland, 22.09.2022; Polish Power Exchange, 29.09.2022; ICE, 28.11.2022; INVESTING.com, 22.12.2022).

Table 6.
Independent variables excluded from the regression model *

Model	β	t	p
X1 - EUA return	-0.003[b]	-0.036	0.9715
X2 - Coal return (PSCMI 1)	-0.271[b]	-0.804	0.4245
X3 - Electricity return (DAM)	0.015[b]	0.199	0.8427
X4 - Gas return (TTF)	-0.031[b]	-0.786	0.4346
X5 - Exchange rate return	1.209[b]	1.858	0.0677

* Dependent variable: Y Portfolio return.

Source: (Own calculation using the Gretl program).

The results of the regression analysis with only one independent variable, X6 - WIG index return, and one dependent variable, Y Portfolio return, are presented in Table 7.

The measure of the fit of the regression line to the empirical data is the coefficient of determination - R^2. The calculated coefficient of determination R^2 is 0.388, which means that 38.8% of the change in the Y Portfolio return can be explained by the change of the independent variable, the X 6 WIG index return. The data in Table 5 show that the value of the significance of F parameter is lower than the adopted significance level $\alpha = 0.05$. It means that there are grounds for stating the existence of a linear relationship between the explained variable and the explanatory variable in the regression equation. The mean square (MS) is at an incredibly low level (0,005), which means that the average deviation of the actual values from the benchmarks is incredibly low. The standard error of estimate (0.153) is not high.

Table 7.
Regression analysis results

Portfolio of 4 companies				
	R Square	Adjusted R Square	Standard Error	Observations
Regression model	0.3968	0.3882	0.1537	72
Predictor (constant) - X6 - WIG index return				
Dependent variable - Y Portfolio return				
	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.0111	0.0082	-1.345	0.1830
X 6 WIG index return	1.0434	0.1537	6.787	<.001
ANOVA				
	df	MS	F	Significance F
Regression	1	0.2230	46.0600	<.001
Residual	70	0.0048		

Source: (Own calculation using the Gretl program).

After receiving the regression analysis results it should be checked whether all assumptions of the regression model are fulfilled. The assumptions of the regression model are as follows:

- existence of a linear relationship between the dependent variable Y and the independent variable X,
- existence of normal distribution of error terms,
- the non-existence of autocorrelation among error terms,
- the absence of heteroscedasticity which means that exists the homoscedasticity of the model (the variance of the error terms in the model is constant, i.e., the random component is homoscedastic).

The test for the existence of a linear relationship between X and Y uses the following hypotheses (A.D. Aczel, J. Sounderpandian, 2019, p. 629):

H_0: $\beta_0 = 0$,

H_1: $\beta_1 \neq 0$.

In order to check the existence of a linear relationship between X and Y, the Student's t-test is performed. The estimated β coefficient determining the direction and strength of the impact of the variable X6 (WIG index return) on the variable Y (Portfolio return) is positive and amounts to 1.0434 (Table 7). This means that an increase in WIG index return (X6) by 1% increases the return on the equity portfolio by 1.0434%. The linearity of the β coefficients is evidenced by p values which are much lower than the adopted significance level. Moreover, the critical value for the t-statistic with 71 (72-1) degrees of freedom and $\alpha = 0.05$ for the Student's t-distribution, 1.99 (read from the Student's t-distribution tables), is lower than 6.787 (Table 7). This proves that we cannot accept the hypothesis H_0: $\beta_0 = 0$.

The normal distribution of error terms is one of the main assumptions of a regression model. The Doornik-Hansen test for multivariate normality was performed to verify the normal distribution of error components. A histogram was also used for this.

The Doornik-Hansen test uses the following hypotheses for the normal distribution of error terms:

H_0: normal distribution of error terms exists,

H_1: normal distribution of error terms does not exist.

The outcomes of the Doornik-Hansen test for the null hypothesis of the normal distribution: Chi-square (2) = 3.987 with a p-value of 0.136 and the histogram (Figure 6) show that the H_0 hypothesis cannot be rejected.

The normality of the distribution of error terms can also be checked by other tests using the Gretl program, such as Shapiro-Wilk test, Lilliefors test, and Jarque-Bra test. The results of these tests are as follows:

- Shapiro-Wilk test = 0.972, with a p-value of 0.114,
- Lilliefors test = 0.089, with a p-value of 0.160,
- Jarque-Bra test = 4.299, with a p-value of 0.117.

All the results of the above tests show that hypothesis H0 cannot be rejected.

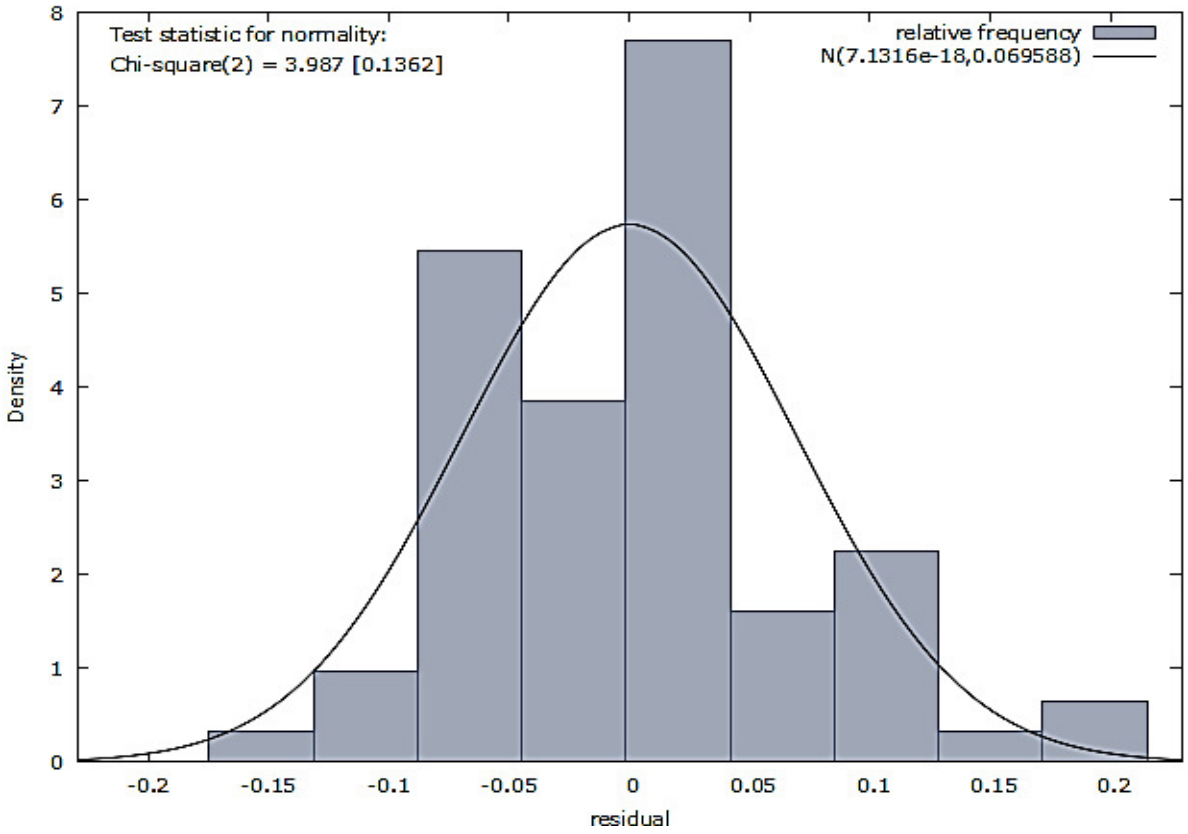

Figure 6. Histogram - test statistic for normality.

Source: (own calculations in the Gretl program based on data from Table 5).

The non-existence of autocorrelation among error terms is the next assumption of a regression model. If autocorrelation does exist, the outcomes of the model might be unreliable. Therefore, it's essential to check this assumption. Autocorrelation occurs when the error terms of a regression model are not independent of each other. In other words, if the value of error terms e_i depends on the value of error terms e_{i-1}. Autocorrelation leads to underestimation of the standard error of predictor variables. Autocorrelation or lagged autocorrelation can be measured for various lags, the most common being lag-1. However, there are also lag-2, lag-3, etc.

- Lag-1: Checks the correlation between $\boldsymbol{e_i}$ and $\boldsymbol{e_{i-1}}$.
- Lag-2: Checks the correlation between $\boldsymbol{e_i}$ and $\boldsymbol{e_{i-2}}$.
- Lag-3: Checks the correlation between $\boldsymbol{e_i}$ and $\boldsymbol{e_{i-3}}$.
- etc.

In order to check the autocorrelation, the Durbin-Watson test and the Breusch-Godfrey test were performed. The Durbin-Watson test checks the first-order autocorrelation (i.e., lag-1). It uses the following hypotheses:

- H_0: First-order autocorrelation does not exist. There is no correlation among the error terms.
- H_1: First-order autocorrelation exists. The error terms are autocorrelated.

The Durbin-Watson test result shows the test statistic DW = 1.99 and is higher than the upper critical value of 1.6457. Therefore, it can be concluded that there is no statistical evidence that the data are positively correlated.

The next test, the Breusch-Godfrey test, checks autocorrelation between first-order, second-order, and third-order, etc. error terms. First and twelfth-order autocorrelation was checked.

The Breusch-Godfrey test uses the same hypotheses as the Durbin-Watson test, namely:

- H_0: First-order and twelve-order autocorrelation does not exist. There is no correlation among error terms.
- H_1: First-order and twelve-order autocorrelation exist. Error terms are autocorrelated.

The coefficient in the Breusch-Godfrey test for Lag-1 is minus 0.024, and the p-value – is 0.8537 while the coefficient for Lag-12 is 0.150, and the p-value – is 0.2999. It can be concluded that there is no autocorrelation among the error terms.

In order to check the correctness of the next assumption of the regression model, i.e., the lack of heteroscedasticity (the variance of error terms in the model is constant), the Breusch-Pagan test and the White test were performed.

The Breusch-Pagan test checks whether error terms' variance depends on the independent variable's value.

The Breusch-Pagan test hypotheses:

- H_0: error terms are distributed with equal variance (there is homoscedasticity).
- H_1: error terms are distributed with equal variance (there is no homoscedasticity, there is heteroscedasticity).

The result of the Breusch-Pagan test for heteroscedasticity shows a test statistic LM -0.6736 and a p-value of 0.411 (not significant, i.e., >0.05). Therefore, the hypothesis H_0 that the error terms are distributed with equal variance cannot be rejected, the error terms are homoscedastic.

The other test, the White test, checks whether error terms' variance depends on the independent variable's value.

The White test uses the same hypotheses as the Breusch-Pagan test:

The White test hypotheses:

- H_0: error terms are distributed with equal variance (there is homoscedasticity).
- H_1: error terms are distributed with non-equal variance (there is no homoscedasticity, there is heteroscedasticity).

The result of the White test for heteroscedasticity shows a test statistic LM =0.6619 and a p-value of 0.718 (not significant, i.e., >0.05). Therefore, hypothesis H_0 that error terms are homoscedastic cannot be rejected.

Research hypothesis H2 assumed that the continuous increase in the prices of EU Allowances in the years 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four power companies. In order to analyze the validity of Hypothesis 2, a statistical analysis was performed using a linear regression

model. Based on the studied literature, it was assumed that, apart from the prices of EU Allowances, the return on the portfolio of shares of the examined four power groups was affected by other variables, i.e., X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return and X6 - WIG index return.

However, the regression analysis shows that only the value of the WIG index return had an impact on the value of the return on investment in the portfolio of shares of the four considered power groups. The change in the return on the WIG index in 38.82% (adjusted R^2) explains the changes in the return on the portfolio consisting of shares of the 4 power companies.

4. Summary

The prices of EU Emission Allowances are influenced by the European Emissions Trading System (EU ETS), whose primary task is to reduce greenhouse gas emissions.

This impact results from the reduction of the maximum amount of CO_2 that can be emitted in the European Union and from the decreasing number of free rights (allowances) transferred to individual enterprises in the European Union in particular accounting periods. In turn, prices of EU Allowances affect the economic results of power companies, and thus their value. Considering the EU's greenhouse gas emission reduction policy until 2050, a further increase in the prices of EU Allowances should be expected. The high level of the prices of EU Allowances is intended to encourage the liquidation of high-emission units for economic reasons.

The article analyzed the impact of the increased cost of EU Allowances on the financial situation of the surveyed companies. Additionally, using the regression analysis, the influence of independent variables was estimated, i.e.: X1 - EUA return, X2 - Coal return (PSCMI 1), X3 - Electricity return (DAM), X4 - Gas return (TTF), X5 - Exchange rate return, and X6 - WIG index return for the profitability of investment in the equity portfolio of the surveyed power groups.

The financial analysis of the combined financial results of the four energy groups and their operating segments shows that the increase in the prices of EU Allowances had a negative impact on the financial results of - Conventional Generation and Heat Generating operating segments in 2019-2020. These companies were unable to increase the prices of electricity sold to take into account the higher operating costs of these segments in 2019-2020, but it was already possible in 2016-2018 and 2021. In conclusion, hypothesis H1 stating that the continuous increase in the prices of EU Allowances in 2016-2021 had a significant, negative impact on the aggregated financial results of the surveyed four power companies cannot be rejected for 2019-2020 and can be rejected for 2016-2018 and 2021.

The second research hypothesis, H2, assumed that the continuous increase in the prices of EU allowances in 2016-2021 had a significant, negative impact on the return on investment in the portfolio of shares of the surveyed four energy companies was not confirmed using the linear regression model. It is not possible to determine the unambiguous impact of the EU Allowance price increase on the share prices of the analyzed companies due to the fact that the analyzed companies are vertically integrated energy groups consisting of many independent operating segments. In addition, the COVID pandemic broke out in 2020 and resulted in a negative GDP in 2020. In 2021, there was a sharp "upward recovery" of the Polish economy after the pandemic, which resulted in a significant increase in GDP in 2021.

To sum up, the lack of action on the part of the state and the surveyed companies, at least in the last dozen or so years, to change the Polish energy mix and the energy mix of the surveyed companies increases the costs of transforming the Polish energy sector towards low-emission energy sources. These costs, in connection with the increase in electricity prices, are and will be borne by the Polish society, shareholders of the surveyed companies and Polish enterprises, which will result in a deterioration of their international competitiveness due to higher electricity costs.

References

1. Aczel, A.D., Sounderpandian, J. (2019). *Startysyka w Zarządzaniu*. Warszawa: PWN.
2. Bankier.pl. Retrieved from: http://www.bankier.pl, 31.07.2022.
3. Bataller, M., Tornero, Á. P., Valor, Micó, E. (2006). *CO_2 Prices, Energy and Weather*. Retrieved from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=913964, 4.03.2021.
4. Benz, E., Trück, S. (2009). Modeling the Price Dynamics of CO_2 Emission Allowances. *Energy Economics*, *Vol. 31, No. 1,* pp. 4-15.
5. Branger, F., Quirion, P., Chevallier, J. (2013). *Carbon leakage and competitiveness of cement and steel industries under the EU ETS: much ado about nothing*. hal-00945187.
6. Chevallier, J. (2010). *The European carbon market (2005-2007): banking, pricing and risk-hedging strategies.* halshs-00458787.
7. Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015. Official Journal of the European Union L 76, 19 March 2018, pp. 3-27 (2018).
8. Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. Official Journal of the European Union, L 275, 25 October 2003, pp. 631-646 (1996).

9. Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community. Official Journal of the European Union L. 140, 5 June 2009, pp. 63-87 (2003).
10. Dziennik Gazeta Prawna. *Powołano Narodową Agencję Bezpieczeństwa Energetycznego. Sasin podpisał umowę*. Retrieved from: http: https://serwisy.gazetaprawna.pl/energetyka/artykuly/8616678,narodowa-agencja-bezpieczenstwa-energetycznego-umowa-sasin.html, 22.12.2022.
11. European Commission (2015). *EU ETS Handbook.* European Union.
12. European Commission. *Etapy 1 i 2 (2005-2012*). Retrieved from: https://ec.europa.eu/clima/policies/ets/pre2013_pl, 30.09.2022.
13. European Commission. *Pułapy i przydziały uprawnień do emisji*. Retrieved from: https://ec.europa.eu/clima/policies/ets/cap_pl, 31.10.2022.
14. Financial statements of the surveyed companies (Energa S.A., Enea S.A., TAURON Polska Energia S.A, PGE Polska Grupa Energetyczna S.A) for 2017-2022.
15. FORSAL.PL. *UE zmniejsza emisję gazów cieplarnianych o co najmniej 55 proc. do 2030 roku.* Retrieved from: https://forsal.pl/swiat/unia-europejska/artykuly/8040626,ue-zmniejsza-emisje-gazow-cieplarnianych-o-co-najmniej-55-proc-do-2030-roku.html, 11.12.2021.
16. Garcia, A., Garcia-Alvarez, T.M., Moreno, B. (2021). The impact of EU Allowance Prices on the stock of the European Union Power Industries: Evidence From the Ongoing EU ETS Phase III. *Organization & Environment*, *Vol. 34(3),* pp. 459-478.
17. Główny Urząd Staytystyczny. https://stat.gov.pl, 21.12.2022.
18. INVESTING.com. Retrieved from: https://www.investing.com/, 22.12.2022.
19. Kirat, D., Ahamada, I. (2011). The impact of the European Union emission trading scheme on the electricity-generation sector. *Energy Economics*, *33(5),* pp. 995-1003.
20. Krajowy Ośrodek Bilansowania i Zarządzania Emisjami (KOBiZE) (2019). *Raport z rynku CO_2, Nr 93, grudzień 2019*. Retrieved from: https://www.kobize.pl/uploads/materialy/materialy_do_pobrania/raport_co2/2019/KOBiZE_Analiza_rynku_CO2_grudzien_2019.pdf, 12.01.2022.
21. Moore, Ch. (2022). *European Electricity Review*. EMBER. Retrieved from: https://ember-climate.org/insights/research/european-electricity-review-2022/#supporting-material-downloads, 23.05.2022.
22. Moreno, B., Pereira da Silva (2016). How do Spanish polluting sectors' stock market returns react to European Union allowances prices? A panel data approach. *Energy*, *103,* pp. 240-250.
23. National Bank of Poland (2022). Retrieved from: http://www.nbp.pl, 22.09.2022.
24. Oberndorfer, U. (2009). EU emission allowances and the stock market: evidence from the electricity industry. *Ecological Economics*, *68*, pp. 1116-1126.

25. Polish Power Exchange (2022). Retrieved from: http://gpi.tge.plhttp://gpi.tge.pl, 29.09.2022.
26. Rabe, M., Streimikiene, D., Bilan, Y. (2019). EU Carbon Emissions Market Development and Its Impact on Penetration of Renewables in the Power Sector. *Energies*, *12*, 2961, doi: 10.3390/en12152961.
27. Rabe, M., Streimikiene, D., Bilan, Y. (2020). Model of Optimization of Wind Energy Production in the Light of Legal Changes in Poland. *Energies*, *13*, 1557, doi:10.3390/en13071557.
28. Reinaud, J. (2007). *CO_2 Allowance and Electricity Price Interaction. Impact on Industry's Electricity Purchasing Strategies in Europe.* International Energy Agency.
29. Rickels, W., Görlich, D., Oberst, G. (2010). Explaining European Emission Allowance Price Dynamics: Evidence from Phase II. *Kiel Working Paper, No. 1650.* Kiel Institute for the World Economy.
30. Schumacher, K., Diekmann, J., Sleich, J. et al. (2012). Price Determinants of the European Carbon Market and Interactions with Energy Markets, Umweltbundesamt. *Climat Change*, *11*, pp. 1-43.
31. Sijm, J, Neuhoff, K., Chen,Y. (2006). CO_2 Cost Pass-Through and Windfall Profits in the Power Sector.*CWPE 0639 and EPRG 0617*.
32. The Intercontinental Exchange (ICE) (2022). Retrieved from: https://www.theice.com/data-services/resources, 28.11.2022.
33. Tian, Y., Akimov, A., Roca, E., Wong, V. (2016). Does the carbon market help or hurt the stock price of electricity companies? Further evidence from the European context. *Journal of Cleaner Production*, *112*, pp. 1619-1626.
34. Ustawa z dnia 29 września 1994 r. o rachunkowości. Dz.U. 1994, Nr 121, poz. 591.
35. Veith, S., Werner, J.R., Zimmermann, J. (2009). Capital market response to emission rights returns: evidence from the European power sector. *Energy Economics*, *31*, pp. 605-613.
36. Velzen, A., Bruyn, S., Bachaus, A. (2019). *Costs of EU ETS and CORSIA for European aviation.* Report prepared by TAKS and CE Delft for Transport and Environment (T&E). Report nr: 19-12. Retrieved from: https://www.transportenvironment.org/sites/te/files/publications/2019_11_Original_report_Costs_EU_ETS_CORSIA_European_aviation_final_report.pdf, 22.03.2021.

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THE ACTIVITY OF BUSINESS ENVIRONMENT INSTITUTIONS IN TERMS OF SUPPORTING THE INNOVATIVENESS

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Purpose: The purpose of this article is to characterize the activity and establish the potential of business environment institutions (BEIs) in terms of supporting the innovativeness of enterprises in Poland. The business environment institutions are a group of entities offering consultancy, training, information and financial aid to businesses, particularly small and medium-sized enterprises (SMEs). This aid is necessary for the implementation of innovative processes and the development of enterprises.
Design/methodology/approach: This paper utilizes subject literature studies, statistical data analysis, results of own research and observation of the economic practice.
Findings: Based on the results of primary and secondary research, one can claim that cooperation between enterprises and business environment institutions leads to increased innovativeness of the former. The shrinking number of business environment institutions, reduction of their activity and clustering in more developed regions and cities, all of which have been happening in recent years, pose a great threat to the support small and medium-sized enterprises are able to receive for the implementation of innovative processes.
Research limitations/implications: It would be worthwhile to learn the up-to-date opinions of entrepreneurs concerning pro-innovation support provided by business environment institutions.
Practical implications: There is a need for wider cooperation between entrepreneurs, local authorities and business environment institutions for sake of building appropriate ecosystems to support the innovativeness of enterprises. The business environment institutions are a key part of such ecosystems, yet their presence in the implementation of innovative processes within small and medium-sized enterprises is insufficient.
Originality/value: Study expands the knowledge about activities supporting the innovativeness of enterprises being carried out in Poland by business environment institutions.

Keywords: business environment institutions, innovativeness, small and medium-sized enterprises

Category of the paper: Research paper.

1. Introduction

For many years, Poland has been ranking low in global and European rankings of innovativeness. In the Global Innovation Index (GII), Poland had placed 38th out of 132 countries (Global Innovation Index, 2022), while the European Innovation Index (EIS) rated it as an emerging innovator, at the fourth last position among the EU member states (European Commission, 2021). Thus, one of the key tasks of Poland's economy is increasing the innovativeness of enterprises. The innovativeness of the country is a result, among others, of innovativeness of enterprises. Currently, according to the new version of the Oslo Manual (2018), an innovation is a new or improved product or process (or their combination), which differs significantly from previous products or processes of the company and which has been made available to potential users (product) or implemented into operations (process).

These innovations are oftentimes the results of companies working with various external partners (Bell, 2005), including other businesses, R&D centers or innovation centers committed to the implementation of innovative processes. The cooperation and help of specialized agencies are particularly necessary for small and medium-sized enterprises (SMEs), which lack sufficient human, non-material and financial resources to implement innovations on their own. The results of author's primary research also indicate the existence and correlation between the closeness of partnership between small and medium-sized enterprises and business environment institutions and their innovativeness and development levels (Kamińska, 2011, 2017).

The goal of this paper is to characterize the operations and establish the potential of business environment institutions (BEIs) within the scope of supporting the innovativeness of enterprises in Poland. For purposes of these deliberations, we have adopted the following definition of the business environment: the term BEI encompasses entities offering consultancy, training, information and financial aid to businesses, particularly small and medium-sized enterprises (SMEs), concerning the implementation of innovations and modern technologies.

2. The essence and categorization of business environment institutions

The definition of business environment institutions is somewhat fluid and very broad. The term itself has different names, e.g. institutions supporting entrepreneurs, business support institutions, business backup institutions, business environment institutions (Matusiak, 2010; Dorożyński, 2013). The term business environment institution encompasses entrepreneurship and innovation centers (technology parks, technology incubators, business incubators, technology transfer centers, innovation centers, training and advisory centers) as well as

financial institutions, including loan and credit guarantee funds. The business environment institutions include non-commercial entities - so-called non-profit institutions, which are not motivated by profits or which commit their income towards statutory goals (Burdecka, 2004) and commercial subjects created in the first decade of the 21st century (seed and venture capital funds financed by the EU).

A shared trait of these entities is the functions for which they have been created. It consists of providing various services, primarily for micro, small and medium-sized enterprises, including advisory, training and informational services, as well as providing the technical infrastructure necessary for carrying out economic activities and financing said economic activities (Bąkowski et al., 2021; PARP, 2019). These institutions aim to remove barriers and obstacles hindering the cooperation between businesses, the scientific community and administrative authorities, supporting innovativeness and growth of businesses. The support in implementation of innovations involves offering ideas, providing contacts and helping coordinate, taking into account the known needs of a given environment. BEIs have the necessary material, technical and human resources, as well as competencies to provide services to the SME sector.

Subject literature categorizes the business environment into three subgroups: innovation centers, entrepreneurship centers and non-bank financial institutions (Bąkowski et al., 2021). Aside from terms such as "innovation centers" and "innovation support institutions", other names are also utilized, such as "business environment institutions", "pro-innovation structures", etc. The innovation centers also include technology and scientific parks, technology incubators, academic business incubators and e-incubators.

Aside from the innovation centers, supporting the development of innovative enterprises, we also distinguish entrepreneurship centers (including advisory and training centers, entrepreneurship centers, business centers, pre-incubators, business incubators) supporting the establishment of and development of companies, as well as non-bank financial institutions (regional and local loan funds, credit guarantee funds, seed investment funds and angel investor networks) providing financial help. The above-mentioned groups of entities are collectively called innovation and business centers.

In practice, the list of institutions impacting the innovativeness of enterprises is much longer. One should also take note of chambers of trade and commerce, chambers of commerce, trade and industry associations, organizations offering commercial training and advisory services, numerous entities created by local authorities and, last but certainly not least, the banks, which help entrepreneurs obtain funds necessary for implementing innovations.

3. Characteristics of activity of business environment institutions in terms of supporting the innovativeness of enterprises in Poland

As of writing, there are 280 non-commercial entities implementing tasks characteristic for BEIs, 164 of which are innovation centers and 116 are business centers (Bąkowski et al., 2021). Among the business environment institutions, the innovation centers have a key role in integrating and increasing the dynamism of the regional innovative environments by creating cooperation networks and clusters. They provide professional expertise, shape competencies and answer key questions troubling entrepreneurs concerning new developments and appropriate means and timing of placing them on the market. They also initiate supra-regional cooperation between entrepreneurs and assist in obtaining scarce resources. One of the key activity types of innovation centers - aside from advising, training and instructing - is supporting transfers of modern technologies from the scientific to business worlds and their commercialization.

Technology parks are of particular significance among the innovation centers, as they create an innovation-fostering environment collecting R&D institutions, innovative enterprises and other institutions supporting innovation (primarily through financing and training) in a single place (Matusiak, 2011). Technology parks create conditions conducive to establishing and growing innovative enterprises, offer the most advanced and comprehensive help (as compared to other support centers) and facilitate easier cooperation between business and scientific communities. The parks allow entrepreneurs to utilize the research resources of a university, while the scientific institutions gain easier access to businesses interested in the development of their scientific achievements. The geographical closeness of entities cooperating within the parks facilitates the exchange of knowledge, helps lower costs and benefit from the synergy effect, ultimately supporting the creation of an innovative environment. Research confirms the positive effect technology parks have on the innovativeness of enterprises operating within their territory (Leyden et. al., 2008).

The local authorities are involved in the creation and operation of such parks, especially in the earliest stages of their functioning, when the support is of particular importance. There are 43 science and technology parks in Poland (PARP, 2021) and the majority of them has been created after 2007, thanks to EU funding.

Other entities offering support to newly established innovative enterprises in their first, hardest years of operation are technology incubators and academic business incubators. Technology incubators are usually created within the territory of a technology park and their offer is targeted primarily at small and medium-sized enterprises, encompassing a wide scope of advisory services in the spheres of management, marketing, law, implementation of new technologies and utilizing labs and the entire infrastructure. The space is leased on preferential terms and the ease of contact with the research and development sphere and other businesses

active within the incubator is a major draw. These unique conditions allow the owners and employees of businesses to gain competencies quicker, have an easier business launch and develop the company with greater ease, resulting in the creation of new workplaces in the region, the development of new economic structures and cooperation networks, promotion of entrepreneurship and entrepreneurial behavior. All of the above will have a positive impact on the socioeconomic development of the region and the country at large.

Research into innovation centers in Poland also distinguishes pre-incubators and academic business incubators. The idea behind these is similar to that of technology incubators, but they are focused on the academic community and supporting students, graduates and research workers at the seed stage of establishing an enterprise (pre-incubation) or in its first period of operation (usually approx. 3 years). The academic incubators allow for wider use of research and scientific resources of a university with the purpose of commercializing the findings and increasing the innovativeness of enterprises.

Aside from academic business incubators (ABI) and technology incubators, the subject literature also identifies business incubators (BI), whose activity isn't strictly focused on supporting innovation, but rather helping establish a company and reach self-sustainability within 3-5 years. A business incubator centers are an effective method of stimulating economic growth end have a positive effect on social, technical, and financial indicators (Olkiewicz et al., 2019).

The development of information and communication technologies (ICT) supports the creation of e-incubators, which assist businesses (including the ICT sector) through new technologies rather than material means, helping obtain knowledge, new technologies and capital. There are 64 technology and business incubators in Poland (including academic incubators), located primarily in southwestern Poland (PARP, 2021).

Aside from the academic business incubators, another structural element of an enterprising university is the technology transfer centers (TTCs) appointed by universities and academies of the Polish Academy of Sciences. The goal of their activities is selling, or providing free of charge, the results of research and development work (Higher Education Act, 2018) to the economy, with the ultimate objective being the adaptation of modern technologies to the needs of businesses, increasing innovativeness and competitiveness of both businesses and regional economic structures. The origins of technology transfer centers reach as far back as the 60s of the 20th century, when the first technology transfer departments have been created in American and British universities to help commercialize their scientific achievements. The first technology transfer center in Poland had been created in 1995 at the Wrocław University of Science and Technology and, as of writing, 82 technology transfer centers (Porozumienie, 2022) are operating at varying activity levels. Some of them actively participate in their region's life, cooperating with small and medium-sized enterprises, advising them and assisting in acquiring knowledge and implementing new technologies.

Nowadays, in compliance with the legal definition (Ustawa Prawo o szkolnictwie wyższym i nauce, 2018), the term TTC has been narrowed to centers affiliated with scientific institutions. The innovation centers, on the other hand, are providing a wide assortment of informational and advisory services focused on bringing business and science closer together and gathering partners to establish contact networks necessary for the implementation of innovative processes. From among the 25 innovation centers, the majority are located in Masovia, Silesia and Greater Poland voivodships (Bąkowski et al., 2021).

Intensification of innovative activities is made possible by creating a network of interrelations between entities. A network is understood here as long-term cooperative relations between equal partners, who trust and understand each other (Koschatzky, 2001). Innovation networks group together entities bringing their knowledge, competencies, material and financial resources (including research equipment) to effectively and efficiently implement innovations. Thanks to the cooperation within the network, each entity gains economic benefits, lowering the prices of purchasing resources, services, technologies and carrying out processes, learning from each other, utilizing shared knowledge, information and databases. An incredibly important matter is shortening the processes of innovation and implementation. Thanks to the synergy effect, network organizations are able to offer their clients a comprehensive, innovative offer and professional service at an oftentimes more attractive price. All these elements contribute to obtaining a competitive advantage and easier adaptation of cooperating entities to the needs of the market.

Numerous authors prove, based on empirical research, that cooperation within the networks results in increased innovativeness of enterprises (Powell, Grodal, 2006).

Examples of such special, innovative networks include the above-mentioned technology parks and clusters, which we will describe shortly. Clusters, also known in the subject literature as local production systems, industrial complexes or groupings, are geographical concentrations of interrelated businesses, specialized suppliers, service providers, companies from related sectors and business environment institutions, both competing and cooperating with each other (Porter, 1990).

The structure of clusters varies greatly and encompasses both enterprises specialized in a given industry and those from related sectors, supporting the effectiveness of the cluster's key members, research and scientific institutions, incubators, financing institutions, economic associations, etc. The geographical closeness of the above-mentioned entities supports their cooperation, frequent contacts and positive relations, while the need to compete stimulates innovation and development processes. The competition between discrete entities distinguishes clusters from networks, in which cooperation is dominant.

Belonging to a cluster offers a wide selection of advantages - enterprises have an easier time accessing knowledge and technologies, specialized services, unique resources, purchasing resources at lowered prices and acquiring funding. This results in increased effectiveness of

operations, increased competitiveness and faster growth. Enterprises associated in clusters tend to be more innovative and effective (Martin, Sunley, 2014).

The clusters are oftentimes considered to be stimulating growth, attracting domestic and foreign investors, supporting the creation of new companies and lowering unemployment. The geographical scope of clusters can vary greatly, ranging from a city, a region, or several regions to even a global scope.

Appreciating the role of clusters in stimulating innovation, it bears taking note of the possible occurrence of negative effects of cluster's operation. These might include cartel collusion to inflate prices, investment difficulties for enterprises from industries outside the cluster's main focus, creating unemployment in the event of cluster's closure.

Innovative activities are usually quite expensive and require access to financial centers. Loan and credit guarantee funds extend the ability to finance innovative projects, primarily those of micro, small and medium-sized enterprises. Loan funds provide access to loans for newly established, developing economic subjects, by utilizing simplified creditworthiness appraisal and loan granting methods. Over the past 22 years, the number of loan funds has increased from 36 in 1999 to 64 in 2021. Their scope of operations is usually that of a single voivodship (Bąkowski et al., 2021).

Local authorities have also created credit guarantee funds, whose activity is focused on providing credit guarantees to enterprises applying for bank credit or loans yet lacking the required credit history or guarantees. According to the National Association of Credit Guarantees (Krajowe Stowarzyszenie Funduszy Poręczeniowych), there are currently 33 credit guarantee funds. By the end of 2021, they had a collective capital of PLN 782 mln. Over 2021, the funds have granted 13,894 guarantees with a combined worth of PLN 1.63 bln, indicating an 11% increase as compared to the year before (Gajewski et al., 2022).

So-called angel investors, or business angels, are also involved in financing innovations. They invest in risky projects in their earliest stages. Seed capital funds, owned by venture capital companies, can provide larger funds than angel investors in exchange for shares in the company. They focus on funding innovative enterprises at seed and start-up stages.

The largest group among the business environment institutions is comprised of training and advisory centers (including Entrepreneurship Support Centers, Business Support Centers and Consultancy and Advisory Centers), offering a wide selection of services adapted to the needs of the local community and the current economic situation. Advisory and training services concerning the establishment of a company, preparing a business plan, obtaining EU funds and implementing innovations are among the most popular. Following years of successive growth, the number of advisory and training centers decreased to 103 in 2021 (Bąkowski et al., 2021).

4. The potential of business environment institutions supporting the innovativeness of enterprises in Poland

Since the 90s of 20th century, the number of various innovation and entrepreneurship centers has steadily increased in Poland, largely due to their operations being supported by regional and national programs financed by the European Union. 2014 proved a breakthrough year, as the number of these institutions began decreasing. This was largely due to closings of training and advisory centers and the fact that the research only took active centers into account. In the following years, the number of business environment institutions has been steadily decreasing. In 2021, the total number of active BEIs has decreased by 162 as compared to the previous year. At the same time, one can notice a large disproportion in BEI spread across voivodships. Most of them are located in voivodship with a high economic potential (Silesia, Lesser Poland, Masovia), primarily in the provincial capitals.

Since some of the entities carry out varied activities, simultaneously fulfilling the roles of BI and TTC, it bears extending the analysis by a number of components (activity types) implemented by these entities, as presented in Table 1.

Table 1.
Number of support components implemented by BEI in Poland in the 1995-2021 period

Listing	1995	1997	1999	2000	2004	2007	2009	2010	2012	2014	2017	2021
Technology parks	1	1	3	3	12	15	23	24	40	42	37	34
Park initiatives							23	21	14	0	0	0
Technology incubators	4	5	49	44	53	16	17	20	29	24	23	16
Business incubators	29	49				46	46	45	58	46	37	41
Academic business incubators	*	*	*	*	*	49	51	62	73	24	20	16
Technology transfer centers	1	5	23	20	39	87	87	90	69	42	55	52
Innovation centers	*	*	*	*	*	*	*	*	*	47	39	25
Loan funds		48	51	33	76	84	82	82	86	81	58	64
Credit guarantee funds				24	57	64	54	54	55	58	52	31
Training and consulting centers		153	147	142	280	326	318	317	319	207	151	103
Total	174	261	273	266	507	688	695	715	743	571	472	382

* The category was not analyzed during the given year.

Source: Compiled by the author based on: Bąkowski et al., 2021; Bąkowski, Mażewska, 2015.

In the 1995-2012 period, business environment institutions have greatly developed their operations in Poland and the number of implemented components has increased. Since 2014, we have seen a steady decrease in the number of implemented components, related to shrinking funding of the institutions promoting entrepreneurship and the overall socioeconomic situation in Poland and the world at large. It also bears mentioning that the entrepreneurs who utilize these services in order to obtain current, professional knowledge from the sphere of management are continually increasing their expectations towards these service providers. Some of the business environment institutions have proven rather inflexible and failed to adjust their offers to the needs of the market - ultimately leading to their downfall. The analysis of previously quoted documents also indicates a lack of systemic action - the goals of these centers remain undefined, no monitoring of their effectiveness is being conducted and there is a lack of a coherent strategy defining a precise role for the business environment institutions in national and regional pro-innovation policies.

The shrinking number of business environment institutions and reducing their activities (expressed as a decreasing number of implemented support components) poses a threat to the innovation activities of small and medium-sized enterprises, which are unable to implement innovations on their own. Another negative factor is the uneven distribution of BEIs across Poland, resulting in reduced access to support for enterprises operating in less developed voivodships.

5. Summary and conclusions

The innovativeness of enterprises is determined by the operations and activities of the numerous innovation centers, including technology parks, innovation centers, technology transfer centers, academic business incubators, as well as loan funds, credit guarantee funds and other organizations whose goal is broadly defined support of innovation. The above-mentioned subjects help entrepreneurs receive support in obtaining knowledge, technologies and scarce resources necessary to implement innovative projects.

Subject literature studies and an analysis of research results lead us to claim that the innovativeness of enterprises depends on the potential and capacity for innovation of the external entities, mutual relations and cooperation between particular actors of the regional innovation scene. The innovativeness of enterprises is bolstered by good cooperation with local authorities and the scientific community, as well as the above-mentioned business environment entities. They all constitute a prerequisite to obtaining and creating new knowledge, skills and technologies. Cooperation between enterprises and external entities allows receiving the synergy effect, increasing the competitive position, effectiveness and efficiency of operations.

The shrinking number of business environment institutions in Poland, their limited activity and concentration in highly developed cities and regions pose a significant threat to effectively supporting small and medium-sized enterprises in implementing innovative processes. Analysis of the potential of business environment institutions over the years 1995-2021 has indicated a successive reduction in the number of these entities since 2014. The number of types of services they offer to enterprises has also decreased. Activity of training and advisory centers related to involvement in innovative projects carried out by enterprises has been considerably reduced. At the same time, it should be noted that business environment institutions are located mainly in large urban centres, which is also an unfavorable phenomenon.

Meanwhile, the dynamics of changes taking place in the environment implies the need for constant supplementing of knowledge, gathering current information, as well as obtaining new resources by entrepreneurs.

It would be beneficial to establish a consistent strategy for the development of business environment institutions, systematizing the action needed for supporting enterprises in implementing innovative processes.

References

1. Bąkowski, A., Mażewska, M. (Eds.) (2015). *Ośrodki innowacji i przedsiębiorczości w Polsce. Raport 2014.* Poznań-Warszawa: SOOIiP. Retrieved from: https://www.sooipp.org.pl/osrodki-innowacji-i-przedsiebiorczosci-w-polsce-raport-2014, 25.09.2022.
2. Bąkowski, A., Mażewska, M., Rudawska, J. (Eds.) (2021). *Ośrodki innowacji w Polsce. Raport z badania 2021*. Poznań: SOOIiP. Retrieved from: https://www.sooipp.org.pl/ osrodki-innowacji-i-przedsiebiorczosci-w-polsce-raport-z-badania-2021, 15.09.2022.
3. Bell, G.G. (2005). Clusters, Networks, and Firm Innovativeness. *Strategic Management Journal, Vol. 26, Iss. 3,* pp. 287-295.
4. Burdecka, W. (2004). *Instytucje otoczenia biznesu.* Warszawa: PARP. Retrived from: https://www.een.org.pl/storage/publications/pdf/instytucje%20otoczenia%20biznesu.pdf, 15.09.2022.
5. Dorożyński, T. (2013), Instytucje otoczenia biznesu a rozwój przedsiębiorstw – ujęcie regionalne. *Zarządzanie i Finanse, No. 1*, pp. 135-150.
6. European Commission (2022). *European Innovation Scoreboard.* Retrieved from: https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/european-innovation-scoreboard-2022_en., 25.09.2022.
7. Gajewski, M., Kubajek, R., Szczucki, J. (2022). Rynek lokalnych i regionalnych funduszy poręczeniowych w Polsce w 2021 r. Warszawa: KSFP.

8. *Global Innovation Index 2022*. Genewa: WIPO. Retrieved from: https://www.wipo.int/global_innovation_index/en/2022/, 5.09.2022.
9. Kamińska, A. (2011). Wpływ instytucji otoczenia biznesu na rozwój małych i średnich przedsiębiorstw w regionie lubelskim. *Barometr Regionalny*, *Vol. 1, Iss. 23,* pp. 53-65.
10. Kamińska, A. (2017). *Uwarunkowania regionalne innowacyjności przedsiębiorstw w Polsce.* Warszawa: CeDeWu.
11. Koschatzky, K., Kulicke, M., Zenker, A. (Eds.) (2001). *Innovation Networks: Concepts and Challenges in the European Perspective.* New York: Physica-Verlag Heildeberg.
12. Leyden, D.P., Link A.N., Siegel D.S. (2008). A Theoretical and Empirical Analysis of the Decision to Locate on a University Research Park. *Engineering Management Journal, Vol. 55, Iss. 1*, pp. 23-28.
13. Martin, R., Sunley, P. (2003). Deconstructing Clusters: Chaotic Concept or Policy Panacea? *Journal of Economic Geography*, *Vol. 3, Iss. 1*, pp. 5-35.
14. Matusiak, K.B. (2010). Uwarunkowania rozwoju infrastruktury wsparcia w Polsce. In: K.B. Matusiak (Ed.), *Ośrodki innowacji i przedsiębiorczości w Polsce* (pp. 335-337). Warszawa: PARP.
15. Matusiak, K.B. (2011). *Innowacje i transfer techniki. Słownik pojęć*. Warszawa: PARP.
16. OECD (2018). European Union, The Measurement of Scientific, Technological and Innovation Activities Oslo Manual 2018 Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition.
17. Olkiewicz, M., Wolniak, R., Eva-Grebski, M., Olkiewicz, A. (2019). Comparative Analysis of the Impact of the Business Incubator Center on the Economic Sustainable Development of Regions in USA and Poland *Sustainability*, *Vol. 11, Iss. 1*, 173. Retrieved from: http://dx.doi.org/10.3390/su11010173.
18. PARP (2019). *Analiza potencjału ośrodków innowacji i ich wpływu na realizację założeń (koncepcji) inteligentnych specjalizacji w Polsce. Raport końcowy*. Retrieved from: https://www.parp.gov.pl/component/publications/publication/analiza-potencjalu-osrodkow-innowacji-i-ich-wplywu-na-realizacje-zalozen-koncepcji-inteligentnych-specjalizacji-w-polsce, 15.09.2022.
19. PARP (2021). *Gotowość Ośrodków Innowacji do wspierania inteligentnej specjalizacji gospodarki.* Retrieved from: https://www.parp.gov.pl/component/publications/publication/gotowosc-osrodkow-innowacji-do-wspierania-inteligentnej-specjalizacji-gospodarki, 10.09.2022.
20. *Porozumienie Akademickich Centrów Transferu Technologii (PACTT)*. Retrieved from: http://pactt.pl/cz%C5%82onkowie-pactt, 25.09.2022.
21. Porter, M.E. (1990). *The Competitive Advantage of Nations*. New York: The Free Press.

22. Powell, W.W., Grodal, S. (2006). Networks of Innovators. In: J. Fagerberg, D.C. Mowery, R.R. Nelson (eds.), *The Oxford Handbook of Innovation* (pp. 56-85). Oxford: Oxford University Press.
23. Ustawa z dnia 20 lipca 2018 r. Prawo o szkolnictwie wyższym i nauce, Dz.U. 2022, poz. 574.

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TECHNOLOGICAL CONDITIONS FOR LOGISTICS 4.0 DEVELOPMENT

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Purpose: The publication presents the results of an analysis of the popularity of technologies used in logistics based on published technical literature. The aim of the work was to determine the participation of individual types of technologies in the development of Logistics 4.0. In the Industry 4.0 policy implemented in highly developed countries, logistics development is referred to as "Logistics 4.0".
Methodology: The work is based on the analysis of empirical data describing the topics of the application of the latest information technology and other technologies related to the fourth industrial revolution. The scope of the analysis covers technologies developed between 2014-2022.
Findings: Based on the investigation, the major technological subfields of Big Data, Cloud computing and networking, Business Intelligence and other, Internet of Things, and Hardware have been proposed as the core utility categories of technologies in Logistics 4.0.
Originality/value: The analysis can be useful for practical aims, e.g., while planning logistics 4.0 trainings, enterprising technical investments, but also for scientific and educational objectives.

Keywords: Industry 4.0, Logistics 4.0, IoT, Big Data, Cloud computing, ICT.

Category of the paper: Case study, literature review.

1. Introduction

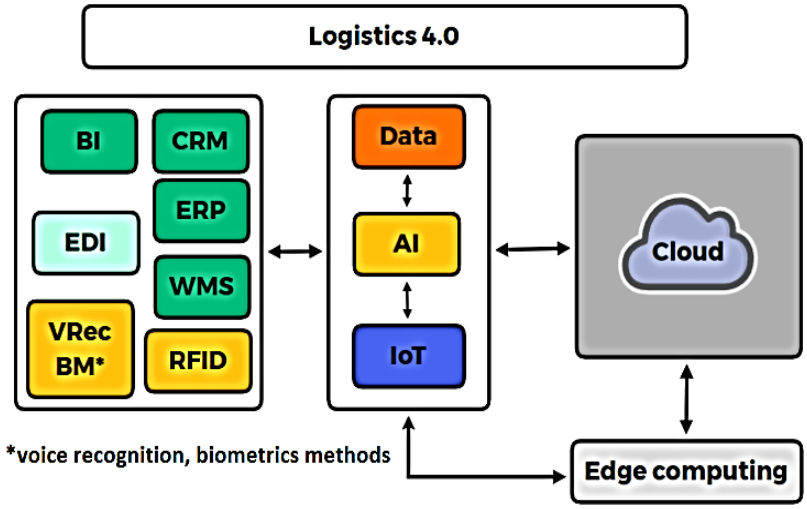
Contemporary logistics is a highly intricate process. The one cause of that, among others, is the large number of commodity streams (raw materials, parts, semi-finished goods, and final products) and information streams that cross and complement one another. In order to optimal driving of products and information flow, enterprises implement the Fourth Industrial Revolution's strategy to improve the process. The new Industry 4.0 technologies complement existing information and communication technologies (ICT) used to support supply chain management (SCM) procedures. The concept of Industry 4.0 was born in Germany in 2011 as

a proposal to Germany's economic in accordance with strategy: "High-Tech Strategy 2020 Action Plan" (Kagermann et al., 2013; Martin, 2015; Mosconi, 2015). The concept of Industry 4.0 is based on key technologies of the Fourth Industrial Revolution that are developing automation of activities, based on artificial intelligence (AI) algorithms, including machine learning (ML), have access to the Internet of Things (IoT) that allows machines to communicate with each other (M2M) (Hermann et al., 2016; Cooper, James, 2009). The Smart Factory fits Industry 4.0 perfectly. The concept of Smart Factory refers to an environment integrated by computers and information technology where reality is supported by virtual computer models. Smart Factory is also a place where data will be obtained, collected, and processed for use, e.g., at the stage of creating production plans, supply plans, types of distribution, etc. (Caggiano et al., 2015). Smart factories for internal and external logistics use machine-to-machine connectivity technology, such as the Industrial Internet of Things (IIoT). Some of the data coming from the sensors of these machines, or generated by users, is processed in real time using edge computing architecture, and huge data sets (Big Data) are stored and processed in cloud computing. Logistics, as well as manufacturing, uses artificial intelligence. Intelligent robots, cobots, autonomous vehicles perform many warehouse operations and activities to customize products (according to order specifications), such as cutting products, painting, picking, etc. The technologies mentioned in this publication, namely AI, Big Data, and IoT, are regarded as critical in Logistics 4.0. The term Logistics 4.0 refers to the application of Fourth Industrial Revolution technologies to internal and external logistics processes (Szymonik, Chudzik, 2020). Industry 4.0 technologies are expanding beyond enterprises (manufacturers), increasingly illustrating the level of competitiveness of the entire supply chain, which is known as the Smart Supply Chain when it is outfitted with contemporary technologies like AI, Big Data, IoT, and others (Dembińska et al., 2018).

The ability to effectively use information and telecommunications technologies and integrate them with the technical environment of the organization in the supply chain is currently one of the key factors in the development of logistics. The Fourth Industrial Revolution's technologies enable supply chains' essential logistics processes and functions to work closely together and be fully integrated. As a result, more and more businesses are making efforts to put Logistics 4.0 into practice.

This article presents the key technologies of Logistics 4.0 (AI, Big Data, IoT, Cloud Computing), along with Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), and Warehouse Management System (WMS), that support Supply Chain Management. The structure of the interrelationships among the technologies discussed is shown in a figure (Figure 1). The paper is divided into a descriptive and an empirical section. The descriptive section is based on a critical analysis of the literature on the topic, while the research section is based on reports from Packt Publishing. The publishing house belongs to international publishers and provides the market audience with knowledge about key ICT technologies and innovative techniques and methods of Industry 4.0. The analysis' methodology

includes a review of the Fourth Industrial Revolution's technological concepts and the extraction of the most important ones for the creation of Logistics 4.0. The key technologies identified were then analyzed in terms of their potential impact on logistics processes and their adoption level in the industry. The findings of the analysis provide insights into the future direction of logistics and supply chain management. In terms of knowledge resources about the use and ubiquity of technology, available publications in the form of books and video presentations have been subjected to quantitative analysis. The analysis made it possible to answer questions: What is the market demand for knowledge about the key technologies of Logistics 4.0? How, in the era of today's technological revolution, knowledge about them is popularized in publications?



Legend: BI – Business Intelligence, CRM – Customer Relationship Management, ERP – Enterprise Resource Planning, WMS – Warehouse Management System, EDI – Electronic Data Interchange, RFID – Radio-frequency identification, AI – Artificial Intelligence, IoT – Internet of Things.

Figure 1. Systems and information technology in Logistics 4.0.

Source: own research.

If companies do not want to fall behind, they must be ahead of their potential competitors. For this purpose, they implement Industry 4.0 technologies in their enterprises and throughout their supply chains, so they have to be the initiators of change. Therefore, a crucial part of logistics development must be learning new things and training cadres—not just in programming, but especially in analytical skills. These specialists will be able to adjust to changes and integrate the new technologies of Logistics 4.0 into supply chains and businesses. By investing in the education and training of logistics professionals, businesses can ensure that they are well-equipped to handle the challenges of an increasingly digital and automated supply chain. This will not only improve efficiency and reduce costs but also help organizations stay competitive in a rapidly evolving marketplace.

2. Information Systems and Technologies of the Fourth Industrial Revolution in Logistics 4.0

Whole supply chains are supported by logistics systems in a broad sense. The use of ICT technologies like Big Data, AI, IoT, Cloud Computing, Edge Computing in supply chain management, and other developments, determines how modern digital businesses operate, (Szymonik, Chudzik, 2020) as shown in the figure (Figure 1). The centralized storage and real-time processing of data in the Cloud faces growing technical and analytical challenges as IoT devices are used more and more in business and daily life, producing an increasing amount of data. An edge architecture could be used as a solution. Edge Computing, also known as fog computing, can move data control to edge servers while keeping the fundamental benefits of Cloud Computing. However, the increasing dispersion of data is causing a data security problem. In this context, discussions about the potential of Blockchain technology are growing. Blockchain technology can provide a secure and decentralized solution to data management, while edge computing can enhance the speed and efficiency of data processing. Therefore, the integration of blockchain and edge computing has the potential to address the challenges of data security and privacy in a more effective way (Luo et al., 2020).

Logistic process management systems are integrated (Integrated Logistics Information Systems (ILIS)). Information systems are modularly organized, e.g., procurement module, order module, complaints module, etc. Logistics information systems are part of Integrated Management Information Systems (IMIS). Within enterprises, IT systems support all areas of business activity, from marketing, planning, and procurement through technical production preparation, production process management, distribution, sales, repair economy, financial and accounting work, and human resource management (Gunia, 2019; Adamczewski, 2014; Banaszak et al., 2016).

The key software used in enterprise logistics is ERP (Enterpirise Resource Planning), which was created on the structure of the Materials Requirement Planning (MRP) system (Radziejowska, 2001). Integrated ERP management systems consist of sales planning, supply management, and warehouse management. They are comprehensive systems, encompassing practically all production and distribution processes. Through the integration of supply chain cells, they improve the flow of information critical to its functioning and allow the participants in the supply chains to respond quickly to changes in demand. By operating on the basis of web resources, these systems enable the creation of web services dedicated to the chain, such as those for customers, cooperatives, and suppliers (Bentyn, 2017). The function of ERP systems has evolved in recent years from basic process support to a superior service platform in the form of data aggregation and exchange between various systems dedicated to different business areas and functions. These systems serve as both a data source for Logistics 4.0 solutions and a hub for data collection, processing, and optimization of logistics operations (Lech, 2003).

IT-computer systems in logistics processes, in addition to supporting inventory planning, are also used to analyze customer behavior and preferences, which helps wholesalers personalize their offerings and improve customer satisfaction (CRM systems). CRM software consists of three basic components for logistics support: operational, communication, and analytical. In modern logistics (Logistics 4.0) in CRM solutions, wholesalers take data segments such as customer data, transactions, products, contact forms, etc. as of particular importance (Lotko, 2003; Szymonik, Nowak, 2018).

At various points in the material demand and warehouse sales cycle, modern warehouses require the application of RFID technology, image analysis and recognition, or augmented reality. RFID, or electronic product recognition, enables the supply chain to identify all items and specific products (Bentyn, 2013; Sarma, 2008). The data exchange systems EDI (Electronic Data Interchange) and VMI (Vendor Managed Inventory) in use throughout the supply chain are of particular significance. When referring to an organization's internal systems, the WMS (Warehouse Management System) should be mentioned as a system that enables more effective operation of warehouses, including full utilization of their capacity, control of the course of warehouse turnover, and the potential for automating specific operations (Bentyn, 2017).

These systems, in conjunction with physical objects and technologies, are interconnected and can communicate with each other in real time via a global network. According to the idea of the IIoT, unlimited communication improves and automates decision-making and the transfer of data and information between connected devices. Modern technologies are based on machine learning (ML) algorithms and real-time decision-making systems (Atzori et al., 2010; Baurer et al., 2014; Hribernik et al., 2010).

The most important element of logistics solutions is the integration of procurement processes. In this area, properly used modern technologies allow for the best results: reduced costs and improved logistics. Maintaining the enterprise's competitive position requires proper use of the potential of new technologies (Gunia, 2019). Supply chains are becoming more self-sufficient and automated. The supply chain management system's full autonomy is the culmination of the logistics process and the computerization of individual supply chain links. Such a chain is characterized by the ability to self-configure, self-repair, self-optimize, and automatically protect processes (Schanne et al., 2003; Bentyn, 2017; Szymczak, 2015). Information sharing in supply chains addresses the idea of the Internet of Things, which potentially improves search, data updates, and identification of materials and resources in the supply chain. Logistics 4.0 seeks to build autonomous and fully automated chains to optimize processes. After Logistics 4.0, another concept of "Smart Logistics" is proposed by the scientific and business communities. In the next concept of logistics development, attention is paid to the importance of the human factor and the sustainability of supply chains. The change is due to the emergence of the "Industry 5.0" concept. The concept of "Industry 5.0" was introduced in 2015. Michael Rada. An attribute of Industry 5.0 is the interaction between human and machine (robot), including in logistics.

Industry 5.0 reflects the growing need to individualize production, which is a result of increasingly individualized customer demand. In the cooperation between human and machine in the personalized production model, the element of human creativity is important. On the basis of Industry 5.0, Logistics 5.0 is expected to emerge (Dembińska et al., 2018).

3. Key Technologies of Logistics 4.0 analysis

This publication recognizes IoT, Big Data, AI as the triad of technological advances in the development of Logistics 4.0.

Active Learning & Learning Strategies ranks second on the World Economic Forum's (WEF) list of top competencies for the future, published in 2020. It should be noted that the first five skills on the list include several soft competencies. WEF experts estimate that up to 50% of the workforce will also require retraining by 2025. In the case of ICT skills, enterprises are constantly struggling to find new employees while also looking for efficient ways to train those who are already employed.

Studying the number of publications, courses in a given field, and area of use can provide added value for logistics. Tracking technological trends and preparing reports in this area shows in which direction the market is developing and can also determine the potential direction of enterprise development. Key activities not only concern the new IT infrastructure itself but also properly trained personnel. The analysis was carried out for the development of logistics processes by studying the usefulness of key IT technologies and Logistics 4.0 technologies.

The conclusions are based on data from publications available at https://www.packtpub.com/. The site used has the character of a library, bookstore, or "training center". The site used is a case study in this publication because it is one of many sites that assist developers and non-developers alike in staying current with the technologies embedded in the Fourth Industrial Revolution. Through various learning formats and a growing ecosystem of ICT resources and products, the site covers both emerging and contemporary tools and trends. Its goal is to provide professionals with effective education and information services in the form of the practical knowledge they need, whether it is specific learning about a new technology or optimizing key skills in more established tools. The data used in the analysis is publicly available.

The scope of the analysis covered four general categories of the latest ICT technologies promoting the development of Logistics 4.0, which were classified in the following categories on the website https://www.packtpub.com/: Data, Cloud&Networking, IoT&Hardware, Business&Other (Figure 2).

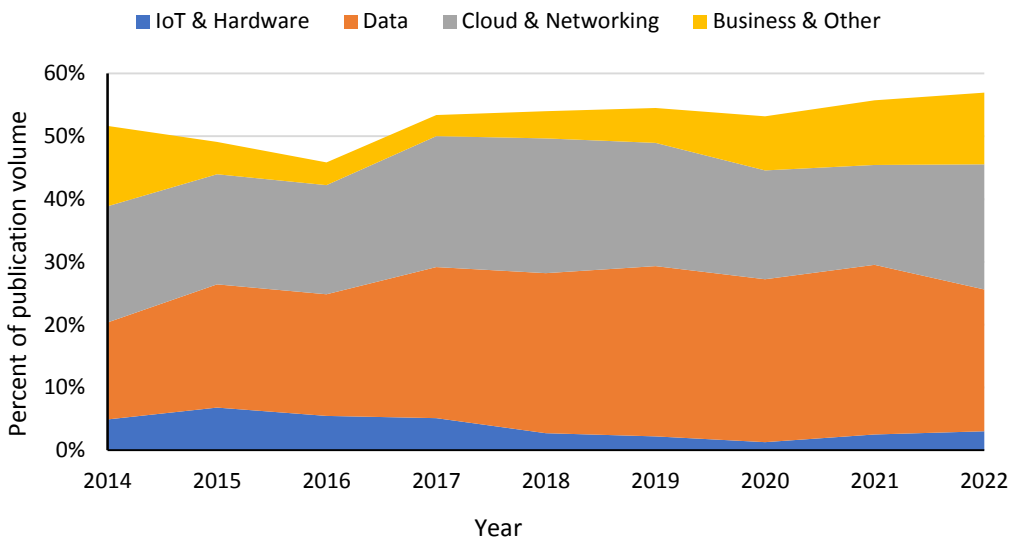


Figure 2. An overview of technologies closely linked to Logistics 4.0.

Source: own research.

In the total number of analyzed publications, the most popular were IT technologies and tools related to data collection, processing, and analysis, which is the category used in the figure as Data. The cloud solutions for storing large amounts of data in the Cloud & Networking category, as well as those that perform other functions like updating device IT software and other functions like system security, device navigation, network administration and management, etc., were ranked second in this report. This indicates that there is a growing demand for cloud-based solutions that offer a wide range of functions and capabilities beyond just data storage. It also suggests that businesses are increasingly looking for comprehensive solutions that can help them manage their IT infrastructure more efficiently. These two technologies would not have developed so rapidly in recent years without IoT and the appropriate IT and hardware software (IoT&Hardware) to support logistics processes. Furthermore, it is noted that the fourth category listed as Business&Other includes the development of logistics systems such as ERP and Business Management as well as additional systems, e.g., design support of logistic processes using digital twins and soft skills solutions. In current IT skills training, increasing importance is given to building soft skills, including critical and analytical thinking, teamwork, interpersonal communication, stress management, etc. (Dean, East, 2019).

Based on the technologies shown in the figure (Figure 2), a detailed analysis was made. In each general category, the techniques used within each concept are listed. Each of the main categories has been color-coded as shown in the figure (Figure 2): orange for Data, gray for Colud&Networking, blue for IoT&Hardware and green for Business&other. The analyzed subcategories within the main category maintain the adopted color scheme, and each subcategory is presented in the charts according to the time range from 2014-2022. Each row represents 100% of the publications over the years in the subject of the main category.

To present the results, heat maps were used, drawn up in R. The intensity of the color represents the number of publications; the more intense (darker) the color, the higher the number. Each of the heat maps also included technologies that had single indications in the tested database and were recorded in one group called "other".

The research methodology is shown in the figure (Figure 3).

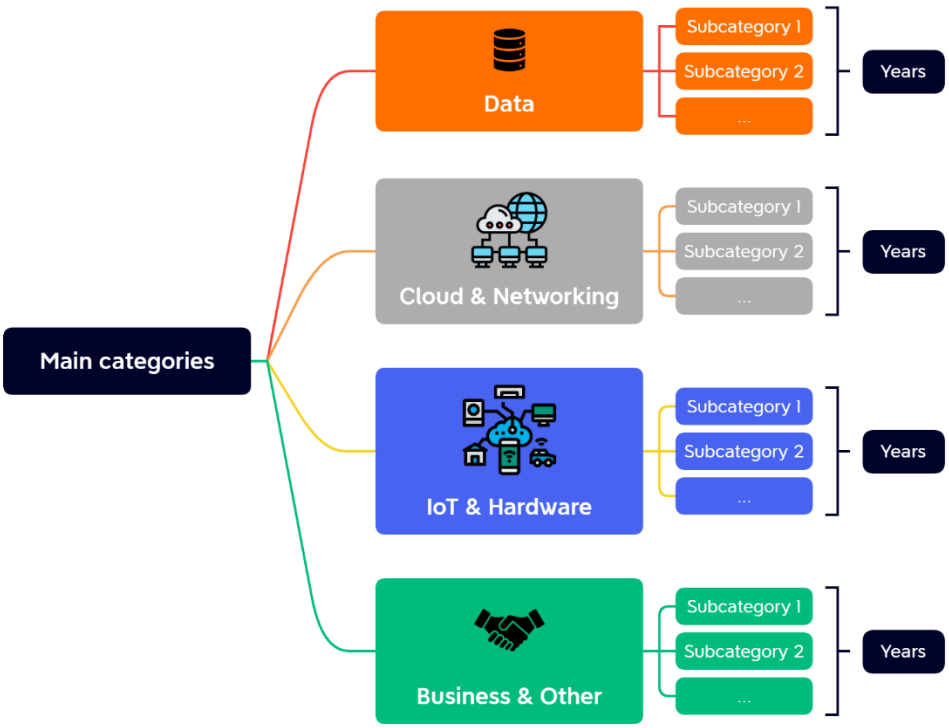


Figure 3. The research methodology.

Source: own research.

The figure (Figure 4) shows that the Machine Learnig (ML) concept, which in Logistics 4.0 is a new form of machine communication, is the most widely discussed concept in scientific publications between 2017 and 2022 (intensive orange color). Machine Learning in logistics is applied to demand forecasting and inventory management, transport routes optimization, machine, and equipment preventive maintenance, and is also used in warehouses such as mobile robots, in voice picking devices for order completion (Uczenie…, 2021).

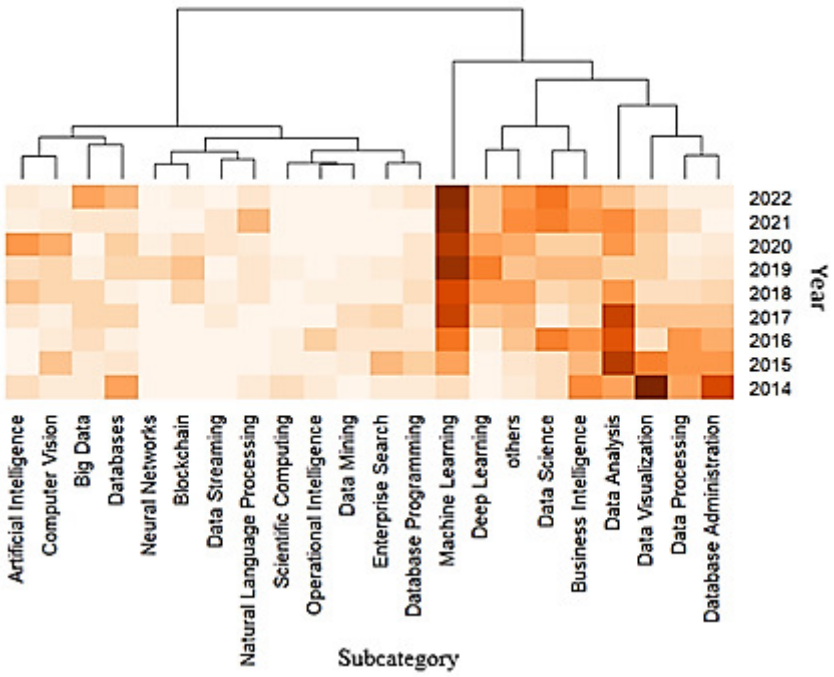


Figure 4. Heatmap for Data category (by row).

Source: own research.

ML, along with deep learning (DL) and neural networks (NN), natural language processing (NLP), and computer vision (CompV), is part of Artificial Intelligence (AI). Relationships between these areas are shown in the Venna diagram (Figure 5).

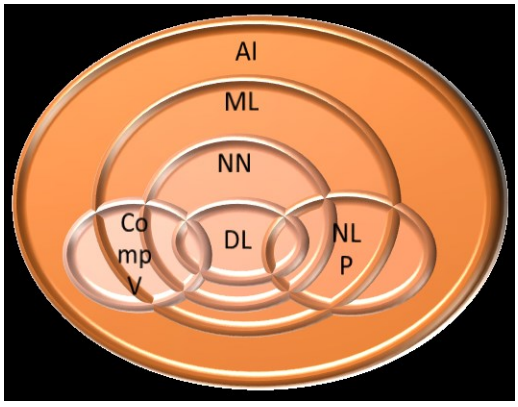


Figure 5. AI and its components.

Source: own research.

NLP and CompV are also increasingly used in logistics. NLP algorithms are used, for example, in creating chatbots to assist customers in logistic processes, as well as other solutions to limit the use of information flow in paper form. CompV helps in locating logistic facilities (goods, vehicles, and people) through QR (Quick Response) codes, barcodes, and optical character recognition (OCR). Codes used in goods control processes using IT-computer algorithms serve to optimize logistics and, in the case of people, to identify persons entitled to monitor processes.

Blockchain (BC), which is linked to Logistics 4.0, gained popularity in 2017-2019. However, it can be assumed that with the popularization of the Industry 5.0 (January 2021) concept of the European Commission (EC) (Industry 5.0: Towards a more sustainable, resilient, and human-centric industry, 2021), the popularity of BC in the life cycle analysis (LCA) aspect will grow, including among all product users.

Data Analysis (DA), Data Visualization (DV), Database Administration (DBA), Databases (Db) preceded the popularity of ML occurring with the greatest intensity in 2014-2017, which is a natural stage in the development of these technologies, because first sensors generate data, which after accumulation are the basis for building ML algorithms. Until 2014 only two publications about ML were created. In contrast, in 2014 in the area of AI, DL, and NN topics there was no publication in the analyzed database. Popularity of these solutions grew after 2014. ML used in logistics processes and other organizations contributes to (Gajdzik, 2014):

- demand forecasting,
- preventive maintenance of machinery and equipment,
- optimization of transport routes,
- reverse logistics in the case of waste and returns of goods,
- recognizing the voice of employees in warehouses entitled to operate the given technology,
- mobile robots for the identification of goods,
- control of inventory levels and minimizing inventory management risks (quick response),
- other functions of the WMS.

The next phase of the analysis was the Cloud&Networking area, which through the collection, transfer, and transfer of data (Big Data), contributes to improving the efficiency of entire supply chains by reducing the logistics costs associated with the rationalization of the bases of participants in the supply chain as well as products and services. The cloud IT systems market includes, in addition to hardware infrastructure, many dedicated IT system classes. The dedicated systems can relate to the service of specific areas of the enterprise, such as warehouses or transportation processes, or to the business service as a whole (Malinowska, Rzerzycki, 2016). Dedicated to logistics processes, computer clouds have been called Cloud Logistics.

Referring to a figure (Figure 2), Cloud&Networking are constantly developing technologies and are strongly popularized in the logistics community. Compared to other technologies used for data management, the share of Cloud Computing (CC) is the highest in the surveyed years 2014-2022, as noted in the heat map by the increasing gray color in a figure (Figure 6). In addition to CC, other important technologies include System Administration, IT Certification (training), and DevOps. The listed technologies do not exhaust all solutions used in process logistics for data management and are closely related to CC. Containerization, Virtualization,

Cloud Native are also emerging in the logistics of the future. The new solutions are strongly linked to modern work methods classified as agility (L'Hermitte et al., 2015).

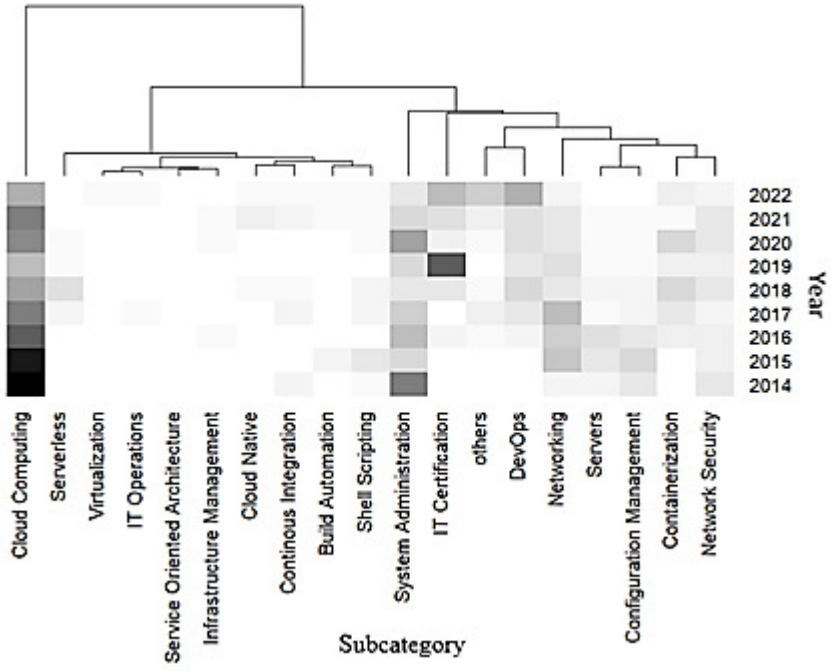


Figure 6. Heatmap for Cloud&Networking category.

Source: own research.

Based on the figure (Figure 7), the following technology areas relevant to logistics development were analyzed: Robotics, IoT Development, Embedded Systems, Microcontroller, Industrial Internet of Things and Security, Single board computers and others. The listed technologies in the analyzed publications are classified under IoT & Hardware. The largest number of publications in the period under review were related to Robotics, Embedded systems, Single Board Computers and IoT development. These technologies are used in modern warehouses. The majority of warehouse and related processes, such as distribution, shipping, and picking, are automated in today's warehouses and transportation hubs, either entirely or to a high degree. In addition, Internet applications, embedded systems, and the use of microcontrollers are used to track goods and monitor their status during transport. Businesses must also accommodate customers' growing interest in tracking the status of their orders.

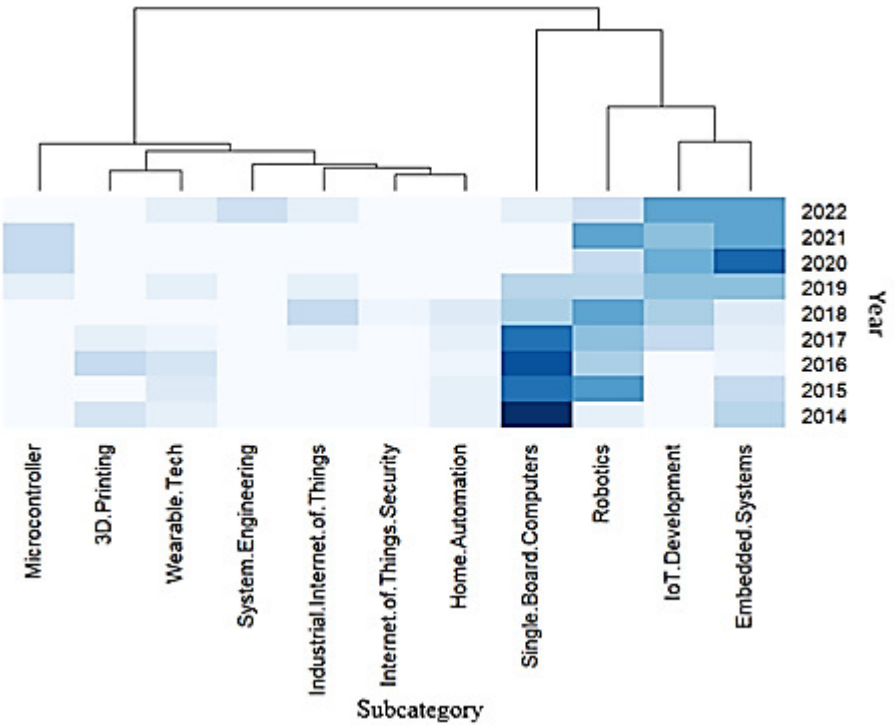


Figure 7. Heatmap for IoT & Hardware category.

Source: own research.

An analysis of the final category, Business & other, is given in a figure (Figure 8). This category includes solutions that support management, administrative, and design processes. During the time period from 2014 to 2022, the greatest scientific and research popularity has been in Project Management (PM) and ERP, where the ratio of the number of publications to the total number of publications in a given category during the study period was 15% and 16%, respectively. Due to the advancement of digital technologies, computer modeling of planned logistics processes within digital twins, simulation, and other factors, PM has a significant presence in scientific publications (Agalianosa et al., 2020).

In addition to technologies that support management-administration processes in logistics, techniques written in the agile subcategory related to PM are becoming increasingly popular. This was particularly highlighted in 2021, as the number of publications in the surveyed category related to PM accounted for 30% and the number of publications related to Agile accounted for 21% of the total number of publications in Bussines & other field. The enterprise environment is changing at an unprecedented pace and scope. As a result, in recent years, more and more companies are using management by projects to achieve their goals. To this end, companies are streamlining their work by creating project teams. Project management takes care of developing specific project goals, assigning roles, and managing budgets. Companies need to offer higher and higher quality products while adapting quickly to new circumstances. (Dryl, 2019). Agile work methods are often the answer to these needs. However, they require a change in thinking about how to manage the business, the product, and the people. Moreover, since agile methods focus more on interactions between people (employees, stakeholders) and

less on processes, more publications may also confirm the importance of collaboration between new technologies and humans and the importance of human creativity.

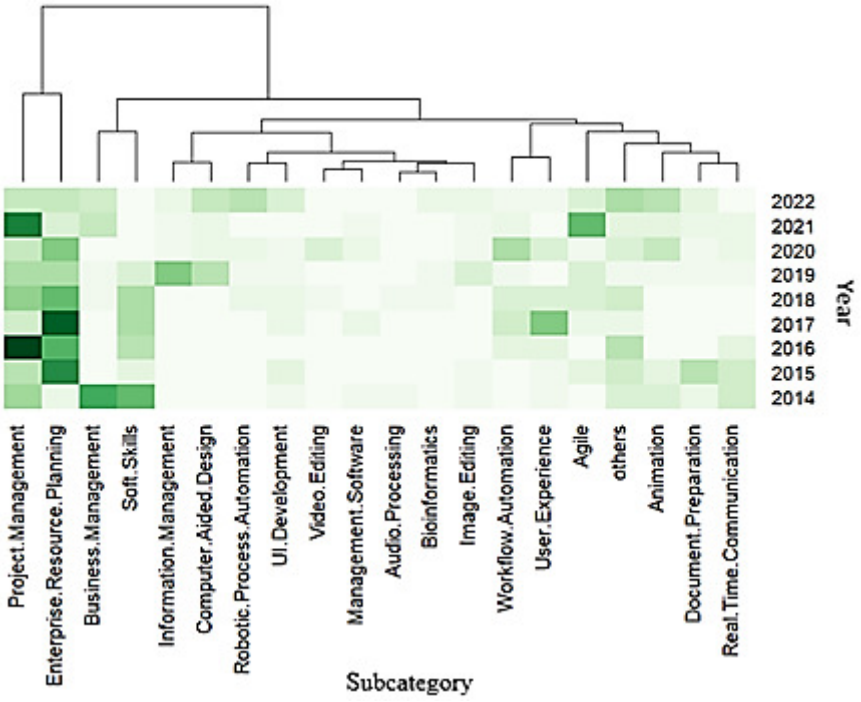


Figure 8. Heatmap for Business & other category.

Source: own research.

Two other factors should be mentioned: Robotic Process Automation (RPA) software and Computer Aided Design (CAD), which in 2022 achieved the same results as PM and ERP. At the same time, in this ranking, these are new solutions, as the first publications appeared for RPA in 2018 and for CAD in 2019. RPA software is a technology for creating digital robots supporting the implementation of business processes, including logistics processes. CAD has been known since the sixties of the last century, however, in recent years, due to technological progress, new tools and applications of computer-aided design have emerged. These tools can be used in both logistic process modeling, systems, creation of virtual warehouses (Plinta et al., 2019).

4. Conclusions

The results were presented according to the category studied:

1. Data.

In Logistics 4.0, Big Data is the typical name for Data, as in modern ICT and AI there are no small data sets. Big Data appeared just in 2013, which was associated with the strong popularization of the pillars of Industry 4.0. This shift towards the name Big Data reflects the

increasing importance of data in all areas of business and industry and highlights the need for companies to effectively manage and utilize their data resources in order to remain competitive. As such, the term Big Data will likely continue to evolve alongside advances in technology and data analytics. In line with Industry 4.0 and Logistics 4.0, it is predicted that databases, along with the increasing demand for data stored in the cloud, will gain popularity, according to the researched publications.

As logistics procedures are created to comply with Industry 4.0 specifications, they seek to be optimized using the most recent ICT technologies (AI, IoT, and CC). The process approach has long been applied in the enterprise but has been limited to the internal enterprise, and in Logistics 4.0, it goes beyond the company, e.g., the collection of data from social media, public rankings, reports, exchanges, auctions, etc.

2. Cloud&Networking.

Cloud & Networking, because of their past use and improvement, are the basis for building IT infrastructure on a macro, mezo, and micro scale. Cloud & Networking technologies are considered a necessity in the global economy and in a digital society. Due to process linkages between participants in logistics processes (internal and external logistics), customization is growing in importance. The customer participates in the design of the product, service and follows the logistics process, determining its agility. Networking was and still is important in logistics, as concurrent technologies, integrated processes, customization, and reverse logistics, as well as the popularization of the green concept, provide opportunities for its growth. Networking is not only the Internet but also internal networks and external networks.

3. IoT&Hardware.

Of the four categories listed, the IoT&Hardware category is the most recent. The total number of publications in the period under review represents 95% of all publications since the founding of the publishing house in 2004. At the same time, it should be noted that logistics is an area that IoT will affect tremendously. The development of chips and microcontroller sensors makes it possible to track vehicles, goods, and containers in real time (not only location but also other relevant parameters such as temperature, humidity, etc.). The data collected and processed by IoT devices allows efficient management and monitoring of logistics processes, responding to emerging problems and faults in real time. In addition, there is a continuous development of automation and robotization in warehouses and distribution centers.

4. Business&Other.

The last category was organizational and management support systems. In this category, special attention was paid to the importance of ERP and Project Management in the development of logistics processes. With the development of modeling and simulation, the importance of virtualizing PM processes under test is growing. On the basis of already well-known ERP systems, other systems are being developed. The realization of the idea of an integrated organization became possible due to the modular design of the ERP system, which covered every aspect of management. When the idea of an extended enterprise emerged,

i.e., an enterprise open to the environment, to suppliers, business partners, and customers, the ERP system evolved into ERP II, the architecture of which became component-based (application-based). The development of e-business played a major role in this process. On the other hand, the boom of cloud technologies, mobile applications, and social networks contributed to the emergence of hybrid ERP systems, combining the functionality of several systems (e.g., ERP, CRM, BI). This type of system is becoming a universal platform for handling enterprise operations. Business processes, which were previously internal processes of the enterprise, can be extended in various directions outside the enterprise. These processes then become extended business processes, multi-application processes, or, in other words, megaprocesses (Missbach, Anderson, 2016; Lenart, 2019).

5. Summary

The analysis's conclusion includes a list of recent technological innovations that can take into account future advancements in logistics and more. According to the analysis, it was found that the development of Industry 4.0's key technologies is the foundation for Logistics 4.0. Previous ICT solutions have received strong support from Data, Cloud and IoT, creating new business solutions in logistics processes (Buissiness & other). A detailed analysis showed that technologies such as AI with ML, general data analytics, CC, system administration, Networking, DevOps, IT certification, IIoT, embedded systems, robotics, single board computers, PM, ERP, and Agile have gained popularity in recent years.

The achievement of company goals should be the result of employee development initiatives. Employee development in an organization is responsible for a number of activities that help employees develop their skills, access the latest knowledge in this field, and improve motivation. This enhances their professional potential and enables them to perform current and future tasks more effectively. The research performed has a use value in training processes, and the technologies analyzed show their popularity through the number of publications in a given technological category that are used as training materials, among other things. The number of publications in a given area is a response to market demand. The analyzed technologies determine the directions of development of Logistics 4.0, which is characterized by digitalization, agility, smartness, and intelligence, and detail the application of Blockchain and Edge computing.

References

1. Adamczewski P. (2014). *Zintegrowane systemy informatyczne w praktyce*. Warszawa: ZNI „MIKOM".
2. Agalianosa, K., Ponisa, S., Aretoulakia, E., Plakasa, G., Efthymiou, O. (2020). Discrete Event Simulation and Digital Twins: Review and Challenges for Logistics. *Procedia Manufacturing, Vol. 51,* pp. 1636-1641, doi: 10.1016/j.promfg.2020.10.228.
3. Atzori, L., Iera, A., Morabito, G. (2010). The Internet of things: A survey. *Computer Networks*, *Vol. 54, Iss. 15,* pp. 2787-2805, doi: 10.1016/j.comnet.2010.05.010.
4. Banaszak, Z., Kłos, S., Mleczko, J. (2016). *Zintegrowane systemy zarządzania*. Warszawa: PWE.
5. Bauer, H., Patel, M., Veira, J. (2014). *The Internet of things: Sizing up the opportunity* (Technical Report). McKinsey&Company. Retrieved from: http://www.mckinsey.com/insights/high_tech_telecoms_internet/the_internet_of_things_sizing_up_the_opportunity.
6. Bentyn, Z. (2013). Nowe zastosowania i usprawnienia radiowej identyfikacji towarów. In: K. Kreft, D. Wach, J. Winiarski (Eds.), *Systemy informatyczne w gospodarce* (pp. 97-112). Gdańsk: Uniwersytet Gdański.
7. Bentyn, Z. (2017). Ewolucja łańcuchów dostaw w kierunku autonomicznych systemów logistycznych. [Evolution of supply chains towards autonomous logistical systems]. *Przedsiębiorczość i Zarządzanie, Vol. 18, Iss. 8, No. 2,* pp. 9-20, Łódź: Społeczna Akademia Nauk.
8. Caggiano, A., Caiazzo, F., Teti, R. (2015). Digital Factory approach for flexibility and efficient manufacturing systems in the aerospace industry. *Procedia CIRP, Vol. 37*, pp. 122-127, doi: 10.1016/j.procir.2015.08.015.
9. Cooper, J., James, A. (2009). Challenges for database management on the Internet of things. *IETE Technical Review*, *Vol. 26, No. 5,* pp. 320-329, doi:10.4103/0256-4602.55275.
10. Dean, S., East, J. (2019). Soft Skills Needed for the 21st Century Workforce. *International Journal of Applied Management and Technology, Vol. 18, Iss. 1,* pp. 17-32, doi: 10.5590/IJAMT.2019.18.1.02.
11. Dembińska, I., Frankowska, M., Malinowska, M., Tundys, B. (2018). *Smart Logistics*. Kraków: Edu-Libri.
12. Dryl, M. (2019). Systemy ERP. In: S. Wrycza, J. Maślankowski (Eds.), *Informatyka ekonmiczna. Teoria i zastosowania* (pp. 501-516). Warszawa: PWN.
13. *European Commission*. *Research and innovation.* Retrieved from: https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/industry-50-towards-more-sustainable-resilient-and-human-centric-industry-2021-01-07_en.

14. Gajdzik, B. (2014). Organizacja działań w ramach TPM w przedsiębiorstwach produkcyjnych [Organization of TPM in Manufacturing Companies]. *Logistyka*, *Vol. 3,* pp. 28-30. Poznań: Łukasiewicz, Poznański Instytut Technologiczny.
15. Gregor, B., Kaczorowska-Spychalska, D. (2020). *Technologie cyfrowe w biznesie. Przedsiębiorstwa 4.0 a sztuczna inteligencja.* Warszawa: PWN.
16. Gunia, G. (2019). Zintegrowane systemy informatyczne przedsiębiorstw w kontekście przemysłu 4.0. *Zarządzanie Przedsiębiorstwem*. *Enterprise Management*, *Vol. 22, No. 2,* pp. 7-12, doi: 10.25961/ent.manag.22.02.02.
17. Hermann, M., Pentek, T., Otto, B. (2016). *Design Principles for Industrie 4.0 Scenarios*. 49th Hawaii International Conference on System Sciences (HICSS), doi: 3928-3937. 10.1109.
18. Hribernik, K., Warden, T., Thoben, K., Herzog, O. (2010). *An internet of things for transport logistics–an approach to connecting the information and material flows in autonomous cooperating logistics processes.* Proceedings of the 12th international MITIP conference on information technology & innovation processes of the enterprises, pp. 54-67.
19. Kagermann, H., Wahlster, W., Helbig, J. (2013). *Securing the future of German manufacturing industry: recommendations for implementing the strategic initiative Industrie 4.0*. Final report of the Industrie 4.0 working group. Berlin.
20. Lech, P. (2003). *Zintegrowane systemy zarządzania ERP/ERP II. Wykorzystanie w biznesie, wdrażanie*. Warszawa: Difin.
21. Lenart, A. (2019). Systemy ERP. In: S. Wrycza, J. Maślankowski (Eds.), *Informatyka ekonmiczna. Teoria i zastosowania* (pp. 519-547). Warszawa: PWN.
22. L'Hermitte, C., Bowles, M., Tatham, P., Brooks, B. (2015). An integrated approach to agility in humanitarian logistics. *Journal of Humanitarian Logistics and Supply Chain Management*, *Vol. 5, Iss. 2,* doi: 10.1108/JHLSCM-04-2014-0016.
23. Lotko, A. (2003). *Zarzadzanie relacjami z klientem*. Radom: Politechnika Radomska.
24. Luo, C., Xu, L., Li, D., Wu, W. (2020). *Edge Computing Integrated with Blockchain Technologies,* doi: 10.1007/978-3-030-41672-0_17.
25. Malinowska, M., Rzerzycki, A. (2016). Rozwiązania cloud computing w logistyce - stan obecny i tendencje rozwojowe [Cloud Solutions in Logistics - The Current State and development Trends]. *Problemy Transportu i Logistyki, Vol. 36, No. 4,* pp. 165-174, doi: 10.18276/ptl.2016.36-17**.**
26. Martin, M. (2015). *Building the impact economy: Our future, yea or nay.* Berlin, Germany: Springer.
27. *Mecalux, rozwiązania magazynowe.* Retrieved from: https://www.mecalux.pl/blog/ uczenie-maszynowe-logistyce, 27.01.2023.
28. Missbach, M., Anderson, G. (2016). *SAP w 24 godziny*. *Wydanie V [Sams Teach Yourself SAP in 24 Hours, Fifth Edition]*. Gliwice: Helion.

29. Mosconi, F. (2015). *The new European industrial policy: Global competitiveness and the manufacturing renaissance*. New York, USA: Routledge.
30. Plinta, D., Krajčovič, M., Svitek, R., Grznár, P. (2019). Computer aided design of logistics systems. *Multidisciplinary Aspects of Production Engineering*, *Vol. 2, Iss. 1,* pp. 416-424, doi:10.2478/mape-2019-0042.
31. Radziejowska, G. (2001). *Logistyka w przedsiębiorstwie, przewodnik do ćwiczeń*. Gliwice: Wydawnictwo Politechniki Śląskiej.
32. Sarma, S. (2008). RFID technology and its applications. In: S. Miles, S. Sarma, J. Williams (Eds.), *RFID technology and applications* (pp. 16-32). Cambridge: Cambridge University Press, doi: 10.1017/CBO9780511541155.003.
33. Schanne, M., Gelhausen, T., Tichy, W. F. (2003). *Adding autonomic functionality to object-oriented applications*. Proceedings of 14th Int. Workshop on Database and Expert Sys. App. DEXA, pp. 725-730, doi: 10.1109/DEXA.2003.1232107.
34. Szymczak M. (2015). *Ewolucja łańcuchów dostaw.* Poznań: Wydawnictwo UE w Poznaniu.
35. Szymonik, A., Chudzik, D. (2020). *Nowoczesna koncepcja logistyki produkcji*. Warszawa: Difin.
36. Szymonik, A., Nowak, I. (2018). *Współczesna logistyka*. Warszawa: Difin.

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LOGISTICS COORDINATION IN BUILDING THE RESILIENCE OF THE DISTRIBUTION NETWORK

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Purpose: The research article is an extension of the concept related to logistics coordination in distribution networks. The concept of logistics coordination extends the flow mechanisms of network governance presented in the literature so far. The aim of the article is to conceptualize logistics coordination as a set of network coordination flow mechanisms that are to strengthen the resilience of the distribution network. Disruptions analysis was used to assess the resilience of the distribution network.
Design/methodology/approach: The first stage of the research was to identify the gap in the research on network governance. The assumptions of logistic coordination indicated in the literature research were the basis for the methodology of empirical research. The research was carried out in the distribution network of household appliances/electronics. The resilience of the distribution network to disruptions was assessed. Disruptions and deviations in the implemented processes were identified on the measurement cards. In assessing the resilience of the network, indicators of timeliness, completeness and orders without damage were used. Subsequently, a cause and effect analysis and FMEA were carried out. The conducted research was completed with recommendations for the coordinator of flows in the distribution network.
Findings: Recommendations for the coordinator of the household appliances/electronics distribution network include mechanisms for logistics coordination that strengthen the resilience of the network. Other mechanisms that the coordinator is already using have also been identified. Among the identified mechanisms are both proactive and reactive actions. The set of mechanisms, in accordance with the proposed concept of logistics coordination, includes mechanisms focused on flexible resources, redundancy of partners in the network, redundancy of stocks at the material distribution point, extraordinary transport and forecasting for the entire network.
Originality/value: The indicated mechanisms, both those used by the coordinator and those proposed to be used to increase the resilience of the distribution network, go beyond the flow mechanisms proposed in network coordination. Thus, it makes sense to extend the flow mechanisms to include logistics coordination in the broadest sense, which aims to synchronise flows, ensure the continuity of the processes carried out and the coherence of the activities of the network nodes.

Keywords: distribution network; network governance; logistic coordination; resilience, disruptions.

Category of the paper: research paper.

1. Introduction

Distribution networks, as systems made up of many cooperating nodes, are sensitive to disruptions. Sensitivity to disruptions manifests itself in deviations in material flows and reduced customer satisfaction. For nodes coordinating the flows of finished goods in distribution networks, the competence to strengthen network resilience is therefore crucial. The resilience of a distribution network will be understood according to the resilience interpretation for the supply chain (Bukowski, 2019), as the ability to reliably execute finished goods flows in a disruption-affected environment. This capability manifests itself in the proficiency to weaken external and internal factors that cause disruptions, as well as the ability to prevent the propagation of these disruptions. Dissemination of disruptions means that the negative effects of disruptions are transmitted to a larger number of participants in a complex distribution system. This type of competence needs to be supported by high relational capabilities manifested by the coordinator's interaction with other network participants. The coordinating links in a distribution network therefore face challenges that are referred to in the literature as network governance. So far, the network coordination discussed in the literature has not focused on distribution networks. This raises the questions of whether the forms and mechanisms of coordination discussed in the literature are sufficient to ensure high levels of customer satisfaction in distribution networks? There is no answer to such a question in the literature. In the search for an answer, it becomes necessary to detail the types of distribution networks and the determinants and challenges of coordination in such complex systems. The aim of this paper is to conceptualise logistical coordination as a dimension of network coordination for strengthening distribution network resilience. The considerations carried out in the theoretical background concern the construct of network coordination against the background of distribution network determinants. The effectiveness of coordination was referred to the reliability of the realised flows of finished goods under the impact of disruptions. Against this background, the importance of strengthening the resilience of the distribution network is indicated. The methodology covers the research procedure, relating the adopted concepts of disruptions analysis and distribution system resilience assessment to the research of other authors. The results and discussion section presents the results of the disruption analysis in the household goods distribution network and the concept of strengthening the resilience of this network.

The company selected for the study is the central link in the distribution network and is responsible for the appropriate organisation of all processes taking place within it. Disruption data were obtained by continuously completing control cards during the study period. In parallel, an analysis of selected reliability indicators of finished goods flows was carried out during the study period. By comparing the level of the indicators and the identified disruptions, key problems were selected, which were further analysed through an Ishikawa diagram and

an FMEA (Failure Mode and Effect Analysis). In this way, the current state was assessed and possible improvement actions were suggested as a proposal to strengthen the resilience of the network under study. In this way, the relevance of including logistical coordination as an extended flow mechanism of network coordination was indicated.

2. Theoretical background

2.1. Resilience of the distribution network

Distribution networks are configured from cooperating manufacturing, trading and logistics companies. In the literature, it can be described that distribution networks are a particularly complex system (Kramarz 2012; Guan et al., 2021; Kazmi et al., 2017; Abbasi, Varga, 2022). This is due to the interaction of multiple companies (network nodes) with diverse strategies, resources, organisational cultures and key processes. In indicating the attributes of a distribution network, graph theory is used, based on graphically translating the entire structure and determining the relevant links between nodes. Distribution network attributes include (Kramarz, 2012): paths between two nodes (number of intermediaries between two nodes - companies), distance (distance between two companies), node input and output degree (number of direct relationships with suppliers and customers/intermediaries), bridges (entities that are intermediaries between subgroups within the analysed network), node intermediation (ratio of the number of shortest edges that pass through a node to the total number of shortest edges), reciprocity (ratio of reciprocal relationships to all relationships), network density (the ratio of the number of relationships to the number of all potential relationships, it can also be assessed in terms of geographical distances between nodes), clustering coefficient for a given node (the total number of relationships that the analysed entity forms), network diameter (the longest distance between the companies within a single network), the phenomenon of preferential attachment (central links in a network are characterised by a greater ability to attract new network members relative to the other entities in a given network).

These attributes are used to determine the configuration of the network and also the relational characteristics of the cooperating companies in the network. Through attributes such as the phenomenon of preferential attachment, agency and clustering coefficient, it is possible to identify nodes that potentially have favourable conditions to undertake coordination due to their central position in the network and their power to influence other nodes. In this way, in the airline industry, research was conducted by Brintrup, Wang, Tiwari, (2015) indicating that the distribution system studied is a network formed by communities connected by central firms. The authors showed that hub firms also tend to interconnect with each other, providing cohesion but making the network highly susceptible to disruption. Furthermore, based on

attributes drawn from network theory, they also showed how to identify firms that are operationally critical and those that are central to the dissemination of information. In this way, it is possible to isolate organisations that not only have an impact on the coordination of flows but also on building the resilience of the network as a whole.

There is little literature on distribution network resilience, and it is therefore useful to look to the literature in the area of supply chain management, where resilience has been studied for many years. In interpreting supply chain resilience, the most commonly presented approach indicates that it is the ability to respond to unforeseen disruptions and restore planned supply chain operations (Kramarz, Kramarz, 2014). Issues related to resilience in supply chains are a very lively topic for discussion around the world. Analysing academic publications, it can be concluded that the issue of resilience is linked to the ability to control the situation when deviations arise due to emerging disruptions and to have adequate adaptive capabilities. These capabilities allow supply chains to become more flexible, resulting in the ability to adapt quickly to changes in the environment.

The key elements that create supply chain resilience are a supply chain structure that allows information (knowledge) to flow more easily, a supply chain baseline strategy, collaboration between companies in the supply chain, agility and flexibility, creating a risk management culture (Christopher, Peck, 2004).

Fiksel (2004), on the other hand, identifies four key characteristics that foster resilience. These are: diversity in terms of forms of behaviour and action, efficiency, i.e. the ability to achieve high performance with moderate use of resources, adaptability, understood as the flexibility to act under pressure, cohesion, i.e. the effect of dependencies between system variables and system elements.

These are all fundamental components of resilience in supply chains and the distribution networks that are part of them. Lu and Stead (2013) provide a graphical representation of the resilience model in a diagram as the relationship between the change in organisational performance from the onset of disruption to the return of optimal performance. The boundaries from the onset of disruption to the return to a state where the firm regains its ability to control the process are clearly marked. The modelling approach sets the rate of system recovery and the threshold for the maximum possible disruption that the enterprise is able to compensate for without passing on the effects to other supply chain participants.

Any resilience-building activity in distribution networks is essentially a response to the vulnerability of that system. Vulnerability can be understood as the susceptibility to succumb to changing external factors that are capable of disrupting the functioning of the entire distribution system (Bukowski, 2019). The reaction to vulnerability is the development of mechanisms that constitute a kind of defence system of the system, which is called resilience. Building resilience in supply chains is now being eagerly addressed by academics especially at a time of such severe disruptions as the COVID 19 pandemic. From the point of view of the flow coordinator, it is a long-term process of creating awareness and working continuously to negate the effects of disruptions that may occur in the future.

2.2. Network Governance

Distribution networks, which are characterised by their considerable breadth (large number of participants), diverse relationships and less integration than distribution channels, are much more complex systems than distribution channels. Complexity arises from both the number of interconnected elements and the diverse nature of the relationships between these elements. Making the joint activities of multiple participants harmonious and efficient is a major challenge, especially under the impact of disruptions. This challenge justifies the great importance attached to network governance (NG). Some authors refer to network governance exclusively to collaborative public goods, indicating that NG is defined as 'entities that fuse collaborative public goods and service provision with collective policymaking' (Isett et al., 2011) that is based on the principles of trust, reciprocity, negotiation, and mutual interdependence among actors (Provan, Kenis, 2008). These same elements of NG are also the characteristics in the definitions of collaborative governance (Fadda, Rotondo, 2020).

Other authors interpret NG more broadly. Young and Dulewicz (2008) and Hoetker and Mellewigt (2009) define NG as the effective and efficient use of the resources of all nodes of an inter-organisational network (including infrastructure, knowledge, and other resources) to achieve the set goals. Network governance aims to ensure consistency of activities, to counteract conflicts by arranging, in some purposeful order, the tasks carried out by multiple participants and to adapt participants with different attributes to the established rules through various mechanisms. Heide (2003) mentions a set of three forms of coordination: market, hierarchical and social, which together occur in networks. Czakon (2008) details these into mechanisms: price (e.g. price, bilateral collateral), non-price (e.g. trust, social norms, decision-making style) and flow (e.g. VMI, QR, CPFR). Hierarchy-driven mechanisms prevail in the enterprise. Going beyond the single organisation and analysing distribution networks, one can see the increasing importance of mechanisms related to the market form of coordination. One and the other mechanisms are strongly intertwined with mechanisms characteristic of the social form of coordination. These three types of groups of mechanisms are most often discussed in the literature in the context of NG. Among the mechanisms characteristic of the market form, Czakon (2013) mentions mainly price but also formal relationships and bilateral collateral. Among the hierarchical mechanisms, he identifies: structures and control systems resulting from management styles, bureaucratic allocation of resources, budgeting and organisational integration. A distinguishing feature of hierarchical coordination is the power that one actor gains over others through knowledge. This is an important point, as there are no organisational structures characteristic of companies in networks. Thus, the source of power is not subordination in the organisational structure but the fact that one organisation has more knowledge and capacity to use it than the other organisations. This organisation naturally becomes the coordinator. Among the mechanisms attributed to social coordination, however, he mentions trust, communication systems and information exchange as well as social norms

(Kramarz, 2018). The analysis of the detailed mechanisms requires consideration of the potential effects of these mechanisms. Among the effects considered are risk, opportunism, and costs (Hoetker, Mellewigt, 2009).

2.3. The construct of logistical coordination as a network coordination mechanism

In line with the concept presented in an earlier publication, forms of NG are assumed to indicate the source of the coordinator's authority, giving him or her the power to coordinate the network through any set of mechanisms (Kramarz, Twaróg, 2017). Sahin, Metzer (2006) emphasise that the effectiveness of the use of a combination of coordination mechanisms depends on the extent to which they are matched to the type of network of interacting organisations. Distribution networks, regardless of their detailed attributes in terms of breadth, degree of centralisation and others, are geared towards ensuring the availability of products in the quantity, time and place expected by the customer. The coordination of distribution networks must therefore be aimed at synchronising processes in such a way as to ensure reliable fulfilment of customer orders (Kramarz, 2018). In this type of network, flow mechanisms that affect the timeliness, completeness, of orders being fulfilled become particularly important. This group of mechanisms is insufficiently discussed in the literature. The set of flow mechanisms will constitute the construct of logistics coordination in the research. As logistical coordination is aimed at reliable process execution (i.e. timely, damage-free and complete fulfilment of customer orders), also under the impact of disruptions, it can be assumed that the selection of flow coordination mechanisms simultaneously aims to strengthen the resilience of the distribution system. Thus, mechanisms are sought that allow for consistency of operations and continuity of processes, regardless of the factors affecting the flows of finished goods. In the study of NG, the authors point to VMI, CPFR and others. These are detailed tools in flow management; however, they do not exhaust the impact on logistical problems that face the coordinator of distribution networks, supply networks or supply chains. Intuitively, the flow mechanisms identified by NG researchers touch on key areas for flow management, including forecasting, inventory management. The proposed construct of logistics coordination in networks of cooperating organisations adopts a broader spectrum, building on the concepts of strengthening resilience.

Sheffi (2005) examining the ways in which companies are able to respond to severe disruptions and carry out actions to reduce the risk associated with disruptions found that:

- Bottlenecks related to disruption are reduced through monitoring, early warning systems, rapid response to changing needs, collaboration and redundancy.
- Operational flexibility is increased through standardisation of parts to facilitate interchangeability (product modularity, logistics-oriented product design), a deferred production strategy or mass customisation of products (multi-variants) in response to hard-to-predict changes in needs, customer and supplier relationship management.

Dos Santos and Alcantara (2015) identified approaches to strengthen the resilience of logistics systems, including supply chains and networks: flexibility of logistics processes, increasing the number of suppliers, minimising process lead times, planning with other links (joint planning in the supply network), preparing contingency plans, certifying suppliers, introducing a risk management culture, increasing network density (a reference to the geographical distribution of individual nodes in a distribution network, where density is inversely proportional to the geographical distance between nodes), redundancy (redundancy, excess resources and (reserve) relationships that offset the impact of change).

Kramarz, Kramarz (2017) combine the aforementioned approaches in proposing four concepts for enhancing resilience, conditional on the degree of product differentiation and demand fluctuations: increase in network width and density (surplus suppliers and intermediaries), flexible resources and processes, surplus inventories (at the material distribution point of the supply chain), emergency transport. The ways of enhancing resilience included in these four groups, extended by a fifth group capturing the transparency (visibility) of resources and needs at the nodes of the network (including integrated forecasting for all network participants), provide a set of logistics coordination mechanisms aimed at synchronising flows, ensuring process continuity and network coherence. At the same time, it is a collection of heterogeneous mechanisms, some of which are proactive and some of which are reactive. A proactive approach to resilience refers to actions taken before a crisis situation occurs (network density, redundancy, visibility, forecasting). Reactive approaches, on the other hand, are actions taken to recover lost capacity after an emergency has occurred (emergency transport, subcontracting, flexible processes).

3. Methodology

The risk of disruption to entire logistics processes is significant. The number of methods available for the identification and analysis of disruptions is also high. Most often, several complementary methods are used, which together give a more accurate picture not only of the number of disruptions themselves, but also of the strength of their impact, understood as effects on the implemented processes or the entire organisation. This makes it easier to adjust corrective actions (Khan et al 2022). Such an approach was used in the conducted research.

Two disruption measurement cards were used to identify disruptions (Table 1 and Table 2). Disruptions were marked at the central node of the network over a period of 2 months on a daily basis by employees at different stations. The first card was generated by the person carrying out the measurements on the basis of the data collected in the IT system.

Table 1.
Disruption measurement sheet

Planned delivery		Delivery made		Does it contain damage?	Has there been a return?	Assortment	Carrier	Delivery type
date	size	date	size					

Source: compiled on the basis of Kramarz M. Kmiecik M. – " Pomiar zakłóceń w wybranym węźle sieci dystrybucji", Zeszyty Naukowe Politechniki Częstochowskiej, Zarządzanie, Nr 26, 2017.

The processing of the collected data started with the determination of cause-and-effect realisations. In order to collect this information, a disturbance measurement sheet for each site was used (Table 2).

Table 2.
Site-specific disruption measurement sheet

Date	Disruption	Cause (description)	Responsible entity	Effect (description)	Point assessment of disruption (organisational)

Source: Kramarz M. Kmiecik M. – „Pomiar zakłóceń w wybranym węźle sieci dystrybucji", Zeszyty Naukowe Politechniki Częstochowskiej, Zarządzanie, Nr 26, 2017.

A five-point scale was used to assess the effects of disruptions, where 1 - the effects of a disruption are negligible, while 5 – results the effects of which are very strong. The effects of disruptions and the ways in which they are dealt with are reflected in the reliability of the orders processed, so reliability indicators were determined in parallel to the measurements carried out. Among the indicators proposed for the distribution study, the following were used:

Completeness of orders carried out

$$KRZ = \frac{Number\ of\ complete\ deliveries}{Number\ of\ all\ deliveries} * 100\%$$

Share of damage in deliveries

$$UWD = \frac{Number\ of\ deliveries\ containing\ damage}{Number\ of\ all\ deliveries} * 100\%$$

Timeliness of deliveries

$$TD = \frac{Number\ of\ on-time\ deliveries}{Number\ of\ all\ deliveries} * 100\%$$

Share of returns

$$UZ = \frac{Number\ of\ returns}{Number\ of\ all\ deliveries} * 100\%$$

The data collected with the second card allowed the calculation of indicators. The research was conducted for stationary sales and online sales. After the deviations in the implemented processes were identified by means of an indicator analysis, three reliability problems were selected and subjected to a cause-and-effect analysis followed by an FMEA. As a result, recommendations were developed for the coordinator of finished goods flows in the distribution network under study.

4. Results and discussion

4.1. Household appliances distribution network

The distribution of household appliances, due to the great diversity of customer segments, is carried out in complex omni-channel networks. The network includes 74 manufacturers, a distribution company (central node of the network which has 3 central warehouses) and retail nodes. The omni-channel system combines three distribution channels: sales in the online shop, sales in the household appliances shop and sales in furniture studios. These channels are integrated with each other and the customer is free to order and return products throughout the system. There are currently 419 shops in the specialist household appliances retailer network and 300 hubs in the furniture studio group. Points belonging to the company's own brand are also points of self-collection by the customer. Increasing the width of the distribution network allows additional services to be offered, which builds the company's competitive advantage against its competitors. At the same time, market penetration and network density increase. To deliver products to its points, the company uses both its own and third-party transport means. The company's own means of transport include 80 fully equipped trucks adapted to adequately secure the transported white goods.

4.2. Analysis of disruptions in material flows

The data collected with Card 1 refers to the operation of the entire distribution network using channels such as sales in household appliance shops, internet sales and sales to customers who additionally place a furniture order at a particular kitchen studio.

This was measured over 2 months on weekdays. Three reliability parameters were identified that deviated from the expected values. These cases were further analysed. The reliability indices of the completed orders determined during the study period are presented in Table 3.

Table 3.
Reliability indicators of the omni-channel procurement process

Indicator	Sale at the point of sale of household appliances	Sales in a furniture shop	Internet sales
KRZ	100%	100%	100%
UWD	0%	0%	12%
TD	92%	94%	86%
UZ	0%	0%	16%

The problems shown in the indicator analysis were selected for analysis, i.e. timeliness in each of the channels analysed, as well as returns and damages in the case of online sales.

In further analysing and looking for what might influence a particular effect, an Ishikawa diagram was a helpful tool.

Delays in order fulfilment can generally have multiple sources of the problem. In the B2B system, employees completing questionnaire 2 indicated that the main problem is the inability to know exactly which of the company's warehouses the goods are in and how many items are in stock. Such information is not available on the B2B platform, which is very problematic because the suggested lead time in some extreme cases can differ significantly from the actual lead time. This is due to the need to add the movement of goods between the company's respective warehouses to the lead time. Equally problematic is outdated and inaccurate information in the system. Discrepancies occurring can be caused by poor input of order data into the system, or by inventory taking being carried out incorrectly or too infrequently to catch such value differences. In addition to this, other causes have also been identified, such as delays from a lack of adequate servicing of the transport fleet, sudden breakdowns or congestion, among others.

The identified damage to delivered goods relates to the processing of online orders via courier companies. Here, the percentage of damage is very high and this is due, among other things, to poor preparation of the consignment for shipping. Such preparation should include adequate additional protection with foils and tapes as well as appropriate additional labelling that informs about the contents and the need for more attention. The identified damage concerned both cooker hoods and induction/gas hobs. This situation occurs due to the use of damage- prone glass in the majority of the product.

The returns identified during the period under review also related to orders placed through the online shop. The main problem with returns is the combination of this problem with the previously mentioned damages. The research did not separate returns from complaints. The occurrence of damage is synonymous with the return of goods. However, there are other reasons for returns, which depend on adequate pre-sales preparation. Such preparation includes creating as accurate and reliable a description as possible of the item the company wants to sell. If there is a discrepancy with the description, or confusion between the description of one product and another, the customer can request a cash refund and send back the ordered product because of the discrepancy. In the cases investigated, there were also hidden defects in the products. The responsibility in this case lies with the manufacturer. Of course, customer confusion by buying goods that do not match, for example, the technical specifications of furniture, is also a factor that can affect returns.

4.3. Analysis of identified causes trough FMEA

The identified causes of the effects were analysed in the next stage using the FMEA tool. The use of likelihood ratios and the importance of given causes in the analysis provided a more complete picture of the risks involved, which made it possible to identify logistical coordination mechanisms for strengthening the resilience of this network.

Table 4.
FMEA analysis

ANALYSIS OF CAUSES AND EFFECTS OF DEFECTS										
No.	**Potential error**	**Consequences of an error**	**Causes of the error**	**CURRENT STATE**				**COMMISSIONED ACTIVITIES**		
				Probability of error occurrence	**Relevance to the customer**	**Probability of error detection**	**Number of risks**	**Recommended preventive measures**	**Responsibility**	**Implementation deadline**
1	Failure to deliver on time	Delay in order fulfilment	Wrongly entered order	3	9	3	81	Provision of additional training for employees	Head of logistics	Immediately for each new employee; periodically once a month for older employees
		Entry of a goods order with a long waiting time	No check on product availability	1	9	2	18	Introduction of control cards requiring the input of values from the B2B platform	Head of logistics	Immediately
		The need to carry out the order again	Incorrectly prepared consignment note	4	9	2	72	Provision of additional training for employees	Head of logistics	Immediately for each new employee; periodically once a month for older employees
		Uncertainty of lead time due to movement of products between warehouses	No quantitative data on the availability of goods in specific warehouses	10	9	9	**810**	Redesign of the B2B platform to increase the volume and accuracy of information	Head of IT	Immediately
		Ordering of goods from the manufacturer only upon receipt of an order from the customer	Outdated data in the system	3	9	4	108	More frequent updating of the product database on the platform	Head of IT	once/week
		Need to order missing goods from manufacturers	Data in the system not in line with reality	3	9	2	54	Taking stock more frequently	Warehouse manager	once/month
		Delay in execution	Car breakdowns	4	6	7	168	Increasing the frequency of inspections	Head of Technical Maintenance	Daily checks on drivers before they start work

		Delay in execution	Obsolete fleet	4	3	1	12	Fulfilment of closer orders using an older fleet	Head of logistics	Immediately
		Delay in execution	Road accidents	5	5	10	250	Use of alternative modes of transport with less risk of accidents	Head of logistics	Immediately for all possible orders
		Delay in execution	Excessive traffic	3	2	6	36	Optimisation of transport routes using routes with less traffic	Head of logistics	Immediately for any orders on a permanent basis
2	Damage to goods in the process of delivery to the customer	Damage to goods	Inadequate protection of the consignment by the packer	6	9	3	162	Training for staff responsible for safeguarding	Warehouse manager	Immediately for new employees; once/month for older employees
		Damage to goods at transshipment depots	Lack of care by the person responsible for handling the goods	7	8	10	**560**	Changing contract terms with courier companies to be stricter when shipments are damaged at subcontractors' warehouses	Head of logistics	Immediately for all contracts with courier companies
		Damage to the consignment due to lack of awareness of the goods at increased risk of damage	Lack of appropriate additional marking of consignments	9	7	8	**504**	Introduction of a commodity database and necessary additional markings for use in packaging	Warehouse manager	Immediately; Immediately on each change of assortment
		Failure to secure the consignment thoroughly	Too much haste in the performance of duties	7	5	9	315	Reorganisation of the work of the postal packer	Warehouse manager	Immediately
3	Return of products from the customer	Misleading information to the customer	Inadequate description of the item for sale	3	8	2	48	Controlling the description of products displayed in the webshop	Head of logistics	Immediately; Daily spot checks on descriptions
		Lack of relevant data necessary for delivery	Incorrectly prepared consignment note	3	7	2	42	Provision of additional training for employees	Head of logistics	Immediately for each new employee; periodically once a month for older employees
		Sending goods to the wrong address or person	Improper shipment of goods	2	9	3	54	Introduction of random label checks	Warehouse department manager	Randomly tested labels on a daily basis

		Receipt by the customer of goods not in conformity with the order	Dispatch of goods not in conformity with the order	2	10	2	40	Introducing the need to scan the codes of products being shipped	Warehouse department manager	Immediately
		Lack of adequate customer service; loss of reputation	Receipt of damaged goods by the customer	5	10	9	**450**	Introducing a policy of additional packages offered to customers in case of such situations	Customer service manager	Immediately
		Lack of adequate customer service; loss of reputation)	Receipt by the customer of goods of dubious quality	2	9	8	**144**	Introduce a policy of additional packages offered to customers in case of such situations	Customer service manager	Immediately

Source: own work.

The proposed mechanisms for responding to disruptions relate to increased transparency in the distribution network, both in terms of order information in the system and stock positions at individual warehouses. Since part of the disruption concerns flow security, it is necessary to strengthen the solutions for securing shipments and the certification of carriers and higher requirements for courier companies. At the same time, it is also necessary here to improve the transparency of information about products and the necessary way of securing and labelling them. The coordinator in the network studied uses mechanisms related to redundancy of stocks in central warehouses and redundancy of intermediaries and carriers as well as sales forecasting for individual assortment groups. One of the necessities of reactive actions is the organisation of emergency transport, which is applied in the network studied thanks to the fact that the central link has its own fleet and at the same time cooperates with carriers.

The indicated logistics coordination mechanisms do not exhaust the possibilities of building the resilience of the studied logistics system. The limitation of the obtained results is the time of conducting the measurement. Thus, the results obtained should be treated as a contribution to further research on logistical coordination. The construction of a system for managing knowledge about disruptions in the distribution network should be a further stage of building the concept of strengthening the resilience of the distribution network.

5. Conclusions

By examining the resilience of the distribution network using a selected distributor as an example, it was possible to identify disruptions and assess the risk of disruptions using analytical tools. During the analysis, the focus was on the reliability parameters that performed weakest in the indicator analysis.

The main problems identified relate to the dispatch of goods via courier companies and the lack of adequate information in the B2B system. In order to adequately improve information exchange, the B2B platform needs to be redesigned. The second major problem is damage to parcels, in transport carried out by a courier company. In this case, the financial impact for the company is not so great due to parcel insurance, but it is an undesirable situation in terms of the final level of customer service.

The solutions identified relate to strengthening resilience using mechanisms that allow for increased transparency (visibility) of the network by all participants.

High resilience to disruption, on the other hand, can be seen in the parameter of completeness of orders processed. Operational activities at the picking stage, a high degree of process flexibility - including combining assortments from different warehouses, surplus stock across the network and surplus suppliers and intermediaries are responsible for this. An additional advantage is the combination of the company's own fleet with external transport companies, which also increases the flexibility of the processes carried out.

The indicated mechanisms, both those used by the coordinator and those proposed to be used to increase the resilience of the distribution network, go beyond the flow mechanisms proposed in network coordination. Thus, it makes sense to extend the flow mechanisms to include logistics coordination in the broadest sense, which aims to synchronise flows, ensure the continuity of the processes carried out and the coherence of the activities of the network nodes. For the implementation of this concept, it will be important to design a system for managing knowledge of disruptions in finished goods flows. At the same time, the research conducted should be extended to other types of networks (characterised by other attributes).

References

1. Abbasi, M., Varga, L. (2022). Steering supply chains from a complex systems perspective. *European Journal of Management Studies. 27(1),* DOI 10.1108/EJMS-04-2021-003, pp. 5-38.
2. Brintrup, A., Wang, Y., Tiwari, A. (2015). Supply Networks as Complex Systems: A Network-Science-Based Characterization. *IEEE Systems Journal, 11(4)*, pp. 1-12.
3. Bukowski, L. (2019). *Reliable, Secure and Resilient Logistics Networks: Delivering Products in a Risky Environment*. Springer.
4. Christopher, M., Peck, H. (2004). Building the resilient supply chain. *International Journal of Logistic Management, 5(2),* pp. 1-14.
5. Czakon, W. (2008). Koordynacja sieci – wielkoraka forma organizacji. *Przegląd Organizacji, 9,* pp. 7-10.
6. Czakon, W. (2013). Uwarunkowania i mechanizmy koordynacji sieci. *Studia Ekonomiczne. Governance – korporacje, instytucje publiczne, sieci, 141,* pp. 62-71.
7. Dos Santos, M.G., Alcantara, R.L. (2015). *Management capabilities in supply chain resilience.* Proceedings of the POMS 26th Annual Conference. Washington.
8. Fadda, N., Rotondo, F. (2020). What Combinations of Conditions Lead to High Performance of Governance Networks? A Fuzzy Set Qualitative Comparative Analysis of 12 Sardinian Tourist Networks. *International Public Management Journal*. doi:10.1080/10967494.2020.1755400, pp. 1-27.
9. Fiksel, J. (2004). Designing Resilient, Sustainable Systems. *Environmental Science and Technology. 37(23),* pp. 5330-5339.
10. Guan, Y., Aamir, M., Dayo, Z., Rahman, Z., Abro, W., Ali, I., Hu, Z. (2021). A Coordinated Optimization Model of the Complex System of the Green Supply Chain Distribution Network. *Discrete Dynamics in Nature and Society, 2(12),* pp. 1-12.
11. Heide, J. (2003). Plural Form Governance in Industrial Purchasing. *Journal of Marketing. 67(10),* pp. 18-29.

12. Hoetker, G., Mellewigt, T. (2009), Choice and performance of governance mechanisms: matching alliance governance to asset type. *Strategic Management Journal, 30,* pp. 1025-1044.
13. Isett, K., Mergel, I., LeRoux, K., Mischen, P., Rethemeyer, R. (2011). Networks in Public Administration Scholarship: Understanding Where We are and Where We Need to Go. *Journal of Public Administration Research and Theory, 21(1),* pp. i157-i173.
14. Kazmi, S., Shahzad, M., Khan, A., Shin, D. (2017). Smart Distribution Networks: A Review of Modern Distribution Concepts from a Planning Perspective. *Energies, 10(501),* doi:10.3390/en10040501, pp. 1-45.
15. Khan, J., Ishizaka, A., Mangla, S.K. (2022). Assessing risk of supply chain disruption due to COVID-19 with fuzzy VIKORSort. *Annals Operations Research*. https://doi.org/10.1007/s10479-022-04940-9.
16. Kramarz, M. (2018). Problem odporności w koordynacji sieci dystrybucji. *Studia Ekonomiczne, 351,* pp. 34-45.
17. Kramarz, M., Kmiecik, M. (2017). Pomiar zakłóceń w wybranym węźle sieci dystrybucji, *Zeszyty Naukowe Politechniki Częstochowskiej, Zarządzanie, Nr 26,* pp. 178-187.
18. Kramarz, M. (2012). *Strategie adaptacyjne przedsiębiorstw flagowych sieci dystrybucji z odroczoną produkcją.* Gliwice: Wydawnictwo Politechniki Śląskiej.
19. Kramarz, M., Kramarz, W. (2017) Elastyczność w kształtowaniu odporności sieci dystrybucji. *Zeszyty Naukowe Politechniki Śląskiej, Organizacja i Zarządzanie, 103,* pp. 95-108.
20. Kramarz, M., Twaróg, S. (2017), Koordynacja sieciowa – model badań nad koordynacją sieci zdominowanych i równorzędnych parterów. In: R. Matwiejczuk, I. Pisz (eds.), *Przedsiębiorczość i Zarządzanie, Logistyka w Naukach Zarządzaniu, tom XVIII, z. 8* (pp. 309-322).
21. Kramarz, W., Kramarz, M. (2014). Czynniki ryzyka w kontekście odporności sieciowego łańcucha dostaw wyrobów hutniczych. *Marketing i Rynek, 5,* pp. 434-441.
22. Lu, P., Stead, D. (2013). Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands. *Cities, 35,* pp. 200-212.
23. Provan, K.G., Kenis, P. (2008). Modes of Network Governance: Structure, Management, and Effectiveness. *Journal of Public Administration Research and Theory, 18(2),* pp. 229-252.
24. Sahin, B.F., Mentzer, J.T. (2006). Supply Chain Management Coordination Mechanisms. *Business Logistics, 27(2),* pp. 129-161.
25. Sheffi, Y., Rice, J. (2005). A Supply Chain View of the Resilient Enterprise. *MITSolan Management Review, 47(1),* pp. 41-18.
26. Young, M., Dulewicz, V. (2008). Similarities and Differences between Leadership and Management: High – Performance Competencies in the British Royal Navy. *British Journal of Management, 19,* DOI: 10.1111/j.1467-8551.2007.00534.x, pp. 17-32.

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RESOLVE MODEL IN MAPPING THE CIRCULAR ECONOMY INITIATIVES OF SILESIAN ENTERPRISES

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Purpose: Changes taking place in the modern world, caused by the depletion of natural resources, and the resulting need to search for such production methods that lead to the minimisation of extraction and processing of primary raw materials, point to the need for a paradigm shift in business towards the implementation of closed material cycles. The aim of this article is to assess the extent to which Silesian enterprises are implementing initiatives related to the implementation of a circular economy with the use of the ReSOLVE model, a research framework that facilitates an overview and mapping of activities that form the basis for building circular business models.
Design/methodology/approach: The study covered companies of different sizes (both SMEs and large entities) which operate in the Silesian Voivodeship. A non-probabilistic and purposive sample was selected, which ultimately included 36 companies (25 SMEs and 11 large companies).
Findings: The study shows that the surveyed SMEs are much more active (when compared to large enterprises) in taking measures that, according to the ReSOLVE model, fall into the categories of Regenerate and Share. In turn, the advantages of large enterprises relate to, among other things, designing products to ensure their longer life cycle, reducing waste production and using systems/equipment that optimise resource consumption, recovering raw materials, implementing virtual services, and upgrading existing or using new technological solutions. In relation to large enterprises, the respondents indicated legal barriers as the most important, while in the SME group, market barriers, including in particular higher costs associated with the production of circular products, were mentioned.
Originality/value: The study results presented in the article complement the previous literature on strategic directions, barriers and benefits while building circular business models. The key scientific contribution of the article is to confirm, in the reality of the Polish economy, the usefulness of the ReSOLVE model for identifying activities related to the implementation of a circular economy at the organizational level.

Keywords: circular economy; ReSOLVE.

Category of the paper: historical case study.

1. Introduction

There are many companies that have, for decades, operated according to a linear management model. In that model, little attention was paid to aspects such as how to maximize efficient management of waste generated in production processes, how to process it and how to design products and processes to facilitate those efforts. There has also been little thought given to what happens to the product after its lifetime, how many such products end up in the landfill, and what the environmental and social impacts of this would be. Most of these companies are still not yet equipped to change their current operating model (Puntillo, 2022). Nevertheless, the inevitable consequences of the predatory use of natural resources are contributing to the search for a new paradigm for managing the relationship with the environment. This applies both to the behaviour of people and companies, the enterprises they pursue and the attitudes of national governments towards the environmental issues (Mies et al., 2021; Khatami et al., 2023).

The ever-growing trend towards the development of a circular economy is meeting these demands. Evidence of the growing popularity of that matter can be seen in the fact that, over the past decades, the number of scientific publications on the topic has increased from 12 papers in 2008 to more than 2,300 in 2020. On the one hand, the research seeks to conceptualise the concept of a circular economy, to establish its relationship with existing theories and concepts in the management science and the implications for the creation of new business models, as well as their implementation in individual industries. On the other hand, research in the area of environmental engineering is focused on applications of CE strategies and the search for viable solutions to production and environmental problems (Alcalde-Calonge, 2022).

2. Background

A circular economy can be defined in many ways. As early as in 2017, more than 114 definitions of the concept were collected (Kirchherr et al., 2017). One indicates that a circular economy is seen as a combination of activities to reduce, reuse and recycle the waste produced (Kirchherr et al., 2017). Another portrays it as an economy that keeps products, components and materials in circulation for as long as possible. As they reach the end of their usefulness, they are reused, forming the basis for further value creation (EC, 2014). The key outcomes of implementing a circular economy are to reduce waste and minimise the extraction and processing of primary raw materials (Takacs et al., 2022).

It is sometimes explicitly emphasised that a circular economy is an alternative (to the linear view) model of sustainable production and consumption. It is defined as a growth strategy that enables the 'decoupling' of resource use from economic growth, thus contributing to the realisation of the concept of sustainable development (Reike et al., 2018; Jabbour et al., 2019). A circular economy is also interpreted as an economic system that requires a paradigm shift in the connection between society and nature. It aims to prevent the depletion of resources, energy and materials. These actions should be accompanied by successive ecological innovations in the ways of legislation, production and consumption in a sustainable society (Puntillo, 2022).

The implementation of a circular economy can be achieved in two ways: top-down, through the formal introduction of environmental policy standards at the national and/or international level (a macroeconomic approach), or bottom-up, through the development of initiatives taken by individual economic actors and/or small communities (a microeconomic approach) (Geng et al., 2019).

From a macroeconomic perspective, researchers mainly emphasise the role of an institutional change (Oluleye et al., 2022; Rizos, Bryhn, 2022) and, above all, the importance of the fiscal and monetary policy tools used by the state (Velenturf et al., 2018; Tedesco et al., 2022). Guided by this research perspective, one can also see the high place of the topic of a circular economy in the strategic documents of individual countries, including in particular Asia (Neves, Marques, 2022) and Europe (EC, 2014a, 2015a). The first European countries to undertake the implementation of initiatives, pilot programmes and policies on a circular economy were Denmark, the Netherlands, Germany, France and the UK (Blomsma et al., 2017; Murray et al., 2017; Reike et al., 2018). In these countries, there are a number of initiatives to promote and develop the circular economy embedded in the European Action Plan for a Circular Economy (EC, 2020). The implementation of circular economy solutions in conjunction with environmental challenges, is also an important direction from an application perspective, including in particular adaptation to the climate change (Yang et al., 2022).

From a microeconomic perspective, researchers emphasise the need for companies to build and implement circular business models in which, according to the definition most often used in the literature by Linder and Williander (2017, p. 183), 'the conceptual logic for value creation is based on utilising economic value retained in products after use in the production of new offerings'. In other words, a circular business model implies using business opportunities in such a way that the company can create value not only economically, but also socially and environmentally. Indeed, a key role of the circular business model is ‘to incorporate the circular economy principles into a design or redesign of business activities and partnerships and to create a cost and revenue structure, which is compatible both with sustainability and with profitability’ (Zucchella, Previtali, 2019, p. 275).

Implementation of the concept of a circular economy from a microeconomic perspective appears to be more effective and sustainable and to lead more quickly to the desired economic and social outcomes. Both large entities and SMEs play a significant role in the implementation

of a circular economy. SMEs account for 99% of all enterprises in the European Union (OECD, 2019; Tackas et al., 2022). This means that they contribute significantly to the pollution emitted into the atmosphere, hydrosphere and lithosphere, as well as to the uneconomic use of available resources. Hence, it is an important issue to determine the level of familiarity with a circular economy in that group of companies and to identify the necessary actions to be taken that would increase their commitment to improvement of the environment.

The analysis presented in this paper uses the ReSOLVE model, a research framework developed by the Ellen MacArthur Foundation (EMF, 2015b). The model provides an overview and mapping of the activities that underpin the building of circular business models by companies in the following thematic areas: Regenerate, Share, Optimise, Loop, Virtualisation and Exchange.

Regeneration (Re) encompasses a broad set of activities that lead to reclaim, retain, and restore health of ecosystems. The activities undertaken by companies relate, in particular, to shift to renewable energy and materials. Returning biological resources to nature, for example through composting, also falls into this category. Actions gathered under Share (S) relate to the key concept of the 'sharing economy' for the development of a circular economy and include practices leading to share assets, reuse, second hand, prolong life through maintenance, design for durability and upgradability. Optimise (O) is about removing energy and material waste in the production of goods and in supply chains, as well as in the process of using them. It also involves leveraging big data, automation, removes sensing and steering to increase performance, and efficiency of products. The Loop (L) set of activities relates to the reuse of used products and their components, through recycling and, more effectively, full or partial remanufacturing. The last two categories, Virtualisation (V) and Exchange (E), describe activities leading respectively to the design and implementation of virtual services by enterprises and the application of new technologies (e.g. 3D printing) and upgrading or replacing existing ways of doing things with new solutions (e.g. replace old with advanced non-renewable materials) (EMF, 2015b).

The described research framework is firmly established methodologically and has been used in a number of studies by, among others, Kouhizadeh et al. (2020) in relation to the application of blockchain technology and Jabbour et al. (2019) in the context of human resource management. While considering the sectoral context, the ReSOLVE model has been a research tool used in analyses of the forest industry (Tedesco et al., 2022), the textile industry (Warwas et al., 2021) and the construction and demolition sector (Superti et al., 2021), among others.

The aim of this paper is to use the ReSOLVE model to assess the extent to which Silesian companies are implementing initiatives related to the enactment of a circular economy. Making such a comprehensive assessment necessitates not only to identify the individual activities undertaken by the enterprises, but also to analyse whether members of the management team of the surveyed companies are interested (or not) in building circular business models. In other words, this article analyses the main barriers to the implementation of circular economy

initiatives at the organisational level classifying them, as recommended by many researchers (Ritzen et al., 2017; Kirchher et al., 2018; Jesus et al., 2018; Oluleye et al., 2022; Rizos, Bryhn, 2022; Takacs et al., 2022), within cultural, legal, technological and market barriers.

The implementation of the concept of a circular economy is associated not only with barriers that can be overcome by taking into account the organisation's strategy and its resources and competencies, but also with a number of benefits that can be achieved (Geng et al., 2007, 2008). Therefore, in order to complement the analysis carried out, it was also necessary to identify the main benefits that might accrue to companies by undertaking initiatives related to the implementation of a circular economy.

Despite the existence of a number of valuable articles on the concept of circular business models (Linder, Williander, 2017; Zucchella, Previtali, 2019; Pichlak, Szromek, 2022), as well as numerous previous research papers whose authors have identified and described the main factors and barriers to implementing the concept of a circular economy at the organisational level, there is a paucity of research papers in the available literature that could offer concrete insights into undertaking such practices in a specific research context, such as the Polish industrial region. This article fills that research gap.

The important theoretical contribution of the article is the confirmation, within the conditions of the Polish economy, of the usefulness of the ReSOLVE model for identifying and mapping activities that constitute the basis for the construction of circular business models by enterprises. Owing to that, the described research framework can be used not only in subsequent studies conducted in the Silesian Voivodeship, but also in other organisational contexts, taking into account the conditions of conducting business in Poland.

The results of the study also provide important, from the point of view of business practice, insights into the implementation of the concept of circular economy in enterprises located in the southern part of Poland, allowing for an empirical verification of the involvement of entrepreneurs in the matter. In addition, identification of the benefits and barriers to the implementation of such practices may help Polish enterprises to plan their strategies and then to build circular business models in the future.

The remainder of the article is divided into three sections: the first section describes the research method used, the second presents the results of the research, while the third includes a reference of the obtained results to the available literature, a summary of the results and an indication of further directions.

3. Methods

The quantitative research method was chosen to achieve the research objective indicated above, as it allows information to be collected in a comprehensive, efficient and generalising manner (Schutt, 2006). The survey was developed and made available with the use of SurveyGizmo, an electronic tool that allows for simultaneous data collection and analysis. This approach facilitates a lower cost of data acquisition, flexibility, a user-friendly format, ease of entry and better structuring of the analysed data (Granello et al., 2004). The structure of the questionnaire contained 28 single-choice and multiple-choice questions. The survey questionnaire was divided into three main parts; in the first part, respondents were requested to indicate which CE practices they applied in their organization and to assign them to the solutions described in the ReSOLVE model. In the second part, the importance of barriers in implementing CE solutions was assessed. Barriers were divided into three groups formal, market and internal. The third part of the questionnaire included statistical questions,

The survey was addressed to both members of the management team of SMEs and large enterprises (with more than 250 employees) operating in the Silesian Voivodeship. The purpose of selecting such a wide range of respondents was to determine what the current level of knowledge and degree of implementation of initiatives related to the implementation of the circular economy was. Six categories of activities (according to the ReSOLVE model) constituting the basis for building circular business models were analysed, as well as, complementarily, the barriers and potential benefits their implementation might create.

The first stage of the adopted research methodology was to develop a structured survey questionnaire consisting of 48 items. The survey questionnaire included closed questions (multiple choice and yes/no/don't know) and open-ended questions, and it was divided into four parts. The first part contained general questions to determine respondents' level of familiarity with the topics covered. Part two of the questionnaire was a tool to assess the degree of implementation of initiatives related to the implementation of a circular economy in the following thematic areas: Regenerate, Share, Optimise, Loop, Virtualise, Exchange. The third part of the questionnaire asked respondents to identify and assess the barriers that hinder (or prevent) the implementation of circular economy initiatives, as well as to identify the associated potential benefits. Finally, the metrics section of the questionnaire covered control variables, in particular company size (measured by number of employees) and industry of operation.

The study was carried out between June and July 2019. Due to the need to meet restrictive prerequisites (a company participating in the study should have belonged to the manufacturing sector, operating in the Silesian Voivodeship and supplying the market with at least one product manufactured using secondary raw materials), a non-probabilistic and purposeful selection of the research sample was decided upon. At the first stage, 127 companies from the Silesian

Voivodeship which fulfilled the initial conditions were selected, to which, at the next stage, an electronic survey questionnaire was sent. The research yielded 41 responses, but after the analysis and elimination of incomplete questionnaires at the third stage, 36 questionnaires remained, completed by members of the management team of 25 SMEs and 11 large enterprises which operate in the following sectors: energy, construction, medical, automotive, packaging and plastics and plastic products.

4. Results

As mentioned above, both large enterprises and SMEs play a significant role in the implementation of a circular economy. However, researchers (Rizos et al., 2015; Tackas et al., 2022) point out that, above all, the activities implemented by SMEs can solve many environmental problems, as a result of the overly extensive use of natural resources, increasing levels of pollutant emissions and a short lifespan of manufactured products and materials used.

The specifics of SME operations obviously differ significantly from those of large enterprises. Among other things, many SMEs are characterised by individualised leadership and management styles (Rizos et al., 2015), a less formalised organisational structure, and greater flexibility to adapt to changing environmental conditions (Jenkins, 2006). Tackas et al. (2022) also note that, SMEs (as opposed to large enterprises) tend to have a rather low level of knowledge about the concept of a circular economy. However, the results of the survey indicate that up to 75% of respondents know and understand the principles of such an economy. The topic of a circular economy was introduced to them as part of the educational activities conducted in their companies, including in particular training for newly hired employees, periodic training or position training on waste segregation. In addition, 76.9% of the companies surveyed conducted reviews/audits to identify where and why waste is generated. More complex activities, such as life cycle assessments, were implemented in only 2.9% of the companies.

4.1. ReSOLVE model analysis

The ReSOLVE model groups the core activities from a microeconomic perspective that form the basis for building circular business models into the following thematic areas: Regenerate, Share, Optimise, Loop, Virtualise and Exchange.

Regenerate - One of the measures conducive to the development of a circular economy is the use of renewable energy sources. The results of the study indicate that Silesian SMEs are far superior to large enterprises in this regard. As many as 30% of the SMEs surveyed use renewable energy sources, while for large enterprises the percentage is only 17%. Photovoltaic cells and solar collectors dominated among the indicated energy sources, although respondents

also mentioned heat pumps, biomass and cogeneration of biogas from methane fermentation of sewage sludge and biodegradable industrial waste.

Share - In terms of sharing available resources, both SMEs and large companies implement practices leading to the development of a circular economy. According to the survey, enterprises share their resources with other entities to a greater extent than they use such resources themselves (23% and 7% for SMEs, 50% and 17% for large companies, respectively). Furthermore, SMEs reuse products that are technically sound and approved for use (second-hand principle) to a much greater extent than large enterprises (40% and 17% respectively). On the other hand, taking maintenance measures to extend the life of used products is more characteristic of large enterprises (67%) than smaller companies (47%). Similarly, probably for financial reasons, large companies are more likely than SMEs to design products to ensure a long-life cycle (50% and 20% respectively).

Optimise - Optimisation measures are not insignificant for the development of a circular economy. These can take the form of, for example, the use of big data, automation, remote sensing, remote control systems, etc. (EMF, 2015b). The results of the study indicate that large enterprises outperform SMEs in all the issues analysed. They strive to increase the efficiency of product manufacturing, reduce waste production (100%), use systems/equipment that optimise the use of water, materials or energy (67%) and introduce activities leading to a reduction in resource consumption (67%). As part of optimisation, companies also aim to minimise losses, e.g. energy or material losses. Among the companies surveyed, both SMEs (43%) and large enterprises (67%) take such measures.

Loop - The possibility of reusing products (or their components) to create new ones is among the practices conducive to a circular economy. It is believed that the production of such products is associated with a reduced negative impact of production activities on the environment, e.g. through reduced consumption of raw materials, including energy, and reduced emissions of pollutants to air, water and soil. A significant proportion of the surveyed enterprises: 36% of SMEs and 67% of large companies, implement practices aimed at collecting used materials (mainly plastics, paper, metals and glass), as well as other waste, such as electro-waste (batteries, fluorescent lamps, light bulbs, accumulators), used oils, used filters (air, oil), cleaning cloths, etc. When assessing the activities of both groups of the surveyed entities in the area of waste collection, it can be concluded that it is at a comparable level. The analysis of the results also shows that 43% of the surveyed SMEs first dispose of the above waste to recycling plants and then sell it (30%). More often than not, these enterprises reuse products within their company (17%) or store them (10%). Large companies follow the same hierarchy, but on a larger scale: sending waste for recycling (67%), selling (50%) or reusing it within the company (17%). These companies additionally transfer waste to other entities that use it in their production processes (50%), which promotes the creation of external closed material cycles. It is noteworthy that 34% of the respondents stated that activities involving the use of materials from one or more products to create a new product do not contribute to lowering its quality. Therefore, for the purpose of production of new products,

both groups of surveyed companies use materials (waste) from their enterprises (this strategy is implemented in 20% of SMEs and 17% of large enterprises, respectively). As part of their activities, respondents also declare recovery of raw materials, understood as a process aimed at utilising part or entirety of waste, substances, materials and energy for reuse. Such activities are carried out by 30% of surveyed SMEs and more than twice as much of large enterprises (67%). Cardboard, pallets and plastics are among the most frequently mentioned types of recovered raw materials. Companies convert their own waste into granulates, reuse process water and rainwater (e.g. by creating closed cooling water circuits), and use waste heat or biogas to generate electricity. The surveyed companies also use electronic parts from old and worn machines to repair other equipment.

Virtualise - In terms of reduction of raw material consumption, the surveyed companies are increasingly implementing virtual services. These mainly consist of conducting meetings with the use of online communication and virtual workflows. According to the survey, 37% of SMEs and 100% of large companies use this way of working. Respondents mostly prefer web-based software that enables calls, meetings, conferences and training (e.g. via Skype, WebEx), as well as the exchange of short information (e.g. WhatsUp, Messenger). Entrepreneurs also use email to transmit, for example, e-invoices and other documents. Some of the respondents also use cloud computing, public clouds for document storage, measurement visualisation technologies, control systems, virtual connection systems to customer-operated equipment, and virtual advisors in the customer services.

Exchange - The last category of activities which leads to the realisation of the idea of a circular economy includes the application of new technologies and the modernisation or replacement of existing solutions with new ones. According to the survey, 30% of SMEs and 83% of large enterprises undertake such activities. Among the most frequently implemented new technologies, respondents indicated: automation of technological lines and processes, water-saving technologies, technologies which enable production of compostable packaging, printing of films with water-based paints, powder painting instead of solvent painting, the possibility of using energy-saving lighting, as well as specialised technologies, such as laser cutting of steel. The surveyed enterprises also declare the use of modern products and/or services (27% of SMEs and 33% of large enterprises, respectively). Furthermore, among the activities contributing to the replacement of worn equipment and the change of economically unprofitable and environmentally burdensome production methods, the respondents mentioned activities which comprised, as follows:

- constant search for new technical solutions for the construction and automation of technological processes,
- use of state-of-the-art materials and electronic solutions in products (signing a contract with a company that provides consulting services and then guidelines on new ways/methods of operation),
- use of compostable raw materials,

- implementation of modern IT systems, and
- use of telemetry for monitoring the district heating network.

All the above-mentioned activities are necessary and essential for the development of a circular economy, but their implementation may be hindered (or even prevented) by the existence of various types of barriers to execute them.

4.2. Barriers and benefits of implementing circular economy initiatives

Both theoretical and empirical in nature studies whose authors identify and classify the barriers that hinder (or prevent) companies from implementing circular business models are new but increasingly popular research trend in the literature related to a circular economy. In this article, the barriers are grouped into the four most common areas related to a circular economy in the literature (Ritzen et al., 2017; Kirchher et al., 2018; Jesus et al., 2018; Oluleye et al., 2022; Rizos, Bryhn, 2022; Takacs et al., 2022). Prominent among these were: (1) cultural barriers; (2) legal barriers; (3) technological barriers and (4) market barriers, and Figure 1 highlights the issues that further characterize them.

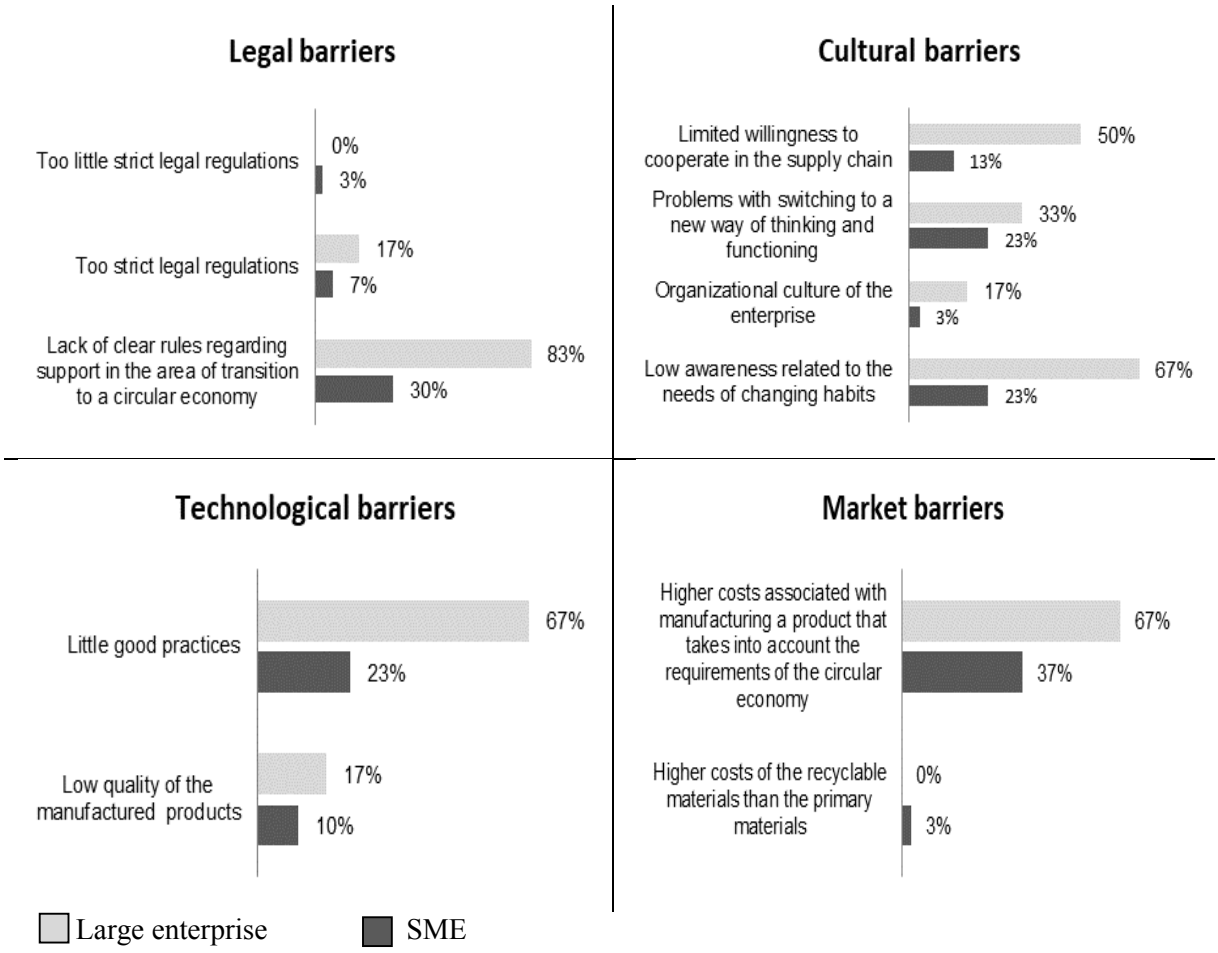

Figure 1. Barriers hindering the implementation of circular economy initiatives by Silesian enterprises. Source: own study.

The results of the research presented in Figure 1 indicate that the impact of individual barriers on the implementation of the assumptions of a circular economy is different depending on the size of the surveyed enterprises. Thus, for large enterprises, the hierarchy of the main barriers is as follows (barriers have been ordered in descending order, guided by the number of responses): (1) lack of clear rules regarding support in the area of transition to a circular economy (legal barrier); (2) low awareness related to the need of changing habits (cultural barrier); (3) few good practices (technological barrier); (4) higher costs associated with manufacturing of a product that takes into account the requirements of a circular economy (market barrier) and (5) limited willingness of actors in the chain to cooperate (cultural barrier).

The obtained results indicate that appropriate institutional and regulatory support is one of the most important factors that support the implementation of circular economy initiatives by Silesian companies. The lack of clear political and legal rules to support the activities undertaken by companies (e.g. waste collection and sorting or quality assurance of secondary materials) is a key barrier to the implementation of circular business models. Similarly, insufficient awareness of management team members and employees related to the need to change habits, resulting, inter alia, from the lack of adequate knowledge management on a circular economy in enterprises, is a factor that significantly limits the search for and implementation of possible circular solutions. The identified barriers are all the more significant as they affect both groups of entities surveyed.

As far as the difficulties encountered by the surveyed SMEs in implementing initiatives related to the implementation of the closed loop economy are concerned, these are as follows: (1) higher costs associated with manufacturing a product that takes into account the requirements of a circular economy (market barrier); (2) lack of clear rules regarding support in the area of transition to the circular economy (legal barrier); (3) low awareness related to the need to change habits (cultural barrier); (4) problems in switching to a new way of thinking and functioning (cultural barrier) and (5) few good practices (technological barrier).

The results of the study confirm the findings of the literature (Oluleye et al., 2022; Rizos, Bryhn, 2022), according to which a lack of financial resources is one of the most frequently cited barriers for companies to implement circular business models. Although the level of investment needed to implement particular practices resulting from the ReSOLVE model may vary, some activities (e.g. the introduction of advanced high quality recycling technologies) require significant financial investment, which is a significant barrier, especially for SMEs.

To summarize, the surveyed companies perceive barriers in each of the four areas mentioned (cultural, legal, technological, market). In addition, it is worth noting that barriers belonging to the cultural area are most frequently mentioned, including, inter alia, limited willingness of entities to cooperate in the supply chain. Such results may be due to the fact that, compared to the linear model, building links that close product and material flows implies greater complexity in the supply chains. Moreover, it should be borne in mind that some of the markets for materials and components necessary for the implementation of closed-loop flows

are still in the development stage, which creates additional difficulties, especially for SMEs (Rizos, Bryhn, 2022).

Respondents were also asked whether they see benefits associated with building circular business models as a derivative of implementing the newly emerging trend of circular economy development. The results of this part of the survey are summarised in Figure 2 below.

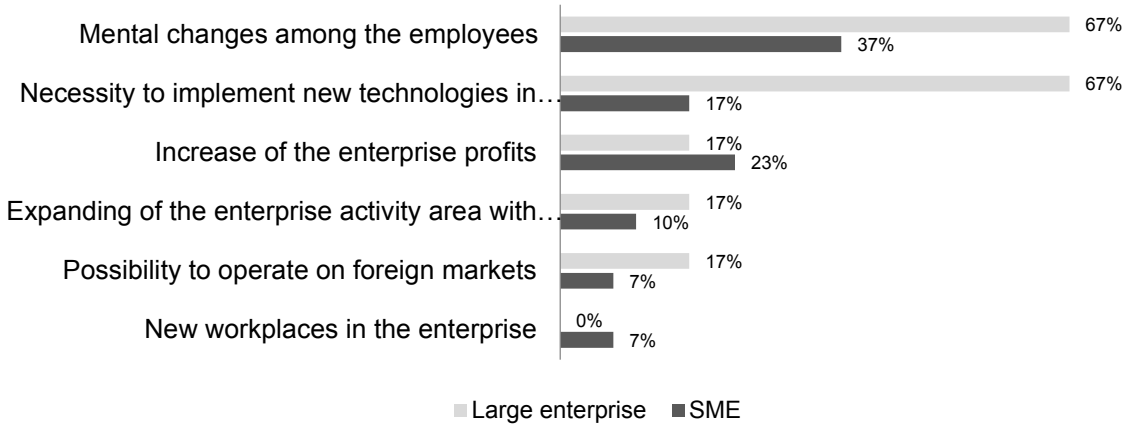

Figure 2. Benefits flowing from the implementation of circular economy initiatives by Silesian companies.

Source: own study.

Analysing the obtained results, it can again be seen that they heavily depend on the size of the enterprise. The systematisation of benefits shows that, despite differently distributed percentages, both large enterprises and SMEs see the same benefits from building circular business models, yet with a notable difference that members of the management team of large enterprises do not see the prospect of new jobs being created in connection with the implementation of circular economy assumptions.

5. Discussion and conclusion

Despite increasing environmental degradation, most economies in the world (including the Polish economy) still operate based on a traditional linear model of economic activity, which does not take into account the environmental burdens generated by production and consumption processes and the natural limits of economic growth. This conclusion is based on the fact that, in 2020 and 2021, only around 10 per cent of the global economy met the requirements of a circular economy (Oluleye et al., 2022; Takacs et al., 2022), despite the assumed significant and measurable benefits.

It is estimated that the implementation of a circular economy (including, inter alia, eco-design, waste prevention and maximisation of reuse) can bring benefits in the form of economic growth, through the creation of new businesses and jobs, as well as resource, material

and energy savings and reductions in waste generation and emissions. The European Commission has estimated that the effect of implementing the aforementioned economic transformations could result in gains estimated at €600 billion for the EU manufacturing sector alone (EMF, 2013; Kalmykova et al., 2018). According to the European Commission (EC, 2019), as early as in 2016, sectors relevant to a circular economy employed more than 4 million workers, an increase of 6% compared to 2012. In 2016, circular activities such as repair, reuse or recycling generated almost €147 billion in added value, contributing to investments worth around €17.5 billion (Eurostat, 2019).

Although both practitioners and academics point to the necessity of implementing the concept of a circular economy, many businesses still find it difficult to comply. This is why research carried out at the organisational level, the results of which can help businesses plan their strategies and then build circular business models in the future, becomes so important. Guided by such a practical rationale, this paper assesses the extent to which Silesian companies are implementing circular economy initiatives with the use of the ReSOLVE model, a research framework widely accepted in the literature and used in many previous studies (Jabbour et al., 2019; Kouhizadeh et al., 2020; Superti et al., 2021; Warwas et al., 2021; Tedesco et al., 2022).

Developed by the Ellen MacArthur Foundation (EMF, 2015b), the ReSOLVE model groups circular activities undertaken by companies into the following thematic areas: Regenerate, Share, Optimise, Loop, Virtualise and Exchange. Within each of these areas, examples of specific implementation strategies are listed. Each strategy illustrates how, with the help of modern technology, existing activities can be changed to fit into a circular economy model. All these activities can be characterised by increased resource utilisation, extended resource life and a shift from the use of non-renewable resources to renewable ones (Kalmykova et al., 2018).

On the basis of the conducted research, the surveyed SMEs were found to be significantly more active (while compared to large companies) in the use of renewable energy sources (Regenerate) and the reuse of worn products that are technically sound and approved for use (Share). The obtained results are in line with the available literature (Sohal et al., 2022; Sohal, De Vass, 2022; Tedesco et al., 2022), both in the context of activities included in Share and Regenerate. With regard to the first group of activities, Neves and Marques (2022) highlight not only their relevance, but even indicate that a sharing economy can be captured as a sub-dimension of a circular economy. In contrast, with regard to the second group of activities, Cavicchi et al. (2022) emphasise the key role of energy management capabilities in the context of building circular business models by SMEs, while Sirin et al. (2022) highlight the need for institutional support for SME activities (e.g. renewable energy subsidies), so as to discount adverse macroeconomic conditions.

In contrast, the advantages of large enterprises are as follows: designing products in a way that ensures their longer life cycle (Share), reducing waste production and using systems/equipment that optimise resource consumption (Optimise), recovering raw materials (Loop), implementing virtual services (Virtualise), and upgrading existing or using new

technological solutions (Ex-change), among others. As part of the optimisation, large companies also seek to minimise losses, e.g. in terms of energy or materials. These measures mainly focus on the selection of equipment with low energy consumption and high efficiency. The operation of these facilities is subject to frequent monitoring, and any deviations within the operation are immediately corrected. Companies strive to use materials rationally, use recycled raw materials in production and order finished components/semi-finished products that do not require additional processing (reduction of energy consumption, own equipment, etc.). The use of such measures contributes to the optimisation of the working time of production equipment and employees, which consequently reduces the consumption of primary resources (Dev et al., 2020; Ghobakhloo, 2020).

The study shows that initiatives related to the implementation of a circular economy by Silesian enterprises may be hindered by the existence of many barriers, including cultural, legal, technological and market ones. These barriers are characterised by different strength of influence, depending on the size of the enterprise. In relation to large entrepreneurs, legal barriers were indicated by respondents as the most significant (lack of clear rules concerning support in the area of implementation of circular economy assumptions), while in the SME group the market barriers, including in particular higher costs related to the production of circular products, were pointed out most frequently. Other often mentioned barriers also included cultural issues, i.e. low awareness related to the need to change habits, problems with switching to a new way of thinking and functioning, and limited willingness of entities in the supply chain to cooperate with each other.

The results of the conducted research clearly indicate the need for specific remedy actions both at the company level and, in particular, from a macro-economic perspective. Indeed, the reduction of regulatory barriers can only be achieved through a coordinated action by policymakers, politicians and industrial practitioners to promote initiatives related to the implementation of a circular economy that are already being implemented by companies, and to establish strategies to implement practices that are still underutilised (Tedesco et al., 2022). Cultural barriers, on the other hand, can be overcome by promoting public dialogue and involving private and public media, non-profit organisations, as well as research and academic institutions (Oluleye et al., 2022). Moreover, organising seminars, trainings and workshops for entrepreneurs can lead to increased awareness of the benefits of implementing circular business models and thus overcome negative attitudes towards the need for change. The provision of funding for R&D and innovation projects, as well as the introduction of economic instruments (e.g. tax incentives for circular businesses), which can significantly reduce market barriers, especially for SMEs, should also be a key course of action to enable circular economy implementation initiatives by businesses (Rizos, Bryhn, 2022).

From the theoretical point of view, the results of the conducted research confirm, within the conditions of the Polish economy, the usefulness of the ReSOLVE model for identifying and mapping activities that constitute the basis for building circular business models by enterprises.

Thus, the described research framework can be used not only in subsequent studies conducted in the Silesian Voivodeship, but also in other organisational contexts which take into account the conditions of business environment in the Polish economy. Another postulated direction for future academic research is to complement the results described in this article with a detailed analysis of sectoral differences in terms of identified barriers and benefits of initiatives related to the implementation of a circular economy by Silesian enterprises. In addition, it would also be interesting to conduct representative quantitative research, the results of which would allow verification of the conclusions described in the article. This is particularly needed with regard to the Silesian Voivodeship, which is one of the most industrialised, second most populous and second most urbanised area in Poland (Eurostat, 2019a, 2019b; BDL, 2019).

Although the purpose of the current study has been achieved, it is burdened by several important limitations. The most important reservation is the low representativeness of the sample (which is a result of its purposeful selection) and its relatively small size, which significantly limits the universal validity of the conclusions drawn. Other limitations of the study include the focus exclusively on companies operating in the Silesian Voivodeship, as well as the significant level of generality in the description of activities undertaken by the respondents. Despite the above-mentioned limitations, this article provides important insights into the implementation of a circular economy concept in enterprises located in the southern part of Poland. In addition, identifying the benefits and barriers to the implementation of such practices contributes to a better understanding of how activities leading to closed product and material cycles should be promoted in the Polish economy

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References

1. Aguilar-Hernandez, G.A., Rodrigues J.F.D., Tukker, A. (2021). Macroeconomic, social and environmental impacts of a circular economy up to 2050: A meta-analysis of prospective studies. *Journal of Cleaner Production, 278,* 123421.
2. Alcalde-Calonge, A., Sáez-Martínez, F.J., Ruiz-Palomino, P. (2022). Evolution of research on circular economy and related trends and topics. A thirteen-year review. *Ecological Informatics, 70,* 101716.

3. Blomsma, F., Brenan, G. (2017). The Emergence of Circular Economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology, 21*, 603-614.
4. Cavicchi, C., Oppi, C., Vagnoni, E. (2022). Energy management to foster circular economy business model for sustainable development in an agricultural SME. *Journal of Cleaner Production, 368,* pp. 133-188.
5. Dev, N.K., Shankar, R., Qaiser, F.H. (2020). Industry 4.0 and circular economy: Operational excellence for sustainable reverse supply chain performance. *Resources, Conservation and Recycling, 153,* 104583.
6. EMF (2015a). *Delivering the Circular Economy a Toolkit for Policymakers*. http://www.ellenmacarthurfoundation.org/.
7. EMF (2015b). *Growth Within: a circular economy vision for a competitive Europe*. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf.
8. European Commission (2014). *Towards a circular economy: A zero waste programme for Europe.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0398R%2801%29.
9. European Commission (2015). *Single Market for Green Products Initiative*. http://ec.europa.eu/environment/eussd/smgp/.
10. European Commission (2019). *Implementation of the Circular Economy Action Plan*. https://ec.europa.eu/environment/circular-economy/index_en.htm.
11. European Union (2020) *Circular economy action plan*. https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en.
12. Eurostat (2019a). https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_gind3&lang=en.
13. Eurostat (2019b). https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_r_nuts06_r2&lang=en.
14. Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production, 252*, 119869.
15. Granello, D.H., Wheaton, J.E. (2004). Online Data Collection: Strategies for Research. *Journal of Counseling & Development, 82,* 387-393.
16. Jabbour, C.J.C., Sarkis, J., Lopes de Sousa Jabbour, A.B., Renwick, D.W.S., Singh, S.K., Grebinevych, O., Kruglianskas, I., Filho, M.G. (2019). Who is in charge? A review and a research agenda on the 'human side' of the circular economy. *Journal of Cleaner Production, 222,* pp. 793-801.
17. Jenkins, H. (2006). Small Business Champions for Corporate Social Responsibility. *Journal of Business Ethics, 67*, pp. 241-256.
18. Jesus, A., Antunes, P., Santos, R., Mendonca S. (2018). Eco-innovation in the transition to circular economy: An analytical literature review. *Journal of Cleaner Production, 172,* 2999-3018.

19. Khatami, F., Vilamová, Š., Cagno E., De Bernardi P., Neri A., Cantino, V. (2023). Efficiency of consumer behaviour and digital ecosystem in the generation of the plastic waste toward the circular economy. *Journal of Environmental Management, 325(B),* 116555.
20. Kirchherr, J., Reike, D., Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation & Recycling, 127,* 221-232.
21. Kouhizadeh, M., Zhu, Q., Sarkis, J. (2020). Blockchain and the circular economy: potential tensions and critical reflections from practice. *Production Planning and Control, 31,* 11-12, pp. 950-966.
22. Linder, M., Williander, M. (2017). Circular Business Model Innovation: Inherent Uncertainties. *Business Strategy and the Environment, 26(2),* 182-196.
23. Local Data Bank (2019). https://bdl.stat.gov.pl.
24. Mies, A., Gold, S. (2021). Mapping the social dimension of the circular economy. *Journal of Cleaner Production, 321,* 128960.
25. Murray, A., Skene, K., Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics 140,* 369-380.
26. Neves, S.A., Marques, A.C. (2022). Drivers and barriers in the transition from a linear economy to a circular economy. *Journal of Cleaner Production, 341*, 130865.
27. Oluleye, B.I., Chan, D.W.M., Olawumi, T.O. (2022). Barriers to circular economy adoption and concomitant implementation strategies in building construction and demolition waste management: A PRISMA and interpretive structural modeling approach. *Habitat International, 126,* 102615.
28. Pichlak, M., Szromek, A.R. (2022). Linking Eco-Innovation and Circular Economy – A Conceptual Approach. *Journal of Open Innovation: Technology, Market, and Complexity, 8,* 121.
29. Puntillo, P. (2022). Circular economy business models: Towards achieving sustainable development goals in the waste management sector - Empirical evidence and theoretical implications. *Corporate Social Responsibility and Environmental Management, 1-4*, pp. 1535-3958.
30. Reike, D., Vermeulen, W., Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? - Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation & Recycling, 135,* 246-264.
31. Ritzen, S., Sandström, G. (2017). Barriers to the Circular Economy - integration of perspectives and domains. *Procedia CIRP, 64*, 7-12.
32. Rizos, V., Bryhn, J. (2022). Implementation of circular economy approaches in the electrical and electronic equipment (EEE) sector: Barriers, enablers and policy insights. *Journal of Cleaner Production, 338*, 130617.

33. Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M., Ioannou, A. (2015). The Circular Economy: Barriers and Opportunities for SMEs, *CEPS Working Documents, 25*.
34. Sirin, S.M., Uz, D., Sevindik, I. (2022). How do macroeconomic dynamics affect small and medium-sized enterprises (SMEs) in the power sector in developing economies: Evidence from Turkey. *Energy Policy, 168*, pp. 113-127.
35. Sohal, A., De Vass, T. (2022). Australian SME's experience in transitioning to circular economy. *Journal of Business Research, 142*, pp. 594-604.
36. Sohal, A., Nand, A.A., Goyal, P., Bhattacharya, A. (2022). Developing a circular economy: An examination of SME's role in India. *Journal of Business Research, 142*, pp. 435-447.
37. Superti, V., Houmani, C., Binder, C.R. (2021). A systemic framework to categorize Circular Economy interventions: An application to the construction and demolition sector. *Resources, Conservation and Recycling, 173*, 105711.
38. Takacs, F., Brunner, D., Frankenberger, K. (2022). Barriers to a circular economy in small- and medium-sized enterprises and their integration in a sustainable strategic management framework. *Journal of Cleaner Production, 362*, 132227.
39. Tedesco, M., Simioni, F.J., Sehnem, S., Soares, J.F., Coelho Junior, L.M. (2022). Assessment of the circular economy in the Brazilian planted tree sector using the ReSOLVE framework. *Sustainable Production and Consumption, 31*, pp. 397-406.
40. Velenturf, A., Purnell, P., Tregent, M., Ferguson, J., Holmes, A. (2018). Co-Producing a Vision and Approach for the Transition towards a Circular Economy: Perspectives from Government Partners. *Sustainability, 10(5),* 1401.
41. Warwas, I., Podgórniak-Krzykacz, A., Przywojska, J., Kozar, L. (2021). Going Green and Socially Responsible – Textile Industry in Transition to Sustainability and a Circular Economy. *FIBRES & TEXTILES in Eastern Europe, 29(3),* pp. 8-18.
42. Yang, M., Chen, L., Wang, J., Msigwa, G., Osman, A.I., Fawzy, S., Rooney, D.W., Yap, P.-S. (2022). Circular economy strategies for combating climate change and other environmental issues. *Environmental Chemistry Letters*, pp. 1610-3661.
43. Zucchella, A., Previtali, P. (2019). Circular business models for sustainable development: A "waste is food" restorative ecosystem. *Business Strategy Environment, 28(2),* pp. 274-285.

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ESCAPING BRAIN WASTE. WORK EXPERIENCE AND QUALIFICATIONS OF HIGHLY SKILLED UKRAINIANS IN POLAND

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Purpose: The research aimed to identify what causes some highly skilled migrants from Ukraine to work according to their qualifications and others work below their qualifications.
Design/methodology/approach: This article discusses the results of a survey conducted among 248 highly skilled economic migrants from Ukraine working in Poland. Two groups were analysed: working according to their qualifications and working below their qualifications. The study was carried out between December 2021 and March 2022. The CATI method has been used.
Findings: There is a statistically significant relationship between the length of work experience of respondents in Ukraine and whether or not they are working according to their qualifications or below their qualifications. There is a statistically significant relationship between working in accordance with or not in accordance with qualifications and the assessment of whether it is difficult for a Ukrainian to get a job in Poland in accordance with his/her qualification.
Research limitations/implications: The limitation of the conducted research is that it is conducted exclusively from the perspective of the migrant and does not take into account external factors such as the situation in the labour market of the host country, legal conditions, employers' attitudes towards employing foreigners in positions requiring higher education. This should be taken into account in future research.
Practical implications: The research also has implications for the management of organisations. They show that there are people among the Ukrainian workforce whose potential is not being used. Their talents could be utilised within the organisation. Further research should look at companies and examine how the process of hiring foreign workers works and determine when a company decides to hire a highly qualified Ukrainian according to his/her background.
Social implications: Poland has become a country of immigration. Economic migrants from Ukraine were joined by refugees from that country after 24.02.2022. The proper use of migrants' qualifications is therefore important from the point of view of the economy, but also of the host society.

Originality/value: It shows the possibility of using highly qualified migrants from Ukraine in the organisation. In the Polish labour market migrants from Ukraine are mainly employed as manual workers.

Keywords: qualification, migration, brain waste, career management, organization.

Category of the paper: Research paper.

1. Introduction

Poland has become a country attracting increasing numbers of economic migrants. In 2021, the country was in first place in terms of the number of documents issued due to migrants taking up employment (Eurostat, 2022). By February 2022, there were an estimated 2 million foreigners in Poland, of which the majority, 1.35 million according to estimates, were people from Ukraine - mainly economically active men (Duszczyk, Kaczmarczyk, 2022). This influx was primarily of a labour-intensive nature. The vast majority were migrants from Ukraine who took up employment in Poland mainly in sectors of the so-called secondary labour market, primarily, according to the structure of their legalisation, in services, industry and construction (Górny, 2017). Economic migrants were treated in Poland mainly as additional hands for work, a labour force that was lacking. Polish public statistics do not record the migrants education level. Research shows that among economic migrants there is a sizable group of people with tertiary education, and their share varies from a dozen to several tens of per cent depending on the study (Górny, Kaczmarczyk, Napierała, Toruńczyk-Ruiz, 2013; Kubiciel-Lodzińska, 2012). A huge challenge faced is how to use the qualifications of people coming to Poland. For many years in Poland, mainly in the context of workers from Ukraine, the phenomenon of brain waste has been a challenge. So far, however, it has not been the subject of a wider debate. The issue of migrants' loss of qualifications is all the more relevant as estimates suggest that around 40-60% of Ukrainian refugees who arrived in Poland after 24.02.2022 have tertiary education (Openfield, 2022; EWL, 2022).

The aim of the research was to identify what causes that some highly skilled migrants from Ukraine work according to their qualifications and others work below their qualifications. This paper analyses selected results of a quantitative survey of 248 highly qualified pre-war migrants from Ukraine working in Poland according to their qualifications (101 persons) and below qualifications (147 persons). Ukrainian citizens are the most numerous on the Polish labour market, as more than 80 per cent of work permits and more than 90 per cent of declarations of assignment of work were intended for this group in 2021 (Kubiciel-Lodzińska, 2020). The survey was carried out between December 2021 and March 2022, so it does not include refugees from Ukraine. The data collection CATI method has been used.

The article contributes to the literature relating to the impact of the work experience obtained by a highly skilled migrant in the country of origin on his/her subsequent situation in the labour market of the host country. It also shows to what extent the opinions on the usability of qualifications translates into the possibility for the migrant to take up a job in line with or below his/her qualifications. A novel approach to the research is to undertake a quantitative analysis relating to the employment of highly skilled migrants from third countries (in particular those from Ukraine). It shows the possibility of using highly qualified migrants from Ukraine in the organisation. On the Polish labour market migrants from Ukraine are mainly employed as manual workers.

The article begins with a literature review that refers to the concepts of brain waste and deskilling, which are used most often in the context of the underutilisation of migrants' qualifications in the host country. It also identifies studies that have addressed the issue of work experience in the country of origin and its transferability to the destination country. The following section describes the research method and the sample. The third section shows the results of the study. Finally, a discussion and conclusions were presented.

2. Research context

The term brain waste refers to the situation where an individual works in an occupation that requires lower skills than those he or she has acquired (Reitz, 2001). It arises when a skilled individual bears the costs of education but does not reap the benefits of possession, i.e. the skilled migrant ends up unskilled. Due to the non-utilisation of qualifications, both the migrants and the host society lose out (Sumption, 2013). Brain waste most often results from low transferability of skills (education), which occurs when, due to the specificity of the skills or other factors (e.g. language barrier), it is not easy to 'transfer' them across borders (Chiswick, Miller, 2009). Moreover, the higher the labour market segmentation, the more likely a migrant is to remain already in a low-skilled job (Fellini, Guetto, 2019). In the European context, brain waste is a complex and interconnected process that is often linked to the definition of skills and their need for recognition. It is recognised that the phenomenon of brain waste is rarely initiated by the migrant himself, and originates from the interaction with the labour markets of the host country (Elo, Aman, Täube, 2020). Related to so-called brain waste, is another concept used in the context of migrants' inability to use their skills, which is skill depreciation (deskilling). This is the process of incomplete (or nonexistent) use of one's education for a specific job, which in the long term renders previous competencies invalid (can occur not only in connection with migration but e.g. in the case of long-term maternity leave). This is most often the case for those with higher education (Pecoraro, Wanner, 2019). Of course, it is worth noting that under-qualified work may not always be considered inferior. Highly skilled workers from the

so-called new EU member states (e.g. Poland) employed in low-skilled occupations in host countries are seen as potentially more effectively employed than in their country of origin, suggesting that this mitigates the effect of brain waste (Fihel, Janicka, Kaczmarczyk, Nestorowicz, 2015).

The phenomenon of brain waste is a challenge faced by most immigration countries. The most common reason for highly skilled migrants to undertake work below their qualifications in so-called 3 D jobs (dangerous, dirty, dull) are economic factors. While they undertake work below their qualifications, they also have the opportunity to earn higher wages than in their country of origin (Favell, 2008). Other factors that cause highly skilled people to take jobs below their qualifications are the difficulty in having the education received in the country of origin recognised (Parrenas, 2001), the lack of or insufficient knowledge of the language of the immigration country, and the short-term nature of the migration.

An immigrant's work experience in the destination country, in contrast to their experience in their home country, is presented in a U-shape. It is meant to represent the migrant's high level of professional achievement (work experience) in the home country and low professional status in the country of immigration (Chiquiar, Hanson, 2005).

This means that a migrant's work experience in the country of origin does not always translate into success in the labour market of the host country. A study in Finland showed that work experience reduces the risk of discrimination and increases the number of potential contacts for a job offer. However, it does not significantly affect the number of call-backs for jobs where vocational training is required or are highly skilled jobs. Foreigners' chances of getting a job do not change significantly even when they have more work experience than native applicants (Ahmad, 2022). Interesting findings also emerge from Canadian studies. They show that migrants who worked in regulated occupations in their countries of origin experienced a significantly greater reduction in occupational classification in Canada than those who worked in unregulated occupations before arrival. In contrast, those who had worked in regulated occupations before emigration and were able to find employment also in regulated occupations in Canada did not experience any downgrading, (downgrading) of occupational qualifications (Banerjee, 1983).

Based on the literature review, the following research questions were asked:

1. Does the length of work experience in the country of origin translate into taking up a job compatible with the qualification?
2. Do migrants' opinions on the usability of qualifications influence whether they work below or in line with their qualifications?

3. Methods

The quantitative survey was conducted from December 2021 to March 2022 among 248 Ukrainians with a university degree. In the study, highly qualified individuals are defined as those who have completed higher education (Docquier, Marfouk, 2006). Due to the differences in the Ukrainian and Polish education systems, the study recruited individuals with at least a bachelor's degree, which can be considered the equivalent of a Polish bachelor's degree, as it provides the opportunity to continue their education in second-level studies. They could be graduates of foreign (Ukrainian or other universities) or Polish universities.

Purposive sampling was used in designing the survey, so it is a non-probabilistic sample. The criteria for the selection of respondents were defined in detail: migrants had to come from the same national group (Ukraine), have the same level of education (tertiary education), and have worked in Poland for at least six months before the survey. The research was comparative as the selection of respondents assumed the recruitment of migrants from Ukraine working in Poland in accordance with their qualifications (in a position requiring a university degree) and working below their qualifications (in positions not requiring a university degree). The snowball method was used when recruiting respondents. The assistance of employers who allowed contact with their Ukrainian employees was used. Recruitment was also done with the support of NGOs that support immigrants, particularly those from Ukraine. Contact was also made with universities, through which contact was made with their Ukrainian graduates. Snowball sampling was used because it is difficult to access group and there is no sampling frame (Heckathorn, 2011).

The research tool used in the quantitative part was a survey questionnaire, which consisted of 12 closed-ended questions and a metric (including gender, age, a field of study, country of graduation, profession pursued in Ukraine and length of work experience in the country of origin, profession pursued in Poland, a branch of employment, length of stay in Poland, the definition of permanent place of residence and was also asked about the year of employment with the current employer). The questions contained in the questionnaire were aimed at indicating the migrant's professional path and concerns, inter alia, the way of finding employment, assessment of the possibility of using qualifications on the Polish labour market, determination of factors stimulating and blocking taking up employment consistent with qualifications, knowledge of the Polish language was also referred to. The data collection method used in the study was a telephone survey (CATI - Computer Assisted Telephone Interviewing). A total of 248 respondents took part in the survey, and among them were 101 people working in Poland according to their qualifications and 147 people working below their qualifications.

The age structure of the respondents confirms that the youngest age groups were most present among (pre-war) economic migrants (details Table 1).

Table 1.
Characteristics of respondents

		Number	%
Gender	Women	100	40,3
	Man	148	59,7
Age	Up to 35 years	113	45,6
	36-44 years	88	35,5
	45-55 years	39	15,7
	Over 56 years	8	3,2
Country of graduation	Ukraine	203	81,9
	Poland	37	14,9
	Other countries	8	3,2
Year of arrival in Poland	2003 and earlier	12	4,8
	2004-2010	19	7,7
	2011-2015	40	16,1
	2016 and later	177	71,4
Nature of work in Poland	In accordance with qualifications	101	40,7
	Below qualifications	147	59,3
Length of work experience in Ukraine	Respondent has not worked in Ukraine	36	14,5
	1-5 years	84	33,9
	6-10 years	57	23,0
	over 10 years	71	28,6

Source: own elaboration.

More than 80% of respondents graduated in Ukraine, nearly 15% in Poland, and more than 3% in another country. These included graduates of construction (10 people), economics (45 people), pedagogy (42 people), technology (37 people), IT (23 people), and medicine (14 people). Respondents were also asked about the length of their stay in Poland. It was found that the largest number of people, over 71%, had arrived in Poland relatively recently, between 2016 and 2022, while the smallest number, only about 5%, had been working in Poland since 2003 or earlier. Nearly 8% of respondents arrived in Poland between 2004 and 2010, and 16% between 2011 and 2015. The adopted ranges relating to the year of arrival in Poland result from the earlier nature of the inflow of migrants from Ukraine. The period before 2004 is before Poland's accession to the European Union. The period from 2004 to 2015 is the post-accession period, in which the outflow of Polish workers who decided to emigrate was more and more noticeable in the Polish labour market. This is a period in which employers increasingly began to employ foreign workers, primarily from Ukraine. After 2015, we have seen a huge increase in both work permits and declarations of the intention to entrust work to a foreigner - hence the choice of the next period. More than two-thirds of the respondents worked in Poland permanently, while about 26% claimed that working in Poland is a temporary occupation for them. i.e. they come to Poland for a few months a year and return to Ukraine. In addition, respondents were also characterised in terms of their situation on the labour market, i.e. whether they work according to their qualifications or below their qualifications, how long their work experience is, whether the job they are doing is their first job in Poland and whether they have worked in another country outside Poland.

Nearly 34% of respondents had 1- 5 years of experience working in Ukraine, 5-10 years worked 23% of the respondents and nearly 30% had worked in their country of origin for more than 10 years. Just over 14% of respondents had not worked in Ukraine at all. Only 1/3 of respondents declared that they had work experience in other countries, while for about 70% of respondents going to work in Poland was the only migration experience.

4. Results

4.1. Length of work experience of respondents in the country of origin and nature of employment in Poland

The aim of the research was, among other things, to establish whether there are any relations between the length of work experience in the country of origin and the nature of work in Poland.

In the surveyed group, among those working according to their education, almost 38% had between 1 and 5 years of work experience in their country of origin. Nearly 1/3 had worked in Ukraine for 5-10 years and just over 18 % had more than 10 years of work experience. About 15% of the respondents had not worked in Ukraine at all (Table 2).

Table 2.
Respondents working in Poland according to education and below education by the length of work experience of respondents in Ukraine

Length of work experience in Ukraine	Work in accordance with qualifications		Work below qualifications		Total	
Years	Number	%	Number	%	Number	%
1-5 years	38	37,6	46	31,3	84	33,9
6-10 years	29	28,7	28	19,0	57	23,0
over 10 years	19	18,8	52	35,4	71	28,6
Respondent has not worked in Ukraine	15	14,9	21	14,3	36	14,5
Total	101	100	147	100	248	100

Source: own elaboration.

Table 3.
Relationship between nature of work in Poland and the length of work experience of respondents in Ukraine

	χ^2Pearson	df	p-value	V-Cramer
Work in Poland according to education and below education by length of work experience of respondents in Ukraine	10,4532	3	0,0151	0,2074

Source: own elaboration.

This suggests that there is a statistically significant relationship between the length of work experience of respondents in Ukraine and whether or not they are working in positions that align with their education level in Poland (p-value = 0.0151 < 0.05) - Table 3. Frequency analysis showed that in the study group, those with longer work experience in Ukraine were

slightly more likely to work inconsistently with their qualifications. This means that the length of work experience obtained in the country of origin does not translate into 'success' in the country of immigration. V-Cramer's value of 0.2074 would indicate a moderate association between the two categorical variables being analyzed.

This shows that the longer the length of work experience in Ukraine, the greater the likelihood of working below qualification.

The survey results show that for employers, the migrant is a 'white card' and their previous work experience gained in their country of origin is not crucial when filling positions. It is more crucial what positions the employer is looking for and whether they are willing to take the job.

A consequence of this is that employers have a different approach to verifying the qualifications of foreign workers. More than 77% of respondents working according to their qualifications claimed to have submitted a university degree when applying for a job. Only 19% of those working inconsistently with their qualifications responded the same way. For nearly 62% of respondents working below qualification, the employer did not check their education and 15% submitted documents proving that they had completed vocational courses. In contrast, in the group working in line with qualifications, only less than 6% of respondents claimed that the employer had not checked their education. Additionally, nearly 22% submitted documents of completion of vocational courses to confirm their qualifications. Nearly 37% of respondents working according to their qualifications took part in interviews, while among those working below their qualifications it was less than 7%. In the first group, all respondents knew how the employer checked their qualifications, while in the second group, 4% said they did not know how the employer checked their qualifications (Table 4).

Table 4.
Method of verification of qualifications by the employer (by nature of work of respondents)*

	Work in accordance with qualifications		Work below qualifications		Total	
	Number	%	Number	%	Number	%
I showed my university diploma	78	77,2	28	19,0	106	42,7
I showed a document of completion of professional course(s)	22	21,8	22	15,0	44	17,7
Employer did not check my education/qualifications	6	5,9	91	61,9	97	39,1
Other	37	36,6	10	6,8	47	19,0
I don't know	0	0,0	6	4,1	6	2,4

*More than one answer possible.

Source: own elaboration.

Table 5.
Relationship between the nature of work in Poland and the way in which the employer verifies qualifications

	χ^2 Pearson	df	p-value	V-Cramer
How the migrant's qualifications were checked	79,7884	1	0,0000	0,4972

Source: own elaboration.

Verification of education/qualifications shows a significantly relationship whether a respondent is working according to or not according to his/her qualifications in Poland (p-value = 0.000 < 0.05) – table 5. Education and qualifications are verified when a migrant is employed according to qualifications. Research shows that a certain group of foreigners' talents are wasted when satisfying the labour market and looking for people willing to do jobs that are unattractive to native workers. Moreover, often the employer does not even know that he is missing out on the potential of a person (e.g. with an engineering degree) because he does not verify the qualifications, education and focuses only on finding people ready to take the job he is looking for. V-Cramer's value of 0.4972 would indicate a strong association between the qualifications of migrants and the method used to check them. This suggests that the method used to check qualifications is highly related to the nature of the work migrants have been employed.

4.2. Respondents' opinions on the usability of qualifications

The research also sought to establish whether there is a relationship between migrants' opinions on the assessment of the possibility of using their education and the nature of the job. More than 46% of respondents working according to their qualifications and more than 87% of those working below their qualifications agree with the statement that it is difficult for a Ukrainian in Poland to get a job according to their education. Nearly 20% of respondents in the first group do not have an opinion on this (against 6.1% of those working below their qualifications). It is worth noting that more than 1/3 of those working according to their qualifications do not agree with this statement (Figure 1).

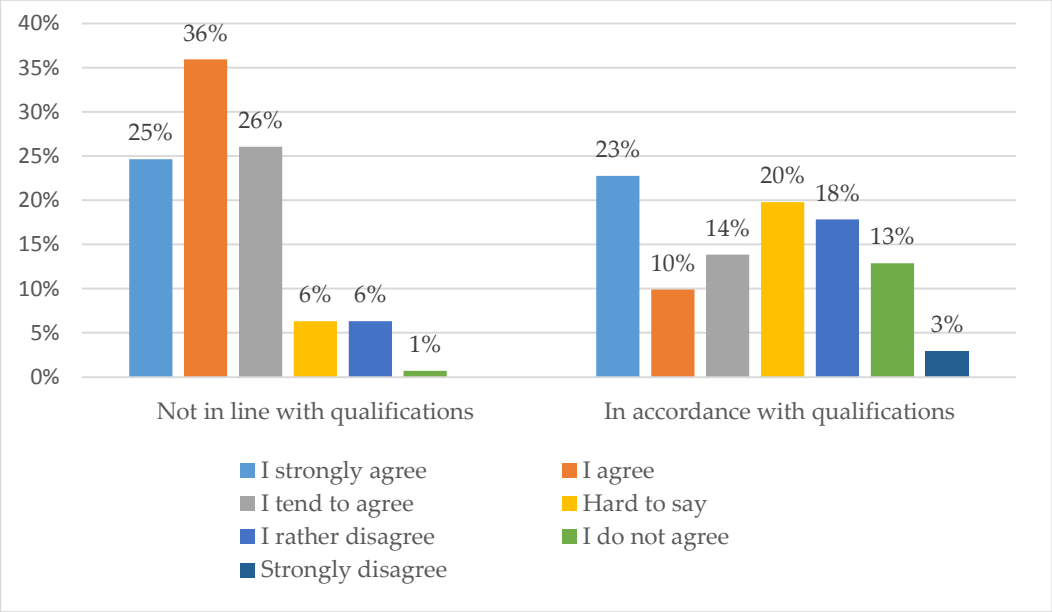

Figure 1. Please specify to what extent you agree with the following statement: It is difficult for a Ukrainian to get a job in Poland that is compatible with his/her qualification according to the nature of the job.
Source: own elaboration.

Table 6.
Relationship between the nature of work in Poland and the rating of the statement "It is difficult for a Ukrainian to get a job in Poland that is compatible with their qualification"

	χ^2Pearson	df	p-value	V-Cramer
Evaluation of the statement "It is difficult for a Ukrainian to get a job in Poland that is compatible with his/her qualification" according to the nature of the work	55,5341	6	0, 0000	0,4781

Source: own elaboration.

There is a statistically significant relationship between working in accordance with or not in accordance with qualifications and the assessment of whether it is difficult for a Ukrainian to get a job in Poland in accordance with his/her qualification (p-value = 0.0000 < 0.05) - Table 6. This means that the migrant's conviction about the possibility of using his/her qualifications is also important when looking for employment. Highly skilled migrants often assume even before they leave the country that they will not be able to get a job in line with their education (e.g. due to a language barrier) and immediately look for employment below their qualifications, which is definitely more readily available. V-Cramer's value of 0.4781 would indicate a strong association between the evaluation of the statement "It is difficult for a Ukrainian to get a job in Poland that is compatible with his/her qualification" and the nature of the work. This suggests that there is a strong correlation between the nature of the work and the perceived difficulty of getting a job in Poland that is compatible with one's education. It is likely that the nature of the work has a strong influence on the perceived difficulty of getting a job that aligns with one's qualifications.

More than 52% of those working according to their qualifications disagree with the statement that recognition of education obtained in Ukraine is very difficult in Poland. Noteworthy, a similar view was expressed by more than 1/3 of those working in accordance with their qualifications. In contrast, 1/3 of those working according to their qualifications and more than 46% of those working not according to their qualifications believed that recognition of education obtained in Ukraine is very difficult.

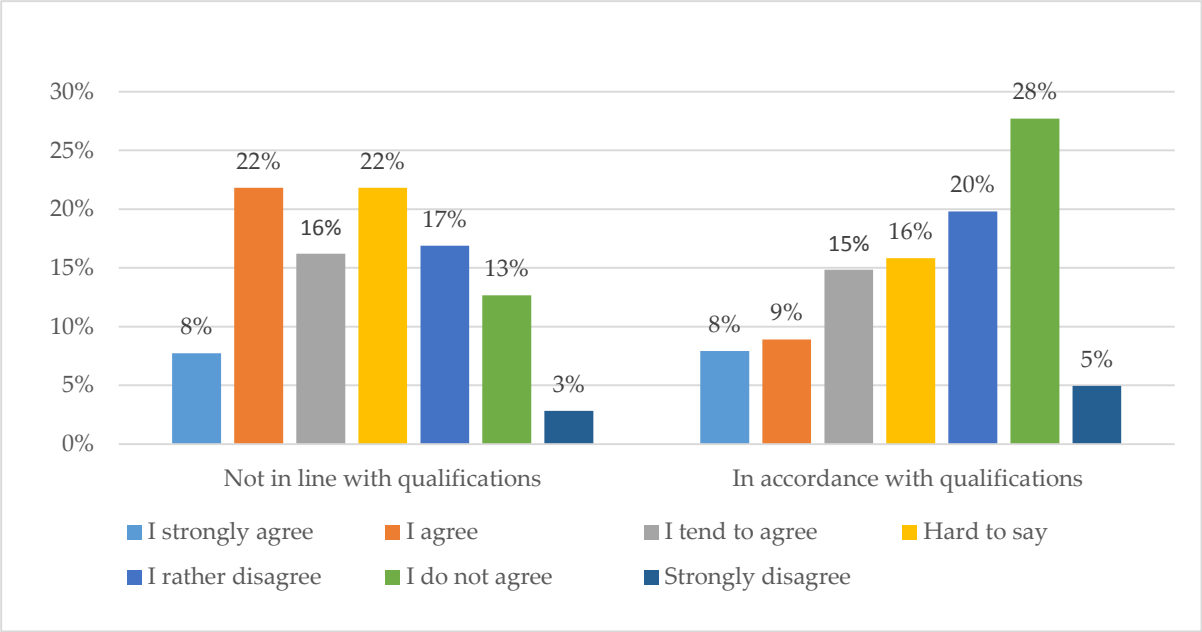

Figure 2. Please indicate to what extent you agree with the following statement: Recognition of education obtained in Ukraine is very difficult in Poland.

Source: own elaboration.

Table 7.
Relationship between the nature of work in Poland and the evaluation of the statement 'Recognition of education obtained in Ukraine is very difficult in Poland'

	χ^2Pearson	df	p-value	V-Cramer
Opinions on the statement "Recognition of education obtained in Ukraine is very difficult in Poland".	15,2091	6	0, 0187	0,2502

Source: own elaboration.

There is a statistically significant relationship between working according to/against qualifications and assessing whether recognition of education obtained in Ukraine is very difficult in Poland (p-value = 0.0187 < 0.05) – table 7. V-Cramer's value of 0.2502 would indicate a moderate association between the two categorical variables being analyzed.

5. Discussion

The important finding is that the longer the work experience of a high-skilled person in the country of origin, the less likely he or she is to obtain employment in line with his or her qualifications. Taking a job below the qualification first results in deskilling and later in brain waste. This shows that the work experience of high-skilled migrants acquired in the country of origin does not affect success in the labour market of the host country, i.e. it does not facilitate obtaining matched employment to the qualification. The first question is therefore answered. This is due to several reasons. This may be due to several reasons including the age of the migrants - the longer the work experience - the older the migrants are. Age, on the other hand,

can affect how a worker perceives his or her capabilities. Older and middle-aged workers, research shows, are more cautious in their career choices (Yeatts et al., 2000). The second reason, Poland has not been interested in attracting highly qualified people to work and has no activities in this regard. An exception might be the facilitation of doctors from abroad introduced during the COVID-19 pandemic. Due to the influx of refugees from Ukraine, regulations dedicated to Ukrainian refugees (e.g. scientists, doctors, and teachers) were introduced to facilitate access to the profession (Pędziwiatr et al., 2022), but these were actions forced by situations rather than deliberate to facilitate highly qualified people taking up work in Poland. There is a lack of a strategic approach to the possibility of more adequately employing high-skilled migrants - both from the state and from the employers themselves. In Poland, labour migrants, who came mainly from Ukraine, were primarily clocked in as a labour force to fill gaps in the labour market. Which concerned professions that were unattractive from the point of view of Polish workers. No thought was given to the use of their qualifications even though, according to estimates, around 20-20% of migrants are tertiary educated (Górny et al., 2013; Kubiciel-Lodzińska, 2012).

It is more difficult to obtain a clear answer to the second question Research has shown that there is a statistically significant relationship between the assessment of statements on the possibility of using qualifications and the nature of employment. However, it is not possible to conclusively indicate that those who evaluated the possibility of using their education more positively obtained a job precisely because of their attitudes. It may be that respondents who work in line with their qualifications are more positive about the possibility of using it because they have succeeded in the host country's labour market. This issue in the case of Ukrainian migrants in Poland would need to be explored further during qualitative research. But we know from other countries, that migrant's career aspirations influence the type of employment and determine career development (Gottfredson, 2002)

A huge challenge that requires a change in the mentality of employers is to stop seeing foreign workers as a 'white card'. Employers, according to analyses of employees' answers, when employing a foreigner in a profession from the secondary labour market, rarely ask about education and work experience. The key for them is to meet the demand for specific professions, and to find people ready to perform certain jobs for which there is a shortage of workers. In the case of Poland, this demand was mainly for workers in simple jobs, people to work in construction, industry, services, and agriculture. And it was primarily for these jobs that foreign workers, mainly from Ukraine, were recruited. This situation is well illustrated by the dual labour market theory (Piore, 1979), according to which the labour market is divided into two segments: primary and secondary. The first includes jobs perceived as attractive and the second characterises jobs perceived as unattractive (usually requiring physical labour in difficult conditions, e.g. agriculture, industry, construction). Migrants are most often hired to fill gaps in the labour market and to take up that employment that native workers reject.

Certainly, an issue that would need to be deepened is the transferability of education and qualifications of migrants from Ukraine. There is no doubt that they are not perfectly transferable, which is due to several reasons. The slightly different education system, but also the incompatibility of education with the work done in the country of origin (migrants already work below their qualifications in their country of origin) and the individual attitudes of migrants (lack of self-confidence, lack of willingness to learn the language, lack of willingness to take up a job in line with their qualifications).

6. Conclusions

The study contributes to the debate, particularly relating to the migration of highly skilled persons from Ukraine in Central and Eastern European countries. Above all, it shows that this group is not homogeneous, which is an important indication for employers and migration policy.

The research has implications for the management of organisations. It shows that there are people among the Ukrainian workforce whose potential is not being used. Their talents could be utilised within the organisation. Further research should look at companies and examine how the process of hiring foreign workers works and determine when a company decides to hire a highly skilled Ukrainian according to his/her qualifications.

The study also has practical implications, mainly for migration policy. Recommendations for better collection of data on the education of migrants. For example, when registering refugees from Ukraine, data on their level of education and occupation was not collected. These dames are also not collected when issuing work permits and declarations on the employment of foreigners. There is also a lack of institutional support to promote the employability of highly skilled migrants, which may indicate that career development and the ability to obtain employment in line with education is seen as something that depends solely on the migrants themselves and their activity in the labour market. This may be an area for future research.

The limitation of the conducted research is that it is conducted exclusively from the perspective of the migrant and does not take into account external factors such as the situation in the labour market of the host country, legal conditions and employers' attitudes towards employing foreigners in positions requiring higher education. The analysis focused on only one aspect - the possibility to use work experience from the country of origin - and the possibility to take up a job in the country of immigration is also influenced by other factors.

In the context of future research, a sectoral analysis would also be relevant, e.g. a more detailed analysis of migrants' occupations and the opportunities and barriers related to their use of qualification in the Polish labour market. It would also be important to refer to local labour

markets and the possibilities of absorbing tertiary-educated migrants into them. Poland has become a country of immigration. Economic migrants from Ukraine were joined by refugees from that country after 24.02.2022. The proper use of migrants' qualifications is therefore important from the point of view of the economy, but also of the host society.

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References

1. Ahmad, A. Does additional work experience moderate ethnic discrimination in the labour market? *Economic and Industrial Democracy*, *24*. doi:10.1177/0143831x20969828
2. Banerjee, B. (1983). The Role of the Informal Sector in the Migration Process – a Test of Probabilistic Migration Models and Labour-Market Segmentation for India. *Oxford Economic Papers-New Series*, *35(3),* 399-422. doi.org/10.1093/oxfordjournals.oep.a041604
3. Chiquiar, D., Hanson, G.H. (2005). International migration, self-selection, and the distribution of wages: Evidence from Mexico and the United States. *Journal of Political Economy*, *113(2),* 239-281. doi:10.1086/427464.
4. Chiswick, B.R., Miller, P.W. (2009). The international transferability of immigrants' human capital. *Economics of Education Review*, *28(2),* 162-169. doi.org/10.1016/j.econedurev.2008.07.002.
5. Docquier, F., Marfouk, A. (2006). International migration by education attainment, 1990-2000. In: C. Özden, M. Schiff (eds.), *International migration, remittances and the brain drain* (pp. 151-199).
6. Duszczyk, M., Kaczmarczyk, P. (2022). War and migration: the recent influx from Ukraine into Poland and possible scenarios for the future. *CMR Spotlight, 4,* 39.
7. Elo, M., Aman, R., Täube, F. (2020). Female migrants and brain waste–A conceptual challenge with societal implications. *International Migration*. doi.org/10.1111/imig.12783.
8. Favell, A. (2008). The new face of East–West migration in Europe. *Journal of Ethnic and Migration Studies, 34(5),* 701-716. doi.org/10.1080/13691830802105947.
9. Fellini, I., Guetto, R. (2019). A "U-shaped" pattern of immigrants' occupational careers? A comparative analysis of Italy, Spain, and France. *International Migration Review*, *53(1),* 26-58. doi.org/10.1177/019791831876793.

10. Fihel, A., Janicka, A., Kaczmarczyk, P., Nestorowicz, J. (2015). *Free movement of workers and transitional arrangements: Lessons from the 2004 and 2007 enlargements*. Unpublished report to the European Commission. Warsaw: Centre for Migration Studies.
11. Górny, A. (2017). All circular but different: Variation in patterns of Ukraine-to-Poland migration. *Population, Space and Place*, *23(8),* doi.org/10.1002/psp.2074.
12. Górny, A., Kaczmarczyk, P., Napierała, J., Toruńczyk-Ruiz, S. (2013). *Raport z badania imigrantów w Polsce.* Warsaw: Ośrodek Badań nad Migracjami Fundacja.
13. Gottfredson, G.D. (2002). Interests, aspirations, self-estimates, and the self-directed search. *Journal of Career Assessment*, *10(2),* 200-208. doi.org/10.1177/1069072702010002.
14. Hall, P.V., Sadouzai, T. (2010). The value of "experience" and the labour market entry of new immigrants to Canada. *Canadian Public Policy*, *36(2),* 181-198. doi:10.3138/cpp.36.2.181.
15. Heckathorn, D.D. (2011). Comment: Snowball versus respondent-driven sampling. *Sociological Methodology*, *41(1),* 355-366. doi.org/10.1111/j.1467-9531.2011.0124.
16. Kostenko, W., Harris, M., Zhao, X. (2012). Occupational transition and country-of-origin effects in the early stage occupational assimilation of immigrants: some evidence from Australia. *Applied Economics*, *44(31),* 4019-4035. doi.org/10.1080/00036846.2011.587774.
17. Kubiciel-Lodzińska, S. (2012). *Imigracja zarobkowa do województwa opolskiego. Skala, warunki i perspektywy.* Opole.
18. Parrenas, R. (2001). *Servants of Migration: Women, Migration and Domestic Work*. California: Stanford University Press.
19. Pecoraro, M., Wanner, P. (2019). Does the Recognition of Foreign Credentials Decrease the Risk for Immigrants of Being Mismatched in Education or Skills? In: *Migrants and expats: The Swiss migration and mobility nexus* (pp. 161-186). Cham: Springer.
20. Pędziwiatr, K., Brzozowski, J., Nahorniuk, O. (2022), *Refugees from Ukraine in Kraków*. Centre for Advanced Studies of Population and Religion, https://owim.uek.krakow.pl/wp-content/uploads/user-files/reports/refugeereport1.pdf.
21. Peixoto, J. (2001). Migration and policies in the European Union: highly skilled mobility, free movement of labour and recognition of diplomas. *International Migration*, *39(1),* 33-61. doi.org/10.1111/1468-2435.00134.
22. Piore, M.J. (1979). *Birds of passage: migrant labor and industrial societies*. Cambridge University Press.
23. Raport specjalny EWL *Uchodźcy z Ukrainy w Polsce* (2022). https://ewl.com.pl/raport-specjalny-uchodzcy-z-ukrainy-w-polsce/.
24. Reitz, J.G. (2001). Immigrant skill utilization in the Canadian labour market: Implications of human capital research. *Journal of International Migration and Integration/Revue de l'integration et de la migration internationale*, *2(3),* 347-378. doi.org/10.1007/s12134-001-1004-1.

25. Siar, S.V. (2013). From highly skilled to low skilled: revisiting the deskilling of migrant labor. *PIDS Discussion Paper Series, No. 30*.
26. Sumption, M. (2013). *Tackling brain waste: Strategies to improve the recognition of immigrants' foreign qualifications*. Washington, DC: Migration Policy Institute.
27. *Tacy sami czy jednak inni? "Przedwojenni" imigranci z Ukrainy vs. uchodźcy z Ukrainy - porównanie*. Raport z badań (2022). Openfield.
28. Yeatts, D.E., Folts, W.E., Knapp, J. (2000). Older Workers' Adaptation to a Changing Workplace: Employment Issues for the 21st Century. *Educational Gerontology*, *26(6)*, 565-582. doi.org/10.1080/03601270050133900.

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CHINESE FDI IN POLAND AND THE CZECH REPUBLIC – INFLOWS, DETERMINANTS AND CHALLENGES

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Purpose: The objective of this paper is to present Chinese investment flows and the nature of participation, to analyze the differences between host countries, and to identify the determinants of Chinese FDI in Poland and the Czech Republic.
Design/methodology/approach: Comparison of the specifics of Chinese direct investments in Poland and the Czech Republic.
Findings: The nature of Chinese investment in Europe is changing. After years of being dominated by mergers and acquisitions, Chinese investment in Europe is now more focused on greenfield projects. In 2021, greenfield investments reached €3.3 billion, the highest ever recorded, and accounted for nearly one- third of all Chinese FDI. More recently, the volume of Chinese FDI in Europe has reached the level of European FDI in China (now constrained by restrictions and risks). It matched the level of FDI by Chinese companies in the United States before declining over the past two years, generally due to Covid-19 and the war in Ukraine. Chinese economic presence in Europe can be divided into three areas based on size, destination, and type of acquisition: The core of Europe is formed by the three major target countries (Germany, UK, France), where more capital-intensive investments are made, followed by other Western European countries (EU-15). The new member states (NMS), which joined the EU in 2004, 2007 and 2013, as well as the Western Balkan countries in the process of accession, are associated with China in the 16+1 format (with the exception of Kosovo) and form another gateway to Europe. Due to fewer market opportunities, they receive less direct investment, but China is building infrastructure (ports, highways, railroads) - segments of the Silk Road that will bring Chinese products to mature EU markets (Richtet, 2019). It is unlikely that Chinese investment in Europe will recover in 2023. The Chinese government is expected to maintain strict capital controls, financial retrenchment, and Covid-19 restrictions. The war in Ukraine and the expansion of regulations to monitor and control Chinese investments in the EU and the UK will cause additional difficulties.

Originality/value: The article could be an attempt to answer the question of combining macroeconomic and institutional factors to better understand the internationalization of firms (Dunning, Lundan, 2008). There is no doubt, that the Covid-19 pandemic and the war in Ukraine made it necessary to deepen the study of the phenomenon of FDI, its inflows, determinants, and related challenges in a turbulent world.

Keywords: foreign direct investments (FDI), People's Republic of China, Czech Republic, Poland, international relationships.

Category of the paper: Research paper.

1. Introduction

To Emerging-country multinational companies are increasingly integrating into the world economy through foreign direct investment (FDI), with Chinese outward FDI being the most spectacular case in terms of rapid growth, geographical diversity and takeovers of established Western brands. Chinese companies invest mainly in Asia, Latin America and Africa, where they seek markets and natural resources. However, the developed economies of Western Europe and the United States have recently also become important targets, offering markets for Chinese products and assets Chinese firms lack, such as advanced technologies, managerial knowledge and distribution networks. In recent years Chinese companies have increasingly targeted central and eastern European countries, with the Visegrad countries (Czechia, Hungary, Poland and Slovakia), together with Romania and Bulgaria, among the most popular destinations.

Global flows of foreign direct investment have been severely affected by the Covid-19 pandemic. In 2020, they fell by a third to $1 trillion, well below the low point reached after the global financial crisis a decade ago. Greenfield investments in industry and new infrastructure investment projects in developing countries were hit particularly hard (UNCTAD, 2021).

It should be noted, that China sees central and eastern Europe as a block of 16 countries. Among the 16 CEE countries which are involved in the so-called Chinese 16+1 initiative there are 11 EU countries (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia) and five EU candidate countries (Albania, Bosnia and Herzegovina, FYROM (Macedonia), Montenegro, and Serbia).

Although compared with the Chinese economic presence globally or even in the developed world, China's economic impact on the central and eastern European countries is fairly small, it has accelerated significantly in the past decade: trade volume is growing constantly, while it can be observed rising inflows of Chinese investments in the region, which are expected to increase due to recent political developments: strengthening Chinese–Hungarian relations, Poland becoming China's strategic partner (at the end of 2011), the establishment of the China-Central and Eastern Europe Cooperation Secretariat in September 2012, the 16 + 1 initiative and the One Belt One Road.

The Covid-19 pandemic caused a dramatic fall in global FDI in 2020, bringing FDI flows back to the level seen in 2005. The crisis has had an immense negative impact on the most productive types of investment, namely, greenfield investment in industrial and infrastructure projects, what significant influenced the entire world economy (UNCTAD, 2021).

In 2021, there was a strong recovery in foreign direct investment flows worldwide after they reached exceptionally low levels in 2020. According to the United Nations Conference on Trade and Development (UNCTAD), global direct investment flows increased by 77%, exceeding pre-pandemic levels. Global Chinese investment was an exception to this trend, stagnating in 2021.

According to official Chinese statistics, China's non-financial outbound investment increased by only 3% to $114 billion (€96 billion) in 2021. China's global outbound M&A activity fell to a 14-year low in 2021, with completed mergers and acquisitions totaling only EUR25 billion, down 9% from 2020 and 45% from 2019. The failure of China's outbound global direct investment (OFDI) to recover was due to several factors: China's outbound investment had been declining since 2016, reflecting domestic restrictions on outbound capital flows and tighter controls on Chinese outbound investment. The lack of recovery is also likely linked to China’s adherence to a zero-Covid strategy, which hindered cross-border travel and thus deal-making activities. What’s more, sharp competition for global assets in a booming M&A context likely put Chinese buyers at a disadvantage due to their limited international experience and emerging regulatory concerns

The aim of this paper is to map Chinese investment flows and types of involvement, and to analyse differences between countries, as well as to identify the determinants of Chinese FDI in Poland and the Czech Republic.

The research method used in this article is based on a comparative analysis of the specifics of Chinese direct investment in Poland and the Czech Republic. The research hypothesis is that in the case of both Poland and the Czech Republic, Chinese direct investment has played an important role in the development of these countries over the years. In recent years, both Poland and the Czech Republic have been the main recipients of Chinese FDI in Europe. Despite the Covid-19 pandemic and the war in Ukraine, Chinese FDI in both Poland and the Czech Republic is expected to continue developing after a temporary stagnation. The article could be an attempt to answer the question of how macroeconomic and institutional factors can be combined to better understand the internationalization of firms (Dunning, Lundan, 2008). There is no doubt that the Covid-19 pandemic and the war in Ukraine call for a deepening of the study of the phenomenon of FDI, its inflows, its determinants, and the related challenges in a rapidly changing world.

2. Theoretical background

Paper According to the definition of OECD, foreign direct investment (FDI) is the category of international investment that reflects the objective of a resident entity in one economy to obtain a lasting interest in an enterprise resident in another economy (OECD). The investor is to gain permanent benefit due to long-lasting influence on the management of the FDI enterprise. The minimum number of shares held in a given enterprise is 10%. However, the influence on management, with such level of shares, may be exerted only if the other shares are highly dispersed (OECD, 2008, p. 234).

The nature and motives of foreign direct investment were determined in Dunnig's eclectic theory of foreign direct investment (Dunning, 2001). He combined the theory of monopolistic advantage (which explains why the investments are made outside the territory of the country of origin, but does not specify why these investments are made in certain markets), the location theory (which explains why FDI is made in certain markets without specifying the reason for the investments made) with the theory of internalization (which explains the mechanisms of exploiting the advantages that the company derives from making the foreign investment). On this basis, the OLI paradigm was developed (OLI stands for ownership, localization, internalization) (Dunning, 2001).

Analysis of the literature on the subject showed, that there is a growing use of the international business literature in economic geography (Beugelsdijk et al., 2010; Jones, 2018; Jones, 2017; Jones, Wren, 2016), for which the eclectic paradigm is the most influential framework for examining FDI determinants (Stoian, Filippaios, 2008; Buckley et al., 2007; Jones et al., 2016; Jones et al., 2018). Recently, there has also been research on FDI motives in CEE countries (Resmini, 2000; Bevan, 2004; Bevan et al., 2004; Carstensen, Toubal, 2004; Baltagi, 2007; Pusterla, Resmini, 2007).

In general, a company transfers capital in the form of foreign direct investment under the following conditions:

- a company must have specific advantages resulting from resources and capabilities that make the company competitive in the international market,
- a company should use the competitive advantage it has gained by building its own structures in foreign markets and not transfer it by selling it (e.g. licenses),
- a company should combine its own advantages with the advantages of the location market, i.e. it should effectively use the advantages of the respective location to maximize its own profits (Jankowiak, 2016).

According to the OLI paradigm described above, the decision to make a foreign direct investment at a given time should be conditioned by the configuration of the three forces mentioned above. Firms enjoy various advantages resulting from the specific nature of their activity, the country from which they originate, and the country in which they operate (Dunning,

2001, p. 176). The first two factors closely depend upon the capabilities and resources of the company, the third factor decides about the direction of transferring the capital in the form of FDI (Jankowiak, 2016).

Indeed, different types of investment incentives attract different types of FDI, which Dunning (1992) divides into four categories: 1.) market-seeking (tariff-jumping or export-replacing FDI is a variant of market-seeking FDI); 2.) resource-seeking; 3.) efficiency-seeking; 4.) and asset-seeking. Factors that attract market-seeking MNEs typically include market size, as reflected in GDP per capita and market growth (GDP growth). Investments aimed at improved efficiency are determined for example by low labour costs, and tax incentives.

Finally, firms interested in acquiring foreign assets may be motivated by a common culture and language, as well as trade costs (Hijzen et al., 2008). It should be emphasised that some FDI decisions may be based on a complex mix of factors (Blonigen, Piger, 2014). Much of the research and theoretical discussion to date relates to FDI outflows from developed countries, for which market-seeking and efficiency-seeking FDI is most prominent (Buckley et al., 2007).

Characteristic of Chinese outbound FDI is the search for natural resources, the search for markets (Buckley et al., 2007), and more recently, the search for strategic assets (Zhang et al., 2012).

The rapid growth of FDI from emerging and developing economies has been the subject of numerous studies that attempt to explain the unique characteristics of emerging market multinationals' behaviour that are not captured by mainstream theories. Mathews extended the OLI paradigm with the Linking, Leveraging, Learning Framework (LLL), which explains the rapid international expansion of firms from the Asia-Pacific region (Mathews, 2006). Linking refers to partnerships or joint ventures that laggards enter into with foreign firms to minimise the risks of internationalisation and to "acquire resources that are otherwise unavailable" (Mathews, 2006).

3. Chinese expansion on the European market

Reforms introduced since 1978 and China's policy of opening up to the world, followed by China's accession to the World Trade Organization (2001), led Chinese companies to start investing intensively outside their own country. This was particularly friendly when the Going Global strategy was introduced in parallel [走出去战略] making the expansion of Chinese enterprises an important element of the economic growth model and encouraging companies to "leave" [走出去] outside China through investment. The Going Global 1.0 stage is currently associated m.in with the anti-corruption campaign and protests by local communities and businesses unfavourable to Chinese investments. One example is the unsuccessful investments of COVEC in Poland between 2009 and 2011. The Going Global 2.0 stage was prepared with

greater care for local sensitivity and image elements of China and focused upwards of the value chain (China Going Global between ambition and capacity, 2017). As a result, Chinese investments reached practically every continent.

After 2008, European Union countries have become the fastest-growing destination for Chinese foreign investment. This was facilitated by (Ma, Overbeek, 2015):

- an increasingly friendly investment environment within the European Union,
- the debt crisis in the euro area (especially Greece, Ireland, Spain and Portugal),
- the willingness of the Chinese side to decouple its GDP from exports,
- plans to diversify China's foreign exchange reserves (previously most of them were kept in USD),
- treating foreign investment as an alternative (to exports) allowing access to the European market.

This has influenced the emerging new patterns of development of Chinese FDI within the EU. They manifested themselves in (Ma, Overbeek, 2015):

- rapid growth of investments,
- location within the main EU Member States,
- the beginning of interest in semi-peripheral and peripheral countries,
- choosing more diverse sectors,
- placement within state-owned enterprises,
- the beginning of interest in private companies and sovereign wealth funds.

Between 2003 and 2010, one of the factors that influenced the settlement of Chinese investments was the foreign community, as it led to greater access to strategic information. According to Bas Karreman's team, there was a stronger relationship between the size of the Chinese community living abroad and the likelihood of Chinese investment in a community where newer generations of Chinese migrants live, as well as individuals with higher education. In European regions, however, a Chinese community alone is not enough to attract more Chinese FDI. Much depends on the right human capital and the fit of the local workforce as well as the specific sector (Karreman et al., 2017).

After 2013, the Belt and Road Initiative (一带一路/ Belt and Road Initiative) became an additional element of China's new economic growth model. This initiative is closer to a declaration of cooperation and an invitation to economic cooperation than to ready-made offers of activities to be implemented. As part of it, China cooperates with more than 140 countries (International Cooperation, Belt And Road Portal), and trade and investment maintain an upward trend (Gu, Zhou, 2020). The Visegrad Group countries are among China's main trading partners, and strategic partnerships have been signed with the Middle Kingdom: the Czech Republic, Hungary and Poland (Parepa, 2020).

A study by Blomkvist and Drogendijk (2016) found that European countries generally receive less investment from Chinese companies compared to other regions of the world. They found that the main motives for Chinese investment in Europe are the search for markets and strategic assets, and that there are large differences among European countries in attracting Chinese investments (Blomkvist, Drogendijk, 2016).

Over the past 20 years, FDI from China to the EU has amounted to more than USD 120 billion. During this period, almost all EU Member States concluded investment treaties with China (Xu, 2022). The impact of Chinese FDI has significantly increased bilateral exports within the EU, and China has become not only the most popular but also the most active investor in the world. The evolution of China's FDI in the period 2005-2021 is shown in Figure 1. Another figure shows the formation of Chinese FDI in the period 1998-2021 globally and narrowly to European countries (Figure 2).

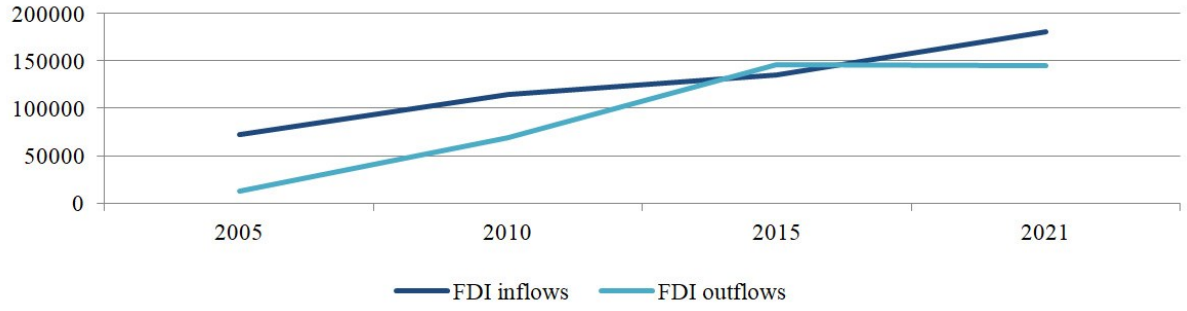

Figure 1. China's FDI in 2005-2021 [USD mill.].

Source: own elaboration based on (UNCTADSTAD).

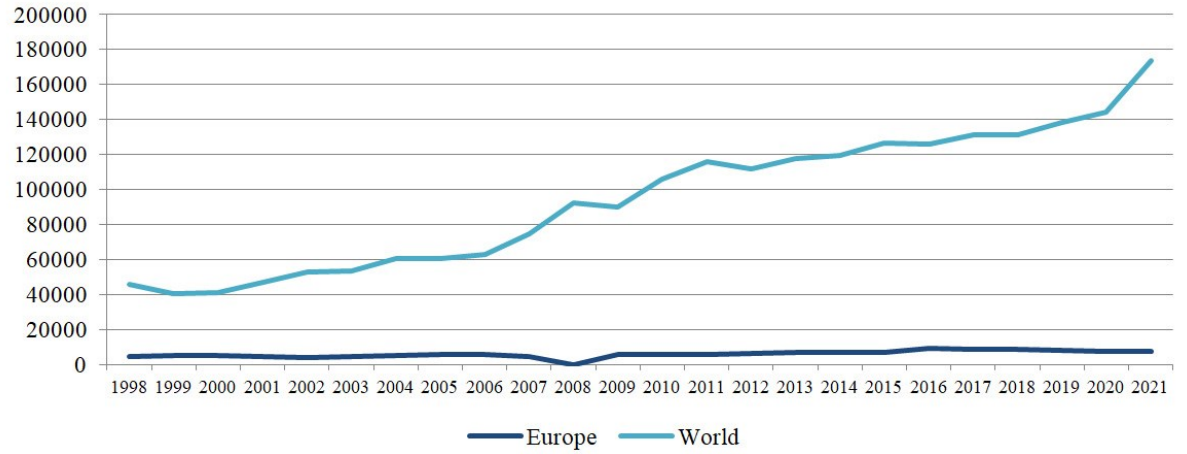

Figure 2. China's FDI actually utilized in 1998-2021 [USD mill.].

Source: Own elaboration based on: (National Bureau of Statistics of China, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999).

Both diagrams show an upward trend in Chinese FDI. For example, in 1998, Chinese FDI on the old continent amounted to USD 4.3 billion, in 2008 – USD 5.5 billion, and after another ten years, in 2018 – USD 8.8 billion. The visible regression that took place in 2008 was related to the global economic crisis, which was accompanied by, the collapse of the business cycle.

The reality of the following years has led to new challenges affecting economic life, above all another crisis related to the emergence of the Covid-19 pandemic. As a consequence, in 2020 Chinese FDI in Europe amounted to EUR 7.9 billion (approximately USD 7.8 billion) and a year later it increased to EUR 10.6 billion (approximately USD 10.5 billion) (Rhodium Group), but was still lower than in 2019.

Generally, China's FDI in Europe (EU-27 and the UK) increased but remained on its multi-year downward trend. In 2021, completed Chinese FDI in Europe increased 33% to EUR 10.6 billion, from EUR 7.9 billion in 2020. The increase was driven by two factors: a EUR 3.7 billion acquisition of the Philips home appliance business by Hong Kong-based private equity firm Hillhouse Capital and record high greenfield investment of EUR 3.3 billion. Still, 2021 was the second lowest year (above only 2020) for China's investment in Europe since 2013 (Merics, 2021).

However, according to Rhodium Group data (Rhodium Group, 2021), the value of Chinese investments in Europe increased by 25% in 2021, while in North America it fell by 34%. On the Old Continent, the Chinese spent nearly USD 13 billion. Interestingly, more than a third of the amount was allocated to greenfield investments, i.e. creating a business on the spot from scratch or recapitalizing a business built by them (Rhodium Group). It turned out, that the Netherlands was the largest recipient of Chinese capital in 2021 (USD 4.5 billion), and over USD billion also went to asset owners from Finland and the United Kingdom.

4. FDI in the Czech Republic

The Czech Republic is known as one of the most successful Central and Eastern European countries in attracting foreign direct investment. According to the Government Agency for Foreign Direct Investment, the Czech Republic ranks first among Central and Eastern European countries in terms of foreign direct investment stock and per capita inflows. This is due to the introduction of investment incentives, the availability of skilled and cheap labour, and the Czech Republic's geographical advantages, such as its location in the heart of Central Europe. Since May 2021, the Czech Republic has introduced a new FDI screening process that is in line with EU guidelines. Under the new law, any non-EU investor must obtain approval before acquiring more than 10% of the shares or voting rights of a company operating in a sector that is sensitive to the country's security or internal or public order (e.g., energy, gas, heating and water, food and agriculture, healthcare, transport, communication systems and IT, financial

market, emergency services and public administration, military material, etc.) (Doing Business, 2020).

The Czech Republic was ranked 41st out of 190 countries in the World Bank's latest Doing Business report, dropping 6 places from the previous edition. This is mainly due to the fact that the country's progress in terms of ease of doing business is almost stagnant (Doing Business, 2020).

Table 1.
FDI in Poland and the Czech Republic in years 2019-2021

FDI	Czech Republic			Poland		
	2019	2020	2021	2019	2020	2021
FDI Inward Flow (mill. USD)	10,108	9,411	5,806	13,510	13,831	24,816
FDI Stock (mill. USD)	171,334	195,240	200,587	240,586	249,723	269,225
Number of Greenfield Investments	90	57	109	448	467	511
Value of Greenfield Investments (mill. USD)	2,369	2,596	3,094	24,462	22,757	21,871

Source: UNCTAD.

Advantages of FDI in the Czech Republic:

- The Czech Republic is a member of the EU, but not the Eurozone.
- The country's central bank is strong and independent and regulates a stable currency. As a result, the country has excellent access to the European market and has positive and stable international relations.
- A stable banking sector that has proven resilient in recent crises.
- Public spending at a satisfactory and controlled level.
- One of the lowest unemployment rates in Europe creates an optimal and healthy business environment.
- The country's long tradition of industrial production (the sector continues to have great potential).
- The quality of the labour force (with high intermediate costs).
- Central geographic location.

Disadvantages of FDI in the Czech Republic:

- The Czech Republic's economy is highly dependent on the level of exports and the inflow of foreign investment, which makes it particularly vulnerable in times of crisis.
- The country's Euroscepticism and the lack of interest in adopting the euro can discourage some European entrepreneurs in the long run and make the country less competitive.
- The country has experienced political tensions, which may jeopardise its stability in the eyes of potential entrepreneurs.
- Legislative and judicial reforms are slow to materialise; this can be explained by a political history made of governmental coalitions.

- The shortage of labour and the ageing of the population also constitute a significant obstacle to the country's development and limit the country's ability to meet production requirements.
- The automotive sector occupies a large share of the economy.

In order to reduce the Czech market's dependence on its European trading partners (mainly Germany), the government has implemented reforms to diversify the country's export opportunities and the structure of its export market as well as its economic structure. To support these changes, an export strategy (2012-2020) targeting fast-growing emerging markets and a competitiveness improvement strategy (introduced in 2011) have been implemented. The Czech Ministry of Industry and Trade and the investment development agency CzechInvest (Investment and Business Development Agency – CzechInvest) have already launched the Welcome Package initiative and are now offering visa support to make immigration procedures as simple as possible for foreign investors who need residence and work permits in the Czech Republic

In addition, the Czech government has launched an economic program based on the promotion of entrepreneurship and the modernization of public administration (in terms of greater functionality and transparency). This has resulted, for example, in making it easier to obtain public funding in the areas of science, research and innovation.

In 2019, the government made significant changes to the Investment Incentives Law, eliminating incentives for investments aimed at growing low-skilled labor and limiting incentive payments to high-value-added investments that focus on research and development and create graduate jobs.

5. FDI in Poland

Poland has a lot to offer to foreign investors - first of all, it is well-connected and guarantees free access to the rich EU market, while remaining a country with relatively cheap, well-educated and numerous labor force. Therefore, it is an excellent location for companies looking to build factories or establish service centers, and scores well in the ranking of the largest recipients of greenfield investments. Poland is among the most attractive countries in Europe in terms of foreign direct investment. According to UNCTAD's 2021 World Investment Report (UNCTAD, 2021) FDI inflows to Poland remained stable in 2020, reaching USD 10 billion, the same as the previous year's figure of USD 10.8 billion, despite the outbreak of the Covid-19 pandemic causing a 42% drop in global FDI. The country's total investment stock amounted to USD 236.5 billion in 2020. In terms of the value of greenfield projects announced in the same year, Poland ranked fifth in the world with a total of USD 24.3 billion (UNCTAD, 2021).

Among the most important projects is Google's construction of a cloud region in Poland for $1.8 billion. Poland is the largest recipient of foreign direct investment in Central Europe. Most holdings are held by the Netherlands, Germany, Luxembourg, and France, with investments flowing mainly into the manufacturing, finance and insurance, wholesale and retail, and real estate sectors. In addition, data from recent years show that a high percentage of investors come from China and South Korea. According to the latest OECD figures, FDI inflows to Poland totaled $12.3 billion in the first half of 2021, up 27.4% from the same period last year (when FDI inflows totaled $9.6 billion). Poland's main assets are its strategic location, large population, membership in the European Union, economic stability, low cost of skilled labour, and a tax system attractive to businesses. In addition, Poland has a number of dynamic Special Economic Zones and the government founded the Polish Investment and Trade Agency (PAIH. Why Poland) to improve conditions for FDI. Under the 2021-2027 EU budget, Poland will receive USD 78.4 billion in cohesion funds as well as approximately USD 27 billion in grants and USD 40 billion in loan access from the EU Recovery and Resilience Facility. However, Polish law limits foreign ownership of companies in selected strategic sectors and restricts acquisition of real estate, especially agricultural and forest land. Furthermore, a new law came into force giving the President of the Office for Competition and Consumer Protection the authority to review FDIs by non-EEA and non-OECD investors on the grounds of public security, order and health. Overall, the Polish business climate is good and the World Bank ranks Poland 40th out of 190 countries in its latest Doing Business ranking (Doing Business, 2021), seven positions lower compared to the previous edition.

Moreover, in 2022, Poland widened and extended its controls on new foreign direct investments for another three years, until mid-2025.

Advantages of FDI in Poland:

- Growing economy.
- Central geographical location in the heart of Europe.
- Multilingual workforce, qualified, able to export trades (at a low cost) and whose productivity is growing rapidly.
- Stable banking sector and a controlled currency.
- A healthy and resilient economy even during economic crises.
- Unlike other Central European countries, its population does not face over-indebtedness.

Disadvantages of FDI in Poland:

- Rigidity of the labour market.
- Slow administrative procedures (120th country for the speed of starting a business according to the World Bank).
- Current account in deficit.

- The adoption of the euro initially planned for 2012 has been jeopardised by the financial crisis, thereby delaying its beneficial effects on the economy.
- The relatively unstable political landscape slows down the implementation of necessary reforms.

6. Comparison of China's investment in Poland and the Czech Republic

As shown in Figure 3, China is investing much more in the Czech Republic than in Poland. Since 2016, China has become the second largest trading partner of the Czech Republic (2018 - EUR 24.3 billion in trade in goods). After Germany, China is the largest supplier of goods to the Czech market. In 2018, imports from the PRC amounted to EUR 22.1 billion and were ten times higher than Czech exports to China.

The negative trade balance is unfavourable for the Czech government, which expects its Chinese partner to deregulate and liberalise the market. This position stems from the ANO (ANO) programme which, which in the context of China mentions respecting the rules of international trade and protecting Czech industry from unfair competition.

The Czech Republic's cooperation with China was established through a declaration on strategic partnership, and both sides signed several memoranda reflecting Czech aspirations to increase trade with China and hope for greater Chinese investment. Initially, it was assumed that in the first year of cooperation in 2016, Chinese investments in the Czech Republic would amount to CZK 95 billion, i.e. approximately EUR 3.5 billion (Bankier.pl, 2016).

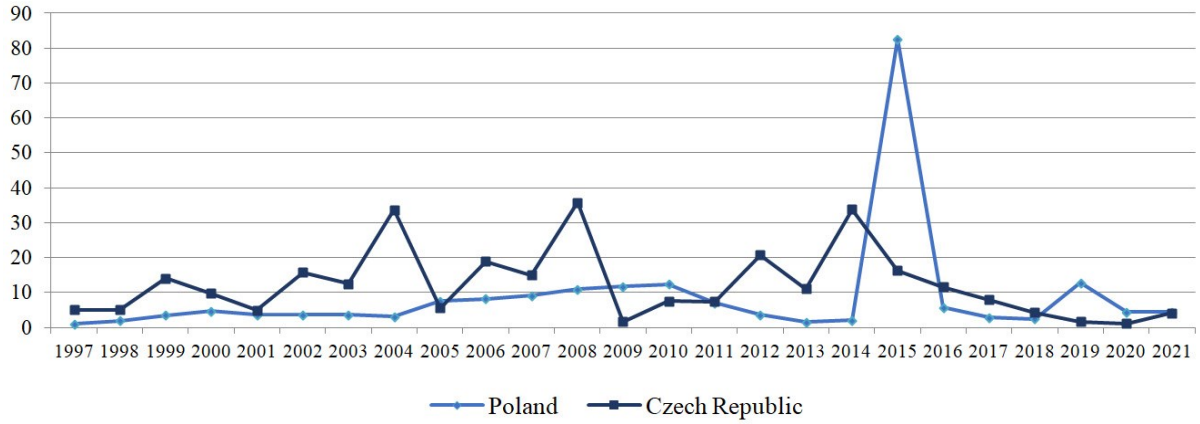

Figure 3. China's FDI actually utilized by Poland and Czech Republic in 1997-2018 [USD mill.].

Source: Own elaboration based on: (National Bureau of Statistics of China, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999).

Unfortunately, FDI, which was supposed to flow to the Czech Republic thanks to the Belt and Road initiative, is not growing in the wake of imports from China. FDI from China in 2017 amounted to around EUR 0.2 billion, whereas it reached EUR 0.5 billion a year earlier.

This result contrasts with President Zeman's announcement in 2016 of an investment inflow of €3.7 billion by the end of that year. In fact, credibility to these plans was added by 17 agreements between economic entities of both countries, concluded together with a strategic partnership. In addition, during Miloš Zeman's visit to China in April 2019, the Bank of China signed memoranda on cooperation with the Chamber of Commerce of the Czech Republic and with the financial company CITIC, the main Chinese investor in the Czech Republic (Ogrodnik, 2019).

Transatlantic relations also have a significant impact on the Czech Republic's policy towards China. The United States wants to stop China's technological expansion in Central Europe. Currently, it is noted that Czech-Chinese relations are deteriorating. Although the Czech government is currently disappointed with the state of investments from the PRC, in the long term they want them to grow. The guarantee that they will not pose a threat will be the regulation of the EP and the EU Council of 19 March 2019, implemented by the Ministry of Industry and Trade (for which ANO is responsible). The 14 EU members, including the Czech Republic, do not have national investment screening mechanisms (Ogrodnik, 2019).

Poland is one of the most attractive locations for foreign investment. Regional aid is the most popular type of aid for companies carrying out investment projects in Poland. They are granted only for "initial" or "new" investments, which are generally defined as investments related to the establishment of a new establishment, the expansion of the capacity of an existing establishment, or the diversification of the production of an establishment to include products not previously produced. The maximum amount of aid a project can receive depends on the size of the company and where in Poland the project is to be located. Regional aid can be granted in Poland in various forms, such as exemption from corporate income tax (CIT) in so-called special economic zones (SEZs), state grants (support from the state budget), and cash grants or loans from EU funds. The state grant (Multi-Annual Support Programme - MASP) is a regional aid programme financed by the Polish government and designed to support large investments in the so-called “priority sectors”: automotive, electronics, aviation, biotechnology, modern services (particularly IT centres, BPOs and telecommunications) and R&D (UNCTAD, 2022).

In Poland, a limited number of sectors have restrictions on foreign ownership and foreign capital. Polish law limits non-EU nationals to 49% of a company's capital in air transport, radio and television, and airport and seaport operations. Licenses and concessions for defense production and seaport management are granted on the basis of national treatment for investors from OECD countries. The Law on Freedom of Economic Activity (LFEA) requires companies to obtain government concessions, licenses, or permits to operate in certain sectors, such as broadcasting, aviation, energy, arms/military technology, mining, and private security services (UNCTAD, 2022).

In May 2020, the Polish government adopted regulations designed to make it more difficult for investors from outside the European Union to acquire at low-cost companies that Poland considers strategic to its economy. The regulations were part of a government rescue package

worth more than PLN 300 billion to help the country survive the new coronavirus pandemic and the resulting economic crisis (UNCTAD, 2022).

Even though Poland is the leading recipient of FDI in central and eastern Europe it has attracted little Chinese FDI. This may be partially explained by the rather cool political relations between the two countries since the early 1990s, when Polish politicians often criticised Beijing for violating human rights and supported the case of Tibet.

McCaleb's findings show that the motivation originally associated with the pursuit of markets and efficiency, mostly involving greenfield entry, has been broadened to include the strategic pursuit of assets, as reflected in the acquisitions of Polish companies in the 2009-2014 and 2015-2018 periods (McCaleb, 2021). Another feature of Chinese companies that have recently gained a foothold in Poland is that their presence is the result of acquisitions by Chinese multinational companies (MNCs) located in third countries, especially Germany. This is a consequence of the Chinese MNCs entry into European value chains. The industrial structure of Chinese MNCs in Poland also evolved from assembly of electronics, to manufacturing of parts and components for automotive sector, utilities, and services. Chinese firms are mainly located in Poland's key industrial regions, namely the Mazowieckie, Dolnoslaskie, Malopolskie and Slaskie voivodeships. The ten largest Chinese employers employ between 372 and 2103 people and are mainly active in the automotive industry (Biswas, Dygas, 2021).

7. Summary

Although the countries examined here – Poland and Czechia – differ in many respects, they have some common features as well. They have been in the process of economic catching up over recent decades; their development paths are defined mainly by the global and European powers, rules and trends; and FDI has a key role in restructuring their economies. In recent years, the abovementioned countries have started to get more interested in Chinese relations – more properly in attracting Chinese investments and boosting trade relations – since the new millennium, although the economic and financial crisis of 2008 drew their attention more than ever to the potential of Chinese economic relations.

In the context of Chinese strategy, the location is an advantage of Poland and the Czech Republic. The initiative created by Chinese government in 2015 “One Belt, One Road” was supposed to open the possibilities for Chinese investors to go global. The scale of Chinises investments in Europe will change and that is an opportunity for Poland, the Czech Republic and other countries from Central and Eastern Europe. Foreign direct investment is one of the most important areas of potential development in bilateral relations. Investment relations between China and CEE countries are expected to develop, based on the announced strategy of Chinese central authorities towards this region (Jankowiak, 2016).

However, the Covid-19 pandemic caused a notable decline in global foreign direct investment (FDI) in 2020, bringing FDI flows back to 2005 levels. The crisis had an immense negative impact on the most productive types of investment, namely greenfield investment in industrial and infrastructure projects, which significantly affected the entire global economy (UNCTAD, 2021).

It is unlikely that Chinese investment in Europe will recover in 2023. The Chinese government is expected to maintain strict capital controls, financial deleveraging, and Covid-19 restrictions. The war in Ukraine and the expansion of regulations to monitor and control Chinese investment in the EU and UK will cause additional difficulties.

The limitation of the conducted research is, among others, the fact that the comparison of Chinese investments was made only in terms of two neighbouring countries, exemplary for the European Union, but certainly not characteristic of each EU member state. Additional, the Covid-19 pandemic and the war in Ukraine, therefore, made it necessary to deepen further research on the phenomena of foreign direct investment, its inflows, its determinants, and the challenges associated with them in a turbulent world.

References

1. Baltagi, B.H., Egger, P., Pfaffermayr, M. (2007). Estimating models of complex FDI: are there third country effects? *Journal of Econometrics, Vol. 140, Iss. 1,* pp. 260-281.
2. Bankier.pl (2016). *Czechy: zawarcie strategicznego partnerstwa z Chinami*. Retrieved from: https://www.bankier.pl/wiadomosc/Czechy-zawarcie-strategicznego-partnerstwa-z-Chinami-3506687.html, 17.02.2023.
3. Beugelsdijk, S., McCann, P., Mudambi, R. (2010). Introduction: place, space and organization – economic geography and the multinational enterprise. *Journal of Economic Geography, Vol. 10, Iss. 4*, pp. 485-493.
4. Bevan, A., Estrin, S. (2004). The determinants of foreign direct investment into European transition economies. *Journal of Comparative Economics, Vol. 32, Iss. 4*, pp. 775-787.
5. Bevan, A., Estrin, S., Meyer, K. (2004). Foreign investment location and institutional development in transition economies. *International Business Review*, *Vol. 13, Iss. 1,* pp. 43-64.
6. Biswas, P.K., Dygas, R. (Eds.) (2021). *Asian Foreign Direct Investment in Europe* (1st ed.). Routledge, doi: 10.4324/9781003186601.
7. Blomkvist, K., Drogendijk, R. (2016). Chinese outward foreign direct investments in Europe. *European J. International Management*, *Vol. 10, Iss. 3*, pp. 343-358.
8. Blonigen, B.A., Piger, J. (2014). Determinants of foreign direct investment. *Canadian Journal of Economics*, *Vol. 47, Iss. 3.* Canadian Economics Association, pp. 775-812.

9. Buckley, P.J., Clegg, J., Cross, A.R. et al. (2007). The determinants of Chinese outward foreign direct investment. *Journal of International Business Studies, Vol. 38, Iss. 4*, pp. 499-518.
10. Carstensen, K., Toubal, F. (2004). Foreign direct investment in Central and Eastern European countries: a dynamic panel analysis. *Journal of Comparative Economics, Vol. 32, Iss. 1*, pp. 3-22.
11. *China Going Global between ambition and capacity* (2017). Beijing: China Policy.
12. Doing Business (2020). Retrieved from: worldbank.org, 6.02.2023.
13. Doing Business (2021). Retrieved from: worldbank.org, 6.02.2023.
14. Dunning, J. (1992). *Multinational Enterprises and the Global Economy*. London: Addison-Wesley.
15. Dunning, J. (1998). Location and the multinational enterprise: a neglected factor? *Journal of International Business Studies, Vol. 29, Iss. 1,* pp. 45-66.
16. Dunning, J. Lundan, S. (2008). Institutions and the OLI paradigm of the multinational enterprise. *Asia Pacific Journal of Management*, *Vol. 25, Iss. 4*, pp. 573-593.
17. Dunning, J.H. (2001). The Eclectic (2001) (OLI) Paradigm of International Production: Past, Present and Future. *International Journal of the Economics of Business*, *Vol. 8, Iss. 2*.
18. Gu, A., Zhou, X.Y. (2020). Emission reduction effects of the green energy investment projects of China in belt and road initiative countries. *Ecosystem Health and Sustainability, Vol. 6, Iss.1,* 1747947, doi: 10.1080/20964129.2020.1747947.
19. Hijzen, A., Görg, H., Manchin, M. (2008). Cross-border mergers and acquisitions and the role of trade costs. *European Economic Review*, *Vol. 52, Iss. 5*, pp. 849-866.
20. International Cooperation, Belt And Road Portal. Retrieved from: https://eng.yidaiyilu.gov.cn/info/iList.jsp?cat_id=10076&cur_page=5, 18.08.2022.
21. Investment and Business Development Agency - CzechInvest.
22. Jacimovic, D., Dragutinović Mitrović, R., Bjelić, P., Tianping, K., Rajkovic, M. (2018). The role of Chinese investments in the bilateral exports of new E.U. member states and Western Balkan countries. *Economic Research-Ekonomska Istraživanja*, *Vol. 31, Iss. 1,* pp. 1185-1197, doi: 10.1080/1331677X.2018.1456357.
23. Jankowiak, A.H. (2016). The Attractiveness of Poland for Asian Foreign Direct Investments in the Context of Clusters Formation. *Asia-Pacific Journal of EU Studies*, *Vol. 14, Iss. 1*.
24. Jankowiak, A.H. (2016). Partnership through Investment- Chinese Foreign Direct Investment in CEE Countries. In: Wardęga, J. (Ed.), *China- Central and Eastern Europe Cross-Cultural Dialogue. Society, Business and Education in Transition*. Kraków.
25. Jones, A. (2018). Geographies of production III: economic geographies of management and international business. *Progress in Human Geography, Vol. 42, Iss. 2,* pp. 275-285.

26. Jones, J. (2017). Agglomeration economies and the location of foreign direct investment: a meta-analysis. *Journal of Regional Science, Vol. 57, Iss. 5*, pp. 731-757.
27. Jones, J., Serwicka, I., Wren, C. (2018). Economic integration, border costs and FDI location: evidence from the fifth European Union enlargement. *International Review of Economics and Finance, Vol. 54*, pp. 193-205.
28. Jones, J., Wren, C. (2016). *Understanding the Location of Foreign Direct Investment*. Palgrave Advances in Regional and Urban Economics Series. London: Macmillan.
29. Karreman, B., Burger, M.J., van Oort, F.G. (2017). Location Choices of Chinese Multinationals in Europe: The Role of Overseas Communities. *Economic Geography*, *Vol. 93, Iss. 2*, pp. 131-161, doi: 10.1080/00130095.2016.1248939.
1. Kierśnikiewicz, M. (2022). *Logistyka w trudnych czasach. Transport towarów na niespokojnych wodach.* Konferencja Naukowa i Forum Ekonomicznym. Polska-Azja. Wojna i pandemia, zmierz dawnej globalizacji i początek nowej. Wrocław, 26.09.2022.
30. Ma, Y., Overbeek, H. (2015). Chinese foreign direct investment in the European Union: explaining changing patterns. *Global Affairs*, *Vol. 1, Iss. 4-5*, pp. 441-454, doi: 10.1080/23340460.2015.1113796.
31. Mathews, J.A. (2006). Dragon multinationals: new players in 21st century globalization. *Asia Pacific Journal of Management*, *Vol. 23, Iss. 1,* pp. 5-27.
32. McCaleb, A. (2021). FDI outflow from China to Poland – two decades of Chinese FDI in Poland. In: Biswas, P.K., Dygas, R. (Eds.). Asian Foreign Direct Investment in Europe (1st ed.). Routledge, doi: 10.4324/9781003186601.
33. Merics (2021). Mercator Institute for China Studies, Chinese FDI in Europe: 2021 Retrieved from: https://merics.org/en/report/chinese-fdi-europe-2021-update, 6.02.2023.
34. Mroczkowski, F. (2022). *Polskie perspektywy dla chińskich inwestorów – Szanse i możliwości współpracy i bariery wejścia na polski rynek*, Konferencja Naukowa i Forum Ekonomicznym. Polska-Azja. Wojna i pandemia, zmierz dawnej globalizacji i początek nowej. Wrocław, 26.09.2022.
35. National Bureau of Statistics of China (2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999). *China Statistical Yearbook*. Retrieved from: http://www.stats.gov.cn/english/Statisticaldata/ AnnualData/, 24.10.2022.
36. OECD (2008). *Benchmark Definition of Foreign Direct Investment*, fourth edition.
37. OECD. Glossary of Statistical Terms - Foreign direct investment Definition.
38. Ogrodnik, Ł. (2019). Czechy wobec wyzwań we współpracy z Chinami. *Biuletyn Pism, Vol. 106, Iss. 1854.* Retrieved from: https://www.pism.pl/publikacje/Czechy_wobec_ wyzwan_we_wspolpracy_z_Chinami, 17.02.2023.
39. PAIH. Why Poland. Polish Investment and Trade Agency.

40. Parepa, L.A. (2020). The Belt and Road Initiative as continuity in Chinese foreign policy. *Journal of Contemporary East Asia Studies*, *Vol. 9, Iss. 2,* pp. 175-201, doi: 10.1080/24761028.2020.1848370.
41. Pusterla, F., Resmini, L. (2007). Where do foreign firms locate in transition countries? An empirical investigation. *The Annals of Regional Science, Vol. 41, Iss. 4,* pp. 835-856.
42. Resmini, L. (2000). The determinants of foreign direct investment in the CEECs: new evidence from sectoral patterns. *Economics of Transition, Vol. 8, Iss. 3*, pp. 665-689.
43. Rhodium Group (2021). *Chinese FDI in Europe: 2021 Update*. Retrieved from: https://rhg.com/research/chinese-fdi-in-europe-2021-update/, 24.10.2022.
44. Richet, X. (2019). Geographical and Strategic Factors in Chinese Foreign Direct Investment in Europe. *Asian Economic Papers*; *Vol. 18, Iss. 2*, pp. 102-119, doi: 10.1162/asep_a_00700.
45. Stoian, C., Filippaios, F. (2008). Dunning's eclectic paradigm: a holistic, yet context specific framework for analysing the determinants of outward FDI: evidence from international Greek investments. *International Business Review, Vol. 17, Iss. 3*, pp. 349-367.
46. UNCTAD (2021). World Investment Report, Investing in sustainable recovery. UNCTAD/WIR/2021.
47. UNCTAD (2022). World Investment Report 2022 International tax reforms and sustainable investment. UNCTAD/WIR/2022.
48. UNCTADSTAD. Retrieved from: https://unctadstat.unctad.org/CountryProfile/General Profile/en-GB/156/index.html, 24.10.2022.
49. Xu, Q. (2022). Scoping the impact of the Comprehensive Agreement on investment: liberalization, protection, and dispute resolution in the next era of EU–China relations. *Asia Pacific Law Review*, *Vol. 30, Iss. 1*, pp. 93-122, doi: 10.1080/10192557.2022.2045708.
50. Zhang, Y., Duysters, G., Filippov, S. (2012). Chinese firms entering Europe: internationalization through acquisitions and strategic alliances. *Journal of Science and Technology Policy in China*, *Vol. 3, Iss. 2,* pp. 102-123.

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MANAGEMENT OF THE CRITICAL INFRASTRUCTURE USED FOR THE TRANSPORT OF FOSSIL RAW MATERIALS – A CASE STUDY

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Purpose: The occurrence of mining damage has a huge impact on the quality and safety of railway infrastructure. Damage to the railway infrastructure due to mining damage may result in the need to temporarily close the railway line, reduce capacity and thus cause disruptions in the supply of goods and services in part of the value chain requiring non-standard actions. Due to the occurrence of mining damage, there is also a need to increase funds for infrastructure maintenance.
Design/methodology/approach: Railway infrastructure is a kind of critical infrastructure and its elements are subject to special protection. In order to prevent threats and minimize their effects, risk assessment should be carried out systematically and control mechanisms should be introduced in order to increase the security and quality of services provided.
Findings: Analyzing the scope of activities of Jastrzębska Spółka Kolejowa sp. z o.o. numerous potential hazards have been noted. The risk may result from deterioration of the quality of railway infrastructure, railway event, incident, potentially dangerous situation, but also loss of human life. Taking into account the location of railway infrastructure in mining areas, ensuring its required quality is a huge challenge for its manager due to the intensity of mining damage.
Originality/value: The article includes, among others, an analysis and risk assessment and presents control mechanisms to increase the security and quality of services provided by JSK sp. z o.o. In the article, this problem was looked at prognostically.

Keywords: critical infrastructure, threat, risk, railway accidents, management.

1. Introduction

The present dynamisation of society significantly increases the standards of human life. Improvement of the life's quality, creation of a friendly space, scientific and technical progress contributed to an increase in the sense of security. Each of the aforementioned aspects is seen as obvious and widely available. By analysing the arising relationships between key state

sectors and possible threats, we can observe how easily the security and existence of the society can be upset. Infrastructures that are part of individual state sectors and have an impact on the proper functioning of the state, economy and society should be subject to special protection.

The concept of Critical Infrastructure (CI), which is important from the point of view of modern society, was introduced and discussed in the Act of 26 April 2007 on crisis management in which the CI is: "systems and their functionally related facilities including civil structures, devices, installations, services essential for the security of the state and its citizens, and for ensuring the efficient functioning of public administration bodies, as well as institutions and entrepreneurs"(Act of 26 April 2007…).

It can be concluded that in the situation of determining the infrastructure as critical, it is all about additional enhancement of the importance of infrastructure without which modern societies and innovative entrepreneurs cannot function.

The critical infrastructure includes, among others, the energy supply system, energy sources, fuels and transport systems (Milewski, 2016, pp. 99-115).

Threats which critical infrastructure is exposed to may be local but also global. There is a reference in the Crisis Management Act to the infrastructure located on the territory of the European Union, under the concept of European Critical Infrastructure (ECI), according to which: "a disturbance or destruction would significantly affect two or more Member States" (Act of 26 April 2007…). Thus, threats to one critical infrastructure may impact and affect other related critical infrastructures in a procedural and social manner.

The transport network has been used for years to transfer people and goods for a fee from point A to point B using an appropriate means of transport. The development and security of the economy largely depend on transport. The area of transport infrastructure is classified as the economic infrastructure which, among others, includes road, rail, air and sea transport. Due to its universality, the technological process of transport is exposed to numerous threats. The very stage of preparing the selected means of transport and loading it is complicated and involves a risk that may affect the timeliness of deliveries (Grabowski, 2019, pp. 183-193; Kolano, 2018, pp. 229-237).

Railway infrastructure is a kind of critical infrastructure in the context of making it available to railway carriers that perform the shipment of, among others, hard coal, from which coke is obtained in the combustion process, which as the basic raw material used in the production of steel is one of the strategic raw materials for the European metallurgy. Thus, the coking coal market has a global dimension and is crucial for the steel industry. Based on an assessment of the risks of deficit, supply and economic importance, coking coal was included in the EU list of critical raw materials. This raw material is obtained in several countries. The leaders of coking coal suppliers in the world are located in Asia and Australia, while in Europe the largest producer is Jastrzębska Spółka Węglowa (JSW S.A.), which covers approximately 25% of the EU demand, the remaining part, i.e. approximately 40 million tons per year, is imported by the European Union (https://www.jsw.pl/ raportroczny/…). Railway transport is inextricably

linked to the functioning of mining plants and coking coal producers. Railway activity is considered to be the last stage of their production cycle. JSW S.A. uses for the transport of coking coal, among others, the railway infrastructure whose authorised manager is Jastrzębska Spółka Kolejowa Sp. z o.o. (JSK), part of the JSW S.A. capital group (https://www.jsw.pl/raportroczny/…).

JSK makes its railroad lines and sidings available to licensed railway carriers. In order to maintain traffic continuity, it also cooperates with other Railway Administrators. Due to the imposed duties on the management of the railway infrastructure, it gradually improves the safety and quality of the railway infrastructure through its ongoing maintenance, repairs, modernisation and new investments. Based on the risk analysis, its manager introduces modern systems ensuring technical consistency (https://www.jsk.pl/oferta/…). Threats that may affect the safety and continuity of rail traffic are divided into three categories:

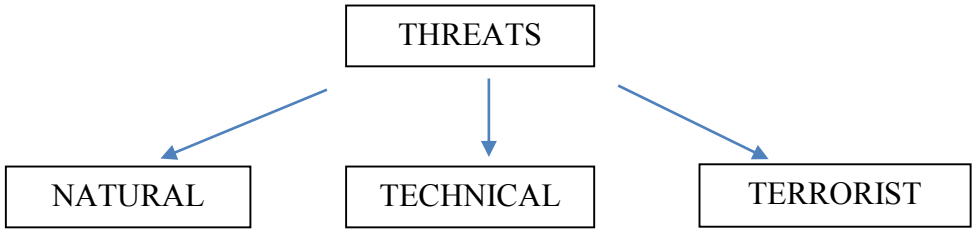

Figure 1. Threats that may affect the safety and continuity of rail traffic.

Source: https://phavi.umcs.pl/…

Further in the paper the following are discussed:

- risk assessment developed on the basis of the FMEA method,
- railway accidents, incidents and potentially dangerous situations that took place in 2016-2021 in the company's railway infrastructure,
- preventive measures taken and their impact on the safety and continuity of rail traffic at Jastrzębska Spółka Kolejowa Sp. z o.o. (JSK),
- damage to the railway infrastructure as a result of mining damage.

2. Risk Assessment

Currently, great emphasis is placed on the quality of the services provided. In order to be able to efficiently manage the critical infrastructure, which is the railway infrastructure, by ensuring safety and continuity of traffic, railway infrastructure managers are obliged to:

- conduct risk analyses,
- identify threats,
- control identified threats,

- keep records of threats,
- introduce preventive measures aimed at increasing the safety of rail traffic and related activities.

Different methods and techniques are used to perform a risk assessment. These methods can be divided into qualitative, quantitative and qualitative-quantitative. Qualitative methods are elected more often due to their simplicity in application and the smaller amount of required data. The methods that are mainly used for risk assessment in railway transport are:

- FTA – Fault Tree Analysis,
- ETA – Event Tree Analysis,
- FMEA – Failure Mode and Effect Analysis,
- HAZOP – Hazard and Operability Study,
- COSO II – Corporate Risk Management – an integrated framework prepared by the Committee of Sponsoring Organizations of the Tradeway Commission,
- Checklist,
- Brainstorm (Jacyna, Szaciłło, 2017, pp. 163-178).

Among the aforementioned methods for risk assessment, the most commonly used is FMEA. This method belongs to the qualitative modes. It is based on determining all risks that can occur in a given process in order to prevent them or minimise the losses incurred in the event of risk. FMEA is based on the determination of cause and effect relationships for a given threat. The resulting list of hazards should be systematically monitored, it must be completed with necessary changes and supplemented with new identified threats, which will allow to increase safety (Garlikowska, Gondek, 2019, pp. 10-16; Jacyna, Szaciłło, 2017, pp. 163-178).

In 2021, the risk assessment of the JSK's railway infrastructure was updated. Twelve risk groups were distinguished to which a total of 281 identified threats were assigned. Each threat is attributed with:

- possible consequences,
- existing measures of supervision,
- probability of occurrence (P) in a range from 1 to 10, where 1 means 'rare' and 10 'frequent' occurrence,
- possibility of its detection (W) in a range from 1 to 10, where 1 means 'easy' and 10 means 'difficult' to detect,
- effects (S) on a scale from 1 to 10, where 1 means 'insignificant' and 10 'catastrophic',
- critical identification (R) calculated on the basis of the following formula (1) (Register of FMEA threats…)

$$R = P*W*S \quad (1)$$

The table below contains five threats with the highest critical identification factor. The level of risk for the following hazards is unacceptable (R > 150), therefore measures should be taken to eliminate or reduce their effects.

Table 1.
Threats with the highest critical identification factor (Register of FMEA threats…)

Item	Threat	Possible consequences	P	W	S	R
1	No licence for a road-rail vehicle driver	Railway accident	8	4	5	160
2	Conducting periodic instructions during the epidemic threat	Exposing employees to loss of health and life	9	2	10	180
3	Mining damage	Destruction of railway infrastructure, railway accident	9	3	7	189
4	Admission of a road-rail vehicle without technical efficiency certificate	Railway accident	8	5	5	200
5	Epidemic threat	Threat to health and life of employees, limitation or suspension of business activities	6	5	10	300

The most common possible consequences after the threat include:

- railway accidents,
- railway incidents,
- damage to the railway infrastructure,
- material losses,
- reduction of throughput,
- limitation to trafficability performance,
- incorrect performance of tasks,
- suspension of traffic (Register of FMEA threats…).

The presented data show how important it is to assess the risk and the need to introduce solutions aimed at eliminating threats and reducing their effects. Railway infrastructure is exposed to a large number of identified threats. The railway infrastructure manager is obliged to take actions aimed at their elimination, which is a huge challenge due to the area of the infrastructure selected for analysis. To be able to meet the challenge, it is important that the manager constantly analyses and updates the risk assessment list. During this assessment, different methods should be used to verify the risks more accurately. It should be remembered that none of the methods used for risk assessment will guarantee the total elimination of threats, but will only improve the process of the organisation's functioning and will influence the improvement of safety.

2.1. Railway accidents, incidents and potentially dangerous situations

Railway accidents, incidents and potentially dangerous situations resulting from undesirable hazards have a significant impact on the deterioration of the company's safety. Jastrzębska Spółka Kolejowa has developed the R3 instruction on dealing with serious accidents and incidents in railway transport. Within this document, information can be found who to notify about the accident, who can conduct an investigation, how to conduct an investigation and what to do after an investigation is finished. The information about all railway events, incidents and potentially dangerous situations in the period from 2016 to 2021 is gathered in the charts below. It can be observed that the number of railway accidents and incidents is gradually decreasing but is still high. Railway carriers are responsible for the direct cause, over 90%, of all accidents occurring in the company's railway infrastructure in the analysed period (Register of potentially…; Register of accidents…).

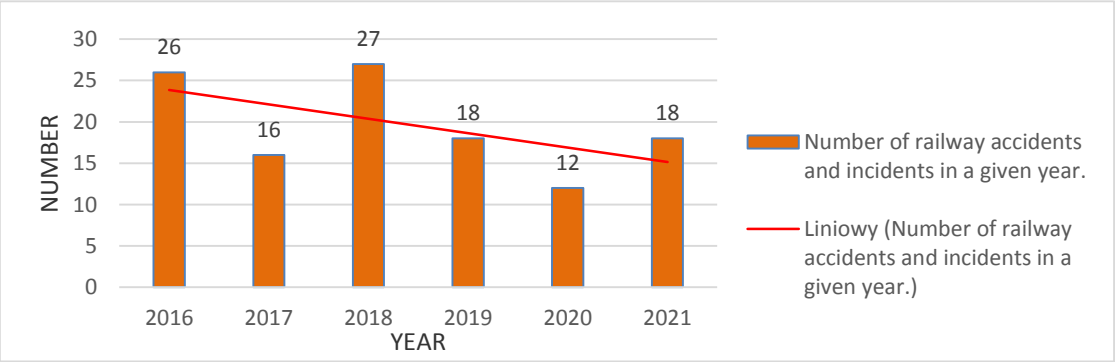

Figure 2. Number of railway accidents and incidents recorded in years 2016-2021.

Source: Register of accidents…

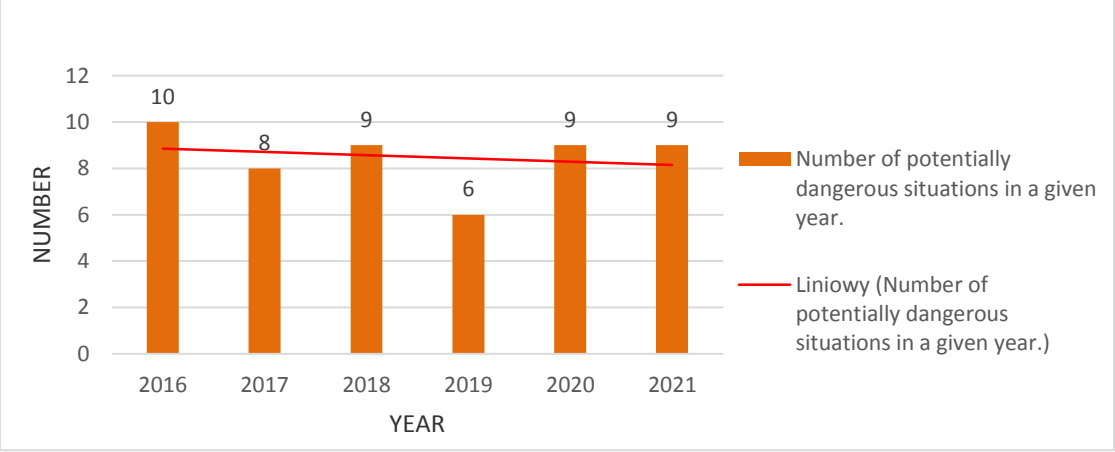

Figure 3. Potentially dangerous situations recorded in years 2016-2021.

Source: Register of potentially…

The railway accident of B09 category of 8 December 2020 on one of the tracks of the JSK railroad line brought the greatest effects of the threat in the analysed period. On that day, three carriages of the train from Pawłowice Górnicze to Kraków NH derailed. According to the findings of the railway commission, the direct cause of the accident was a cant deficiency and excessive track gauge. The original cause of the accident was the excessive degradation of the track surface caused by the sharp increase in traffic in a short period of time. During the investigation, numerous irregularities were found during the visual inspection and measurements of the freight wagon, which had an indirect impact on the cause of the accident. The track where the wagons were derailed was closed for over half a year. The removal of the effects of the derailment continues up to this day. Currently, the cost of the derailment has been estimated at around one million zlotys. Considering the scale of the effects of the derailment of wagons, appropriate preventive measures should be taken. Following the risk assessment, the following preventive conclusions were made:

- controlling and providing information in situations of a significant increase in transport on the lines and its sections,
- increasing the frequency of track and turnout measurements,
- the occurrence should be included in the company's information bulletin on railway accidents,
- the accident should be discussed in periodic trainings for employees (Protokół Ustaleń Końcowych…).

Figure 4. On-site inspection of B09 accident. The first derailed wagon.

Source: Protokół Ustaleń Końcowych…

Figure 5. On-site inspection of B09 accident. The second derailed wagon.
Source: Protokół Ustaleń Końcowych…

2.2. Damage to the railway infrastructure as a result of mining damage

Mining damage has a huge impact on the quality and safety of the railway infrastructure. The activities of Jastrzębska Spółka Kolejowa are conducted in active mining areas, therefore they are exposed to coping with numerous effects of mining damage. On the basis of the risk assessment, a risk sheet has been developed in which the probability of damage to railway infrastructure elements (such as: railway surfaces, control stations, buildings and structures) as a result of subsidence is assessed. In the area of the company's operations, an increased intensity of rock mass movement is recorded, as a result of which elements of the railway infrastructure are destroyed. Typical damage for individual groups of railway structures:

a) railway surface - buckling, uplifting, crimping and breaking rail joints; degradation of sleepers, base plates and rail bonds; distortion of turnout geometry,
b) control stations - mainly diagonal cracks; horizontal cracks in the ceilings, side walls; sinkholes under the facility,
c) other structures (bridges, viaducts, culverts, embankments, electro-traction power supply devices as well as security and traffic control devices) - excessive and non-uniform slopes, formation of funnels over culverts, expansion gap openings, flooded outlet heads, displacement of bearing parts, stresses of central anchor ropes, cracked foundation heads; tilts of railway signals, overhead power masts, overhead transmission lines, displacement of supports, breaking cable and communication routes through excessive straining of cables.

Hence, the occurrence of risk in the area of the company's operations in the coming quarters is almost certain, therefore the weight of probability is assessed at 5 points on a scale of 1 to 5, where 1 means ‘rare’ and 5 ‘common’ (Risk Sheet…).

The occurrence of infrastructure destruction due to mining damage may cause the necessity to temporarily close the railway line, limit capacity, and as a result make disruptions in the shipment of goods and services in part of the value chain demanding non-standard actions.

In connection with the occurrence of mining damage, there is also a need to increase funds to maintain infrastructure. Due to the amount of losses oscillating in the range from PLN 3 to 30 million incurred as a result of mining damage, the effects of primary risk have been assigned with a weight of 3 on a scale from 1 to 5, where 1 means ‘insignificant effects’ below PLN 300 thousand per year and 5 means ‘catastrophic effects’ above PLN 100 million (Risk Sheet…).

By multiplying the probability weight with the primary risk effects, the risk significance value is determined to be 15. Current mechanisms that have been implemented in order to supervise the risk involve:

- conducting inspections and monitoring damaged areas,
- introducing speed limits in selected sections,
- obtaining information from mining corporations on land subsidence forecasts in periods not shorter than 3 months,
- introducing transport systems eliminating the number of devices, buildings and railway structures exposed to mining damage.

Due to limitations in implementation, the current inspection mechanism is given a weight of 3 points on a scale from 1 to 5. The reduction in the rating is also caused by the possibility of improving the inspection mechanism including the implementation of additional inspection mechanisms and measures aimed at minimising the risk (Risk Sheet…).

On the basis of the model presented below (Table 2), the value of the residual risk is defined at a weight of 9.

Table 2.
Residual risk assessment (Risk Sheet…)

25	**Primary risk value**	25	20	15	10	5
20		20	16	12	8	4
16		16	12,8	9,6	6,4	3,2
15		15	12	9	6	3
12		12	9,6	7,2	4,8	2,4
10		10	8	6	4	2
9		9	7,2	5,4	3,6	1,8
8		8	6,4	4,8	3,2	1,6
6		6	4,8	3,6	2,4	1,2
5		5	4	3	2	1

Cont. table 2.

4		4	3,2	2,4	1,6	0,8
3		3	2,4	1,8	1,2	0,6
2		2	1,6	1,2	0,8	0,4
1		1	0,8	0,6	0,4	0,2
		Evaluation of inspection mechanisms				
		1	2	3	4	5

In order to improve the current inspection mechanism, a "Technical and economic study for the optimization of transport and its reliability by rail transport from JSW sidings" has been commissioned. The aforementioned data is presented in the Risk Sheet (Table 3).

Table 3.
Risk sheet of damage to the railway infrastructure as a result of mining damage (Risk Sheet…)

Risk Sheet		
Name of risk	**Damage to the railway infrastructure as a result of mining damage**	
Definition of risk	Risk of damage to railway infrastructure elements such as the track surface, control stations, buildings and structures (bridges, viaducts, culverts, embankments, electric traction power equipment, and security and traffic control devices) as a result of mining damage.	
Significance of primary risk	Probability	5
	Effect	3
	Significance according to the formula	**15**
Assessment of current inspection mechanisms	Assessment	3
	Justification	A risk management plan has been defined and implemented. Inspection and risk minimisation measures have been implemented and are in operation. There are limited possibilities to improve inspection mechanisms.
Residual risk value	According to the model	**9,0**
Type of reaction to risk	Monitoring inspection mechanisms	
Current action plan	Action plan in the event of mining damage, the "Technical and economic study of the optimisation of transport and its reliability by rail transport from JSW sidings" has been developed	
	Status:	In progress
Category	Operating activities	
Area	Logistics (storage, transport, distribution)	

Summary

JSK's railway infrastructure creates conditions for the operation of mining plants and coking coal producers. Railway transport is involved in the process of creating value and constitutes an added value in the trade exchange of fossil raw materials including raw materials recognised as strategic or critical due to their importance in the European economic area. Considering the aforementioned, railway infrastructure is a kind of critical infrastructure and its elements are

subject to special protection. In order to prevent threats and minimize their effects, it is necessary to systematically assess the risk and introduce inspection mechanisms in order to increase the safety and quality of the services provided. While analysing the scope of the company's operations, numerous possible threats are recorded. The occurrence of threat may result, among others, in deterioration of the quality of railway infrastructure, railway accident, incident, potentially dangerous situation, but also the loss of the most valuable human life. Taking into account the location of the railway infrastructure, ensuring its required quality is a huge challenge for the manager due to the intensity of mining damages. In order to prevent or reduce the effects of mining damage, the issue should be considered with a prognostic approach.

References

1. Act of 26 April 2007 on crisis management (Journal of Laws of 2007, No 89, item 590).
2. Garlikowska, M., Gondek, P. (2019). Metody i techniki wyceny i oceny ryzyka w transporcie kolejowym ze szczególnym uwzględnieniem metody FMEA. *Prace Instytutu Kolejnictwa. Bulletin, 162,* pp. 10-16.
3. Grabowski, K. (2019). Kolejowy system zarządzania kryzysowego w świetle ochrony infrastruktury krytycznej. *Gospodarka materiałowa i logistyka, No. 10*, pp. 183-193.
4. https://phavi.umcs.pl/at/attachments/2020/0318/223159-ik-ca1-i-2.pdf.
5. https://www.jsk.pl/oferta/udostepnienie-linii-kolejowych.
6. https://www.jsw.pl/raportroczny-2020/nasze-otoczenie/otoczenie-rynkowe-i-konkurencyjne.
7. Jacyna, M., Szaciłło, L. (2017). Wybrane aspekty zarządzania ryzykiem w transporcie kolejowy. *Prace Naukowe Politechniki Warszawskiej. Transport. Bulletin, 119*, pp. 163-178.
8. Kolano, S. (2018). Identyfikacja zagrożeń krytycznej infrastruktury państwa. *Współczesne Problemy Zarządzania, 6(1(12)),* 229-237.
9. Milewski, J. (2016). Identyfikacja infrastruktury krytycznej i jej zagrożeń. *Zeszyty Naukowe AON, Vol. 4(105),* pp. 99-115.
10. Protokół Ustaleń Końcowych (PUK) (*Minutes of Final Decisions*) of 24 February 2020 in relation to the accident category B 09. Internal document owned by Jastrzębska Spółka Kolejowa Sp. z o.o.
11. Register of accidents and incidents. Internal document owned by Jastrzębska Spółka Kolejowa Sp. z o.o.
12. Register of FMEA threats for year 2021. Documents prepared for the needs of Jastrzębska Spółka Kolejowa Sp. z o.o.

13. Register of potentially dangerous situations. Internal document owned by Jastrzębska Spółka Kolejowa Sp. z o.o.
14. Risk Sheet – Damage to the railway infrastructure as a result of mining damage. Documents prepared for the needs of Jastrzębska Spółka Kolejowa Sp. z o.o.

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

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APPLICATION OF THE CREEPING TREND MODEL FOR FORECASTING OF ACCIDENT EVENTS IN THE STEEL INDUSTRY IN POLAND

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Purpose: The aim of the study to assess the possibility of using the creeping trend model in the forecasting of accidents at work in the steel sector in Poland, was presented.
Design/methodology/approach: A four-stage research methodology was used to analyze the accident rate trend in the steel sector, based on: collecting empirical data, forecasting (creeping trend model), qualitative assessment of forecasts and determining the direction of activities in the field of health and safety.
Findings: Based on the conducted research, it was found that it is possible to use the creeping trend model in forecasting the number of persons injured in accidents at work. The forecasts and their acceptance based on the criteria adopted in the methodology of own work made it possible to determine the directions of activities in the field of occupational health and safety in the steel sector in Poland.
Research limitation/implications: The conducted analyses were limited to statistical data published by Statistic Poland. Forecasts of the number of persons injured in accidents in the steel sector were possible to determine thanks to the forecasting process using the creeping trend model. The forecasts are subject to errors, which is why it is important to interpret them more broadly, taking into account the specificity of the industry being the subject of the analyses.
Practical implications: The forecasts can be important information on health and safety issues for the steel sector in Poland. The use of the creeping trend model, with the fulfillment of methodological assumptions (qualitative ocean of forecasts), can be useful in determining the direction of OSH activities in enterprises.
Social implications: The article addresses the issue of the occurrence of accidents at work, the implementation of effective preventive measures in order to reduce them.
Originality/value: The article presents the possibility of using the creeping trend model in the forecasting of the total number of persons injured in accidents in the steel sector in Poland. The forecasts and trend analysis can provide information for employers and employees of health and safety services regarding the effectiveness of the implemented preventive measures.

Keywords: Creeping trend model, forecasting, accidents at work, steel industry.

Category of the paper: Research paper.

1. Introduction

Professional work plays an important role in human functioning and is of interest to many scientific disciplines, including psychology, sociology, economics and medicine. In the field of labor law, the subject of analysis is subordinate work, under voluntarily accepted conditions, performed personally by an employee, for an employer and under his control (Florek, 2017). Only work that meets the definition becomes relevant in terms of occupational health and safety. The totality of material factors characterizes the place where the work process is carried out. The occurring factors may be dangerous, harmful or burdensome for an employee. And it is against the negative impact of those factors that protective prevention should be implemented, which is most often a combination of technical and organizational solutions.

Accidents at work and occupational diseases are the adverse effects of the factors related to material working environment. The issue of examining accidents at work and occupational diseases is still a valid subject of numerous scientific studies, which is why solutions (Hoła et al., 2017; Jacinto et al., 2009; Rydlewska-Liszkowska, 2006; Piňosová et al., 2021), methods and tools supporting – effective occupational health and safety management are still being sought.

Therefore, the study presents the possibility of using forecasting for an assessment of the trend in the number of registered accidental events in the steel sector. The forecasts will allow for an initial assessment of the effectiveness of the implemented preventive solutions. They will also be helpful for the managerial staff, allowing them to set further directions for occupational health and safety activities.

The purpose of this article is to evaluate the possibility of using the creeping trend model for the forecasting of the number of persons injured in accidents at work, and to determine the function that forecasting performs, in the area of accident rate in the steel sector.

2. Literature review

Forecasting is a science-based prediction of future phenomena and processes (Nowak, 1998), the aim of which is to reduce risk in the decision-making process (Dittmann, 2003). The root of the term forecast (Greek prognosis) consists of two parts, in which the prefix pro indicates the initial preparatory phase, while gnosis means knowledge about something that has not yet happened (Sobczyk, 2008).

The main purpose of forecasting is to support decision-making processes (Cieślak, 2001), which also includes actions taken to improve work safety. Therefore, forecasting becomes a valuable tool for employers as the possibility of assessing the effectiveness of the implemented preventive solutions, as well as taking other actions to improve occupational safety. Forecasts perform the following functions (Nowak, 1998; Cieślak, 2001; Sobczyk, 2008; Zeliaś, 2013), i.e.:

- informative function – informing about upcoming changes,
- preparatory function – forecasting is a preparation – it is a preparation for any other action taken by a decision-maker,
- activating function – involving stimulation to action, which is to support the implementation of the forecast if it announces a favorable event or abandonment in the case of actions that may be unfavorable for a decision-maker,
- warning function – the forecast is intended to warn against the arrival of undesirable events for a recipient of the forecast.

Forecasting plays a vital role in occupational health and safety management as managers make different decisions on a day-to-day basis. These forecast functions may refer, among others, to decisions related to the need to introduce radical changes in the existing working conditions (e.g. a growing trend in the number of persons injured in accidents at work, occupational diseases, potential accidents). The classification of events defined as accidents at work or the recognition of occupational diseases is defined in legal regulations (Ustawa, 2002; Rozporządzenie, 2009). In accordance with applicable law, an employer should prevent their occurrence and implement preventive measures.

In the forecasting process, various methods are used, which can be divided into quantitative (mathematical and statistical) and qualitative (non-mathematical, heuristic). The mathematical and statistical methods are based on deterministic or econometric models (e.g. Holt's, Winters', Brown's, moving average, creeping trend model, etc.). On the other hand, the non-mathematical methods include survey methods, expert opinions, intuitive methods, etc. (Sobczyk, 2008).

As part of this work, the possibility of using the creeping trend model in the forecasting of accidents at work in the steel sector was presented. The creeping trend model - the method of harmonic weights – has been widely used in the literature on the subject, among others, in the field of forecasting: prices (Szilágyi et al., 2016), freight transport by rail (Mróz, 2019), demographic variables (Sojka, 2016), annual electricity (Piotrowski et al., 2017), steel production volume (Gajdzik, et al. 2016), electricity production volume from RES (Mularczyk, 2016), plant yields (Sroka et al., 2008), number of grid failures water supply system (Iwanejko et al., 2012), hard coal mining (Gworek et al., 2005), demand for mineral resources (Uberman, 2016), which is collectively presented in Table 1.

Table 1.
Creeping trend model - harmonic weights method – literature review

No	Author, year of publication	Application of the method of harmonic weights
1	Mróz, 2019	Forecasting the volume of freight transport using rail transport in Poland
2	Sojka, 2016	Forecasting demographic variables (including population, age)
3	Piotrowski, Marzecki, 2017	Forecasting the annual demand for electricity in field transformer stations
4	Gajdzik, Szymszal, 2016	Forecasting the volume of steel production in millions of tons
5	Sroka et al., 2008	Plant yield forecasting (wheat, barley, rape, rye)
6	Iwanejko, Bajer, 2012	Forecasting the number of water supply network failures on the example of the city of Kraków
7	Gworek, Utrata, 2005	Forecasting hard coal production in million tons
8	Mularczyk, 2016	Forecasting the volume of electricity production from renewable sources in Poland
9	Uberman et al., 2016	Forecasting the demand of the Polish economy for mineral resources (e.g. aluminum, antimony raw materials, zinc, tin raw materials, fluorite, phosphates, cobalt raw materials, copper, etc.)
10	Szilágyi et al., 2016	Methanol price forecasting

Source: Own elaboration.

Choosing the method and then determining the forecasts does not end the forecasting process. Therefore, it is necessary to determine their accuracy using metrics that allow to determine and compare the accuracy of forecasts. Therefore, for the purposes of the study, ex post measures were used, which are often used in the qualitative assessment of forecasts – Table 2.

Table 2.
Measures used in the assessment of forecasts

No	Error	Mathematical dependence
1	mean error ψ	$\psi = \frac{1}{T-n}\sum_{t=n+1}^{T}\frac{\lvert y_t - y_t^*\rvert}{y_t}$ n - number of elements of the time series T - number of the last period
2	adjusted average relative ex post error Θ	$\Theta = \frac{1}{T-n}\cdot\sum_{t=n+1}^{T}\left\lvert\frac{y_t - y_t^*}{(y_t + y_t^*)/2}\right\rvert$
3	Rot Mean Square Error RMSE	$RMSE = \sqrt{\frac{1}{T-n}\cdot\sum_{t=n+1}^{T}(y_t - y_t^*)^2}$
4	standard deviation of the S_e model residuals	$S_e = \sqrt{\frac{1}{n-2}\cdot\sum_{i=1}^{n}(y_t - y_t^*)^2}$
5	Theil coefficient I^2	$I^2 = \frac{\sum_{t=n+1}^{T}(y_t - y_t^*)}{\sum_{t=n+1}^{T} y_t^2}$

Source: Own elaboration based on: Cieślak, 2001; Dittmann, 2003; Nowak, 1998; Halicka, 2013; Hong, 2020; Nazarko, 2018; Nowak, 1998; Sobczyk, 2008; Zeliaś, 2003; Snarska, 2005, Gajda, 2001; Sopelsa Neto et al., 2022; Chai et al., 2014).

3. Methodology

The achievement of the aim of the work was possible thanks to the development of a four-stage methodology of own work (Fig. 1). As part of the first stage, statistical data (Statistic Poland, 2022) on the total number of persons injured in accidents in the steel sector in Poland were compiled (a ten-year period of analyses – 2011-2021). The analyses were carried out using the PQstat computer software and an Excel spreadsheet.

The second stage consisted in setting forecasts for 2022-2023 using the creeping trend model – the harmonic weights method (Goryl et al., 2004; Cieślak, 2001; Dittmann, 2003; Nowak, 1998; Zelisaś, 2003; Sobczyk, 2008; Witkowska, 2006).

As part of the third stage, a qualitative assessment of the forecasts was made based on ex post forecast errors. For the determined values of ex post errors, the following criteria were adopted for the purposes of this study (Sobczyk, 2008; Cieślak, 2001; Snarska 2005):

- the value of the estimated relative error of the ex post forecast $\psi < 10$ %,
- the forecasts will be considered satisfactory when RMSE $\leq S_e$ (S_e – standard deviation of the S_e model residuals),
- the values of the adjusted mean ex post relative error are in the range [0% to 200%].

Due to the impossibility of determining ex ante prediction accuracy measures (no publication of statistical data on accidents for 2022 and 2024), the Theil I^2 coefficient was determined a measure of the total relative prediction error, which has been extensively described in the literature on the subject (Goryl et al., 2004; Dittmann, 2003; Nowak, 1998; Zelisaś, 2003; Sobczyk, 2008; Sojda, 2014; Czyżycki et al., 2006; Mróz, 2021). According to the literature assumptions, the value of the coefficient should be equal to zero – then the forecast is perfectly accurate. In practice, however, it assumes numerical values in the range [0;1] (Sobczyk, 2008).

The fourth stage consisted of assessing the possibility of using the creeping trend method (harmonic weights) for predicting a total number of persons injured in accidents. The estimated forecasts were assessed in OSH field regarding the trend in the number of persons injured. Directions for further actions aimed at creating safe and hygienic working conditions for employees were also defined.

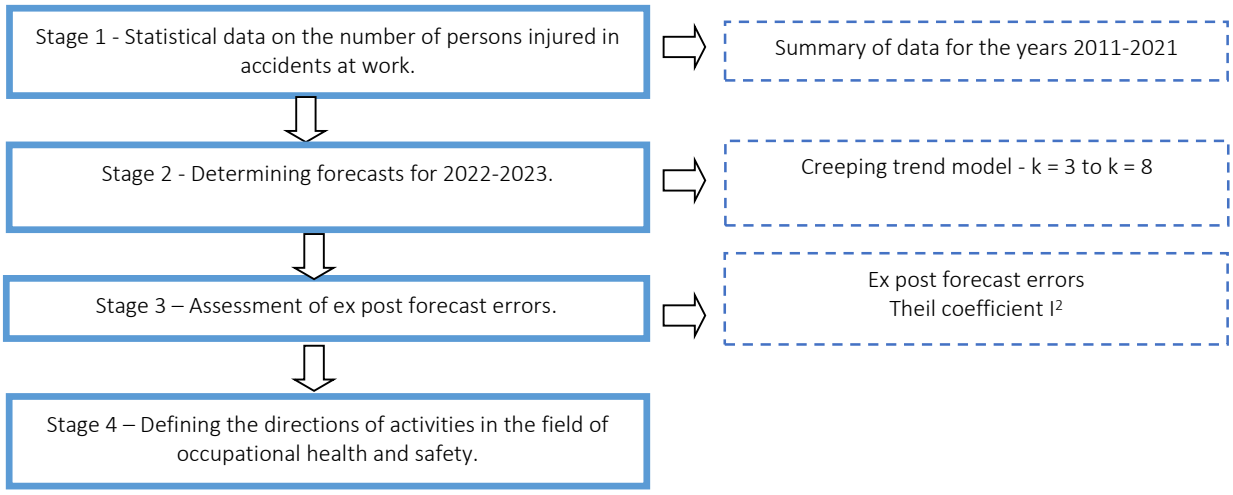

Figure 1. Methodology of own work.

Source: Own elaboration.

4. Problems of accidents at work and their forecasting

4.1. Accidents at work in steel sector in Poland

The specificity of the work performed and occupational hazards translate into the occurrence of accidents at work. Accidents at work are still recorded although the applicable legal regulations (Rozporządzenie…, 1997, 2010, 2017) impose an obligation on employers to ensure safe and hygienic working conditions and to indicate the types of work that carry a risk of accidents (e.g. blast furnace operation, transport work, sorting scrap, etc.).

In 2011-2021, an average of 896 victims of accidents at work were registered in the steel industry in Poland. In 2011, 1.127 victims of accidents at work were registered, while a significant decrease in the number of victims of accidents at work, compared to the analyzed period, was recorded in 2020 (620 victims of accidents in total). That decrease was related to the COVID-19 pandemic, which significantly affected the production capacity and operation of enterprises (Casella, 2021; Saniuk et al., 2021; Nowacki et al., 2021). An increase in the total victims of accidents was recorded in 2021, where the total number of such victims was 782 (an increase of approx. 21% compared to 2020). In connection with the above, it becomes important to conduct analyses of accidents in the steel sector in Poland. The total number of persons injured in accidents at work (Table 3) in the period under analysis was characterized by low variability (13%) (Małysa et al., 2021). The average rate of change was -3.59%, which means that the average rate of decrease in the number of employees in the period in question amounted to 3.59%.

Table 3.
Selected statistics of descriptive characteristics for the number of persons injured in accidents at work - years 2011-2021

Specification	Min	Max	Median	Average	Deviation standard	Coefficient of variation	Average rate of change, %
Selected characteristics statistics for the total number of persons injured in accidents at work	620	1127	901	896	125.08	0.13	3.59

Source: Own elaboration based on Statistic Poland.

4.2. Creeping trend model – forecasting accidents at work

The implementation of the assumed goal of the work (stage 2) was possible thanks to the adaptation of the creeping trend model for the prediction of statistical data (Statistics Poland, 2011-2021) regarding the total number of persons injured in accidents. For the purposes of the study, six variants of the creeping trend model were adopted, allowing for the determination of ex ante forecasts for 2022-2023. The adopted variants differ from each other by constant k, which was a variable value for the developed models. For the first model k = 3, therefore, 9 creep steps were adopted, the first for t = 1-3, the last for t = 9-11); and the same method was applied by analogy to the subsequent models.

Based on the analyses of the ex ante forecasts (Table 4, Fig. 2), a decrease in the total number of persons injured in accidents was recorded in 2022 compared to 2021 – which is important information in relation to OSH issues. The highest value (max) of the forecast of the number of injured persons was obtained for the creeping trend model – k = 8 (757 persons injured in accidents at work). The lowest value (min) of the forecast was obtained for models where constant k was 3 and 4, respectively – 738 injured persons in accidents in total. In 2023, the forecast values show a decrease in the total number of persons injured in accidents. The highest forecast value (max) was recorded for the creeping trend model k = 8 (732 injured persons), while the lowest forecast value (min) was recorded for the creeping trend model, where k = 3 – 694 persons injured in accidents at work (Table 4).

Table 4.
Forecasts for 2022-2023 and ex post forecast errors

Specification	Forecast		Ex post forecast errors			
	2022	2023	Ψ	Θ	RMSE	S_e
creeping trend model, k = 3	738	694	0.05	0.013	53.05	59.31
creeping trend model, k = 4	738	695	0.05	0.013	54.31	60.72
creeping trend model, k = 5	739	695	0.06	0.015	63.20	70.66
creeping trend model, k = 6	748	714	0.06	0.015	65.83	73.60
creeping trend model, k = 7	753	723	0.07	0.016	71.85	80.33
creeping trend model, k = 8	757	732	0.07	0.017	76.99	86.08

Source: Own elaboration.

According to the adopted assumptions specified in the methodology of own work, forecasts can be considered acceptable when (Table 4):

- the values for the estimated relative ex post forecast error ψ are less than 10% - for the developed models they ranged from 5% to 7%,
- the values of the RMSE error (the mean square error of the forecast) for each model (Table 4) are smaller than the value of the standard deviation of the residuals of the S_e model,
- the values of the adjusted ex post mean relative error in the verification interval Θ are within the accepted range of 1.3% to 1.7%.

For the purposes of the study, the Theil's divergence coefficient was also determined. The lowest value of Theil coefficient was obtained for the creeping trend model k = 3 (I^2 = 0.0033), and the highest value for the creeping trend model k = 8 (I^2 = 0.0091). The total error of forecasts of the number of persons injured in accidents at work ranged from 0.00572 (a model with constant k = 3) to 0.0953 (a model with constant k = 8). These errors should be considered not high – close to zero. The analyses lead to the conclusion that, the model of creeping trend k = 3 was the best because of, the lowest values of the forecast errors.

Table 5.
Theil coefficient and relative error values of ex post forecasts

Specification	Theil coefficient I^2	Total error forecasts
creeping trend model, k = 3	0.0033	0.0572
creeping trend model, k = 4	0.0037	0.0641
creeping trend model, k = 5	0.0054	0.0737
creeping trend model, k = 6	0.0061	0.0782
creeping trend model, k = 7	0.0079	0.0892
creeping trend model, k = 8	0.0091	0.0953

Source: Own elaboration.

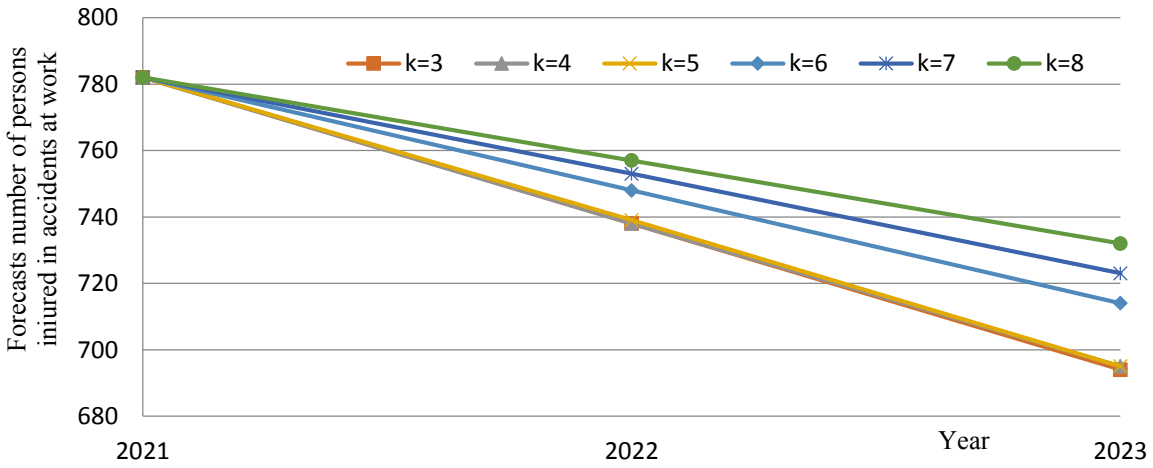

Figure 2. Trends and forecasts of the total number of persons injured in accidents at work (2022-2023) for creeping trend models (k = 3 – k = 8).

Source: Own elaboration.

5. Discussion and conclusion

Accidents at work contribute to the occurrence of social and economic problems (Usnar et al., 2009), and they are therefore the subject of many scientific studies. Methods and tools allowing for their effective reduction or the monitoring of health and safety in enterprises are still sought after. The use of econometric models in the field of health and safety issues allows for an assessment of the trend in registered accidental events, as well as for the promotion of solutions that have an impact on reducing the number of registered accidental events. The use of the harmonic weights' method (the creeping trend model) made it possible to determine the trend in the number of persons injured in accidents – a downward trend. In the scope of the OHS issues in question, the numerical values determined for the number of persons injured in accidents at work (models k = 3 to k = 8) are positive information for the management staff (information function of the forecast). The results of the forecasts obtained under the creeping trend model k = 3 would be the most optimistic because, the lowest forecast values of the number of persons injured in accidents were obtained for that model – 738 persons injured in 2022 and 694 in 2023, with the simultaneous acceptability of the forecast errors values.

The conducted analyses lead to the conclusion that the use of forecasting made it possible to assess the trend in the number of persons injured in accidents at work. On the basis of the forecast values, it is possible to propose implementing actions aimed at improving occupational safety, as well as to determine further actions in the field of occupational health and safety and, determining further actions in the field of occupational health and safety.

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References

1. Casella, F. (2021). Can the COVID-19 epidemic be controlled on the basic of daily test reports? *IEEE Control Systems Letters*, *vol. 5, no. 3,* pp. 1079-1084, doi:10.1109/LCSYS.2020.3009912.

2. Chai, T., Draxler, R.R. (2014). Rot mean square error (RMSE) or mean absolute error (MAE)? *Geoscientific Model Development Discussions*, *7,* pp. 1525-1534. doi: 15.5194/gmdd-7-1525-2014.
3. Cieślak, M. (2001). *Prognozowanie gospodarcze. Metody i zastosowanie*. Warsaw: PWN.
4. Czyżycki, T., Hundert, M., Klóska, R. (2006). *Wybrane zagadnienia z prognozowania.* Szczecin: Economicus.
5. Dittmann, P. (2003). *Prognozowanie w przedsiębiorstwie*. Cracow: Oficyna Ekonomiczna.
6. Florek, L. (2017). *Prawo pracy.* Warsaw: C.H. Beck.
7. Fu, L., Wang, X., Wang, D., Griffin, M.A., Li, P. (2020). Human and organizational factors within the public sectors for the prevention and control of epidemic. *Safety Science*, *vol. 131,* pp. 1-9, doi.org/10.1016/j.ssci.2020.104929.
8. Gajda, J.B. (2001). *Prognozowanie i symulacja a decyzje gospodarcze*. Warsaw: C.H. Beck.
9. Gajdzik, B., Szymszal, J. (2016). Prognostic modeling of changes in steel production in Poland until 2020. *Prace Instytutu Metalurgii Żelaza*, *4(68),* pp. 26-33.
10. Gębalska-Kwicień, A., Żurakowski, Z. (2015). Potrzeba szkoleń z zakresu bezpieczeństwa i higieny pracy w przedsiębiorstwie w ocenie pracowników. *Zeszyty Naukowe – Organizacja i Zarządzanie*, *vol. 77,* pp. 85-91.
11. Goryl, A., Jędrzejczyk, Z., Kukuła, K., Osiewalski, J., Walkosz, A. (2004). *Wprowadzenie do ekonometrii w przykładach i zadaniach*. Warsaw: PWN.
12. Gworek, S., Utrata, A. (2005). Wykorzystanie predyktorów typu neutral network do prognozowania szeregów czasowych. *Górnictwo i Geoinżynieria*, *29(3)*, pp. 53-62.
13. Halicka, K., Winkowski, C. (2013). Wykorzystanie metod wygładzania wykładniczego do prognozowania kursu sprzedaży EUR. *Ekonomia i Zarządzanie*, *vol. 2,* pp. 70-80. doi: 10.12846/j.em.2013.02.05.
14. Hoła, B., Szóstak, M. (2017). Methodology of analysing the accident rate in the construction industry. *Procedia Engineering*, *vol. 172,* pp. 355-362. Retrieved from: https://doi.org/10.1016/j.proeng.2017.02.040, 20.12.2022.
15. Hong T., Pinson, P., Wang, Y., Weron, R., Yang, D., Zareipour, H. (2020). Energy forecasting: a review and outlook. *IEEE Open Access Journal of Power and Energy*, *vol. 7,* pp. 376-388. doi: 10.1109/OAJPE.2020.3029979.
16. Hyndman, R.J., Athanasopoulos, G. (2018). *Forecasting: principles and practice*. Melbourne, AustraliaŁ OTexts. Retrieved from: www.otexts.com/fpp2.
17. Iwaniejko, R., Bajer, J. (2012). Zastosowanie matematycznych modeli prognozowania uszkadzalności sieci wodociągowej na przykładzie Krakowa. *Czasopismo Techniczne*, *2(23),* pp. 139-148.
18. Jacinto, C., Canoa, M., Guedes Soares, C. (2009). Workplace and organizational factor in accident analysis within the food industry. *Safety Science, vol. 47, iss. 5,* pp. 626-635. Retrieved from: https://doi.org/10.1016/j.ssci.2008.08.002.

19. Małysa, T., Szymszal, J., Gajdzik, B. (2021). Analiza wypadkowości w transporcie i gospodarce magazynowej w aspekcie poprawy bezpieczeństwa pracy. *Gospodarka Materiałowa i Logistyka*, *no. 9,* pp. 32-41.
20. Mróz, M. (2019). Prognoza wielkości przewozu ładunków transportem kolejowym w Polsce metodą wag harmonicznych. *Gospodarka Materiałowa i Logistyka, no. 10,* pp. 370-403. doi:10.33226/1231-2037.2019.10.24.
21. Mróz, M. (2021). Predykcja wielkości sprzedaży modelem Browna elementem rachunku ekonomicznego na przykładzie firmy Comarch. *Gospodarka Materiałowa i Logistyka*, *no. 10,* pp. 46-59. doi: 10.33226/1231-2037.2021.3.5.
22. Mularczyk, A. (2016). Prognozowanie wielkości produkcji energii elektrycznej z odnawialnych źródeł energii w Polsce. *Zeszyty Naukowe Politechniki Śląskiej – Seria: Organizacja i Zarządzanie*, *96*, pp. 133-142.
23. Nazarko, J. (2018). *Prognozowanie w zarządzaniu przedsiębiorstwem – cz. IV – Prognozowanie na podstawie modeli trendu*. BiałystokŁ Wydawnictwo Politechniki Białostockiej.
24. Nowacki, K., Grabowska, S., Łakomy, K., Ocieczek, W. (2021). Occupational risk management at production plants in Poland during the Covid-19 pandemic. *Management Systems in Production Engineering*, *vol. 29, iss. 3*, pp. 193-202. doi: 10.2478/mape-2021-0024.
25. Nowak, E. (1998). *Prognozowanie gospodarcze – metody, modele, zastosowania przykłady*. Warsaw: Placet.
26. Piňosová, M., Andrejiova, M., Badida, M., Moravec, M. (2021). Occupational Disease as the Bane of Workers' Lives: A Chronological Review of the Literature and Study of Its Development in Slovakia. Part 1. *International Journal of Environmental Research and Public Health*, *vol. 18*, 5910. Retrieved from: https://doi.org/10.3390/ijerph18115910.
27. Piotrowski, P., Marzecki, J. (2017). Ekspert kontra klasyczne metody prognostyczne w zadaniu prognozowania rocznego zapotrzebowania na energię elektryczną terenowych stacji transformatorowych SN/nN. *Przegląd Elektryczny*, *no. 4,* pp. 82-85. doi: 10.15199/48.2017.04.21.
28. Rozporządzenie Ministra Gospodarki z dnia 14 lipca 2010 r. w sprawie bezpieczeństwa i higieny pracy w hutnictwie żelaza i stali (Dz.U. 2010. 142.951).
29. Rozporządzenie Ministra Pracy i Polityki Socjalnej z dnia 26 września 1997 r. w sprawie ogólnych przepisów bhp (Dz.U. 2021.2088).
30. Rozporządzenie Ministra Rozwoju i Finansów z dnia 15 grudnia 2017 r. w sprawie bezpieczeństwa i higieny pracy w odlewniach metali (Dz.U. 2018.48).
31. Rozporządzenie Rady Ministrów z dnia 30 czerwca 2009 r. w sprawie chorób zawodowych (Dz.U. 2022.1836).
32. Rydlewska-Liszkowska, I. (2006). Costs of occupational diseases and accident at work in Poland. *Medycyna Pracy*, *vol. 57, iss. 4*, pp. 317-324.

33. Saniuk, S., Grabowska, S., Gajdzik, B. (2022). The state of SME enterprise in the face of the crisis caused by the Covid-19 epidemic. *Cyber Physical Systems*. USA: CRC Press, pp. 42-53.
34. Snarska, A. (2005). *Statystyka. Ekonometria. Prognozowanie.* Warsaw: Placet.
35. Sobczyk, M. (2008). *Prognozowanie – teoria, przykłady, zadania*. Warsaw: Placet.
36. Sojda, A. (2014). Analiza statystyczna wskaźników finansowych dla przedsiębiorstw górniczych. *Zeszyty Naukowe Seria: Organizacja i Zarządzanie*, *vol. 68,* pp. 255-264.
37. Sojka, E. (2016). Adaptive forecasting method in demographics. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, *vol. 270*, pp. 252-264.
38. Sopelsa Neto, N.F., Stefenon, S.F., Meyer, L.H., Ovejero, R.G., Leithardt, V.R.Q. (2022). Fault Prediction Based on Leakage Current in Contaminated Insulators Using Enhanced Time Series Forecasting Models. *Sensors*, *vol. 22,* 6121. Retrieved from: https://doi.org/10.3390/s22166121.
39. Sroka, W., Sulewski, P., Kocielska, U. (2008). Ocena przydatności wybranych metod do prognozowania plonów roślin. *Roczniki Nauk Rolniczych, Seria G*, *95(2),* pp. 67-82.
40. Statistic Poland, www.stat.gov.pl.
41. Szilágyi, R., Verga, B., Géczi-Papp, R. (2016). *Possible methods for price forecasting. MultiScience - XXX.* microCAD International Multidisciplinary Scientific Conference, University of Miskolc, Hungary, 21-22 April 2016, doi: 10.26649/music.2016.135.
42. Uberman, R., Kulczycka, J., Cholewa, M. (2016). Potrzeba i możliwości prognozowania zapotrzebowania polskiej gospodarki na surowce mineralne. *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk, 96*, pp. 323-344.
43. Usnar, S., Sut, N. (2009). General assessment of the occupational accidents that occurred in Turkey between the years 2005 and 2005. *Safety Science*, *vol 47, iss. 5,* pp. 614-619. doi: 10.1016/jssci2008.08.001.
44. Ustawa z dnia 30 października 2002 r. o ubezpieczeniu społecznym z tytułu wypadków przy pracy i chorób zawodowych (Dz.U. 2021, poz. 1621,1834).
45. Witkowska, D. (2006). *Podstawy ekonometrii i teorii prognozowania*. Cracow: Oficyna Ekonomiczna.
46. Zeliaś, A., Pawełek, B., Wanat, St. (2003). *Prognozowanie ekonomiczne. Teoria, przykłady, zadania*. Warsaw: PWN.

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INNOVATIVE POTENTIAL OF ENTERPRISES IN THE LUBLIN REGION ON THE EXAMPLE OF START-UP ORGANIZATIONS

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Purpose: The aim of the paper is to identify the potential of the Lublin Region in the context of the innovativeness of Lublin enterprises. The study presents the position occupied by Lublin Region compared to other Regions in the country based on selected criteria. Innovative start-up organizations from the Lublin Region were also analyzed in the paper.
Design/methodology/approach: The theoretical part of the study was based on a review of the available literature on the subject. The empirical part of the study was developed based on reports from external institutions, data from the Central Statistical Office, and research conducted in 2020-2021 for the doctoral thesis.
Findings: The study shows that in the Lublin Region: micro-enterprises are established most frequently, the share of innovative enterprises in the total number of enterprises increases, and there is a high percentage of enterprises active in innovation and undertaking cooperation for innovation. Based on the research, Lublin is a friendly place for future entrepreneurs. Innovative start-ups from the Lublin Region are constantly developing their innovative activity (depending on the high potential of their employees, availability of qualified staff, and customers, accessible internal communication, and flexible organizational structure). They are planning to implement other innovative solutions; the most important thing for them is product development and achieving satisfactory profitability.
Research limitations/implications: The main limitation was the difficulty in collecting empirical material for a study of start-ups from the Lublin Region. The COVID-19 pandemic was ongoing in 2020-2021, which meant that entrepreneurs were mainly focused on survival, were not interested in participating in the study, and the shift to remote working contacted them completely impossible.
Practical implications: The research shows that many initiatives to support creative entrepreneurs setting up small businesses should be created in the Lublin Region. In addition, entrepreneurs should focus on expanding into foreign markets, strengthening the Region's potential, and contributing to greater international recognition of the Lublin Region.
Social implications: In their strategy, entrepreneurs in the Lublin Region should undertake actions that favor the local community, create solutions to improve social welfare, and aim to reduce the level of poverty in the Region so that the least affluent part of society has access to modern solutions and the possibility of personal development.
Originality/value: Based on the conducted studies, it should be stated that the Lublin Region is constantly developing its innovative potential. Despite the unfavorable economic conditions of the Region, the number of small, thriving businesses focused on innovation is increasing.

The Lublin Region and its initiatives create conditions for further investment activities, bringing benefits to entrepreneurs and the local community and developing the Region's potential.

Keywords: innovative organizations, start-up, Lublin Region.

Category of the paper: literature review, research paper.

1. Introduction

The country's socio-economic situation, the high competitiveness of companies in a leading position on the market, and the dynamically changing needs and expectations of customers result in an out-of-the-box approach to business. Today's entrepreneurs face the challenge of creating innovative organizations that generate unique customer value. The workforce competencies, creative solutions, and an innovation-friendly culture are all essential here. It is also important to cooperate based on sharing knowledge and resources and exploit the potential inherent in a given region.

The aim of the study is to identify the potential of the Lublin Region in the context of the innovativeness of Lublin enterprises, taking into account such criteria as the share of particular types of enterprises by the number of employees in the total number of enterprises in the Region, the share of innovative enterprises in the total number of enterprises in the Region, granted patents and the position occupied in national and international rankings of innovativeness. The study presents Lublin Region compared to other Regions in the country based on the above criteria. Innovative start-up organizations from the Lublin Region were also analyzed in the publication. The study included an indication of the number and type of innovations introduced by them, an assessment of the start-up's innovativeness, an indication of factors influencing innovativeness, the importance of key performance indicators in the adopted strategy, an indication of the number of patents obtained and plans for innovation implementation.

The study is based on a review of the literature on the subject, an analysis of reports from various external institutions (Startup Poland Foundation, Polish Agency for Enterprise Development, Millennium Bank, Foreign Direct Investment), data from the Central Statistical Office, as well as on research conducted in 2020-2021 for the doctoral thesis.

2. Innovative organizations - a literature review

Innovation is a broad concept referring to creativity undertaken by human beings. It most often describes the nature of activity in modern companies. An appropriate organizational culture based on sharing knowledge and generating collaborative solutions of unique value to

the customer is critical. Innovation also manifests itself in the orientation of organizational, technical, financial, scientific, and commercial activities toward implementing innovative solutions (OECD, 2008, p. 49).

Innovation is difficult to define unambiguously, so many interpretations exist in the literature. Initially, it was identified with innovative technology. The forerunner of this approach is J. Schumpeter, who emphasizes that innovation refers to the introduction of a solution (product, service, or new manufacturing method) into economic circulation on a global scale. Nowadays, the term has a slightly broader meaning - innovation is a new solution that improves efficiency and enables a sustainable competitive advantage in the market (Czubała, 2015, p. 2). The definition of innovation proposed in the Oslo Manual, according to innovation is 'the implementation of a new or significantly improved product (product or service) or process, a new marketing method or a new organizational method in economic practice, workplace organization or relations with the environment,' has also gained popularity (OECD, 2008, p. 48). Different classification criteria for innovation have also been introduced in the literature. The most popular one distinguishes between product innovation (focusing on the introduction of a new product/service), process innovation (related to the modification of the value chain), marketing innovation (based on the implementation of a new marketing strategy or concept) and organizational innovation (related to the introduction of a new distribution or work organization) (OECD, 2008, pp. 50 et seq.).

Innovative organizations are distinguished by their ability to continually anticipate and adapt to changes in their environment. They create, absorb, and sell new products or services. In turn, the effect of their innovativeness is several benefits directed toward the producer and the final purchaser (Janasz, 2011a, p. 46). Additionally, according to A.H. Jasiński (1992), innovation-oriented organizations:

- carry out research and development work,
- they provide significant funding for this type of activity,
- have a high proportion of novelties in their production volume,
- constantly introduce new developments of a scientific and technical nature,
- are focused on systematically innovating in the markets.

A study by the Polish Agency for Enterprise Development (PARP, 2007, p. 19) shows that, in the opinion of entrepreneurs, the innovativeness of an organization depends to a large extent on the personality of the company's managers. Openness to innovation, which creates an organizational culture based on ingenuity and the manifestation of individual initiative, is essential. It is also vital to create an organizational structure that includes a person, unit, or department responsible for the company's innovation activities. Focusing on innovation also means concentrating on the correct information flow and strategy to operate in a market niche. However, an innovative organization's cornerstone is attracting the right personnel with formal education, relevant qualifications, practical experience, and an internal need to monitor the market situation.

According to M. Dolińska (2010), an innovative enterprise is distinguished by its ability to create innovation, flexibility, the continuous implementation of new solutions, and forward-thinking. Also important is the ability to build and effectively use innovation potential based on critical competencies, acquire, develop, and manage knowledge, employ creative employees and develop their competencies, and conduct research and development work. Innovative organizations should also base their activities on state-of-the-art technologies, exploiting synergies, building relationship capital, and openness to change.

Unfortunately, constant experimentation, risky decision-making, and learning from mistakes make innovation easier to initiate in smaller organizations with a more flexible structure (Adamczyk, 2015, p. 204). Additionally, L. Dimitrovy (2013, p. 6) found that managers who own the company have a much higher propensity for risk than those merely employed in managerial positions. In turn, innovation advantage in small-scale enterprises is dependent on (Rothwell, Dodgson, 1991; Stawasz, 1999; Pawlicz et al., 2017):

- flexible management structures - they enable the introduction of pro-innovative activities in the company, a dynamic response to changing environmental conditions, and give the readiness to make risky decisions,
- complete freedom of action by the developers and a reward commensurate with the effort put in to achieve success,
- size of capital - in smaller companies, the capital frozen in obsolete technological generations is much smaller than in established companies (operating obsolete technologies for an extended period), which are cautious about commercializing innovative solutions.

According to D. Janczewska (2012, p. 16), innovation potential in micro-enterprises should be understood as the sum of intangible and tangible resources of a given enterprise. Intangible resources are an essential component of small enterprises. Namely, they represent unique and unrepeatable values, such as knowledge, traditions, experience, absorptive capacity for knowledge, or specialized skills. Tangible resources are the physical foundation that enables the generation of new products, services, or practical solutions. They form a limited set of machinery, computers, technological equipment, buildings, etc.

The business models of today's entrepreneurs mainly focus on innovation, which is a process focused on finding value to improve current products/services or to meet previously unrecognized demand (Saura et al., 2019). There are many organizations on the market. They take risks and implement innovative solutions while creating unique value for the client. These types of organizations mainly include start-ups, inherently focused on introducing cutting-edge technological solutions. The literature on the subject says, "there is a belief that innovation is the foundation of the start-up and failure is inherent in its everyday life" (Berezowski, Kretek, 2016, pp. 58-59).

Start-ups are among the organizations that are the backbone of global economies focused on innovation in today's economic, environmental, techno-technological, and socio-cultural landscape (Chrzanowski, Zawada, 2018, p. 42). According to A. Skala (2017, p. 37), a start-up is perceived as a new company:

- testing an innovative business model,
- with no operational history,
- operating in a low-demand, high-risk environment,
- whose primary resources are the skills, experience, knowledge, and social capital of the founders,
- whose main element of the business model is an innovative product or service based on modern technology and knowledge,
- which is organizationally sprawling,
- having a flexible, networked, and flat structure,
- whose core element of organizational culture is strong leadership.

Start-up organizations are open to sources of the capital present in the environment, which results in the acquisition of unique knowledge that enables the creation of breakthrough solutions and their implementation (Chrzanowski, Zawada, 2018, p. 43). Their activities often focus on process, environmental, product, organizational, and marketing innovations (Janczewska, 2012, p. 15). Start-ups become known as innovative organizations due to their undertaking of activities in the high-tech circle, as well as their focus on data, knowledge, and information processing, which underpins their scaled business model (Chrzanowski, Zawada, 2018, p. 51).

3. Characteristics of the Lublin Region concerning the innovativeness of enterprises

Lublin Region is in the eastern part of Poland. It is the third largest Region in the country (25,122 km2) with a population of 2,038,299. The population density in the Lublin Region is 81 persons/km2, and the urbanization rate is 46.2%. According to data from the Central Statistical Office, Lublin Region is the Region most at risk of poverty (Lublin Region - 24.4%, Poland - 14.8%).

In 2021, there were 199 541 entities registered in the REGON register in the Lublin Region. Based on the number of employees, the most significant number of entities were micro-enterprises employing 0-9 employees (193 081), fewer were small entities employing 10-49 employees (5210), and medium-sized entities employing 50-249 employees (1125). The smallest were large enterprises employing 250 or more employees (125). The analysis of entities with legal personality in the context of the number of employees in the Lublin Region

in 2010-2021 (Table 1) proves that year by year, the percentage share of micro-enterprises in the total number of entities is successively increasing, while the number of small, medium and large enterprises is decreasing.

Table 1.
Legal entities registered in the REGON register by the number of employees in Lublin Region in 2010-2021 (% share)

Company size	Share (%) of companies in a given year												Rank
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Large (250 or more employees)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4
Medium (50-249 employees)	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	3
Small (10-49 employees)	4.0	4.0	3.5	3.4	3.3	3.3	3.3	3.2	3.1	2.9	2.7	2.6	2
Micro (0-9 employees)	95.2	95.2	95.7	95.8	95.9	95.9	95.9	96.0	96.2	96.4	96.6	96.8	1
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Source: own compilation based on data from Central Statistical Office of 16.11.2022.

The average share of innovative enterprises in the total number of enterprises (Table 2) over the last 12 years in the Lublin Region ranged from 12.1% to as high as 30.9%. As a result, Lublin Region is ranked 4th in the ranking of 16 Regions from the country. Moreover, it was well above the national average in 2014, 2016, and 2018. It was weakest in 2019, recording a 3.3 p.p. decline compared to the national average.

Table 2.
The average share of innovative enterprises in the total number of enterprises in the Regions in 2010-2021 (%)

Region	Year												12-year average	Rank
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Greater Poland	14.3	15.1	11.8	12.1	11.3	13.0	15.3	13.8	19.0	15.8	29.7	18.1	15.78	10
Kujawsko-Pomorskie	13.6	15.4	14.2	11.0	12.4	12.5	14.2	12.1	21.0	10.8	25.8	15.9	14.91	12
Lesser Poland	14.5	15.3	15.2	14.9	13.5	15.2	17.3	15.1	22.2	19.3	35.0	22.5	18.33	2
Lodz	11.9	9.8	12.6	13.0	13.5	12.5	13.0	12.7	15.9	14.8	29.2	18.6	14.79	13
Lower Silesia	14.9	12.3	16.8	16.2	16.3	14.2	13.4	14.8	22.8	17.2	28.2	22.7	17.48	5
Lublin	14.6	14.5	13.6	13.0	19.4	13.5	22.9	14.1	24.9	12.1	30.9	19.5	17.75	4
Lubusz	13.4	11.3	14.3	14.4	10.5	11.6	13.2	13.0	18.1	10.2	19.5	13.6	13.59	15
Mazovia	16.4	13.8	16.1	16.8	17.1	14.5	19.7	16.8	27.3	17.7	37.9	24.7	19.90	1
Opole	16.5	15.2	14.0	15.0	17.6	15.0	12.4	12.6	21.2	11.7	24.4	17.3	16.08	9
Podlaskie	12.7	13.0	15.0	17.7	14.7	15.3	11.5	12.2	23.4	12.3	29.1	23.1	16.67	8
Pomerania	14.3	15.2	10.9	12.5	12.3	12.6	18.1	15.5	25.6	15.4	31.1	23.7	17.27	6
Silesia	16.4	14.2	14.0	13.1	15.7	13.1	15.6	14.3	20.6	13.8	29.5	22.1	16.87	7
Subcarpathian	17.2	16.2	14.8	14.7	14.6	14.2	18.0	15.3	19.7	17.7	28.0	22.9	17.78	3
Swietokrzyskie	14.0	11.6	13.3	12.1	11.1	11.5	10.4	12.2	14.3	11.5	25.8	14.2	13.50	16
Warminsko-Mazurskie	13.6	12.4	11.9	14.6	10.9	11.3	9.1	9.1	14.9	15.8	31.0	21.0	14.63	14
West Pomerania	13.3	9.8	14.9	14.6	14.1	15.8	11.9	13.7	20.2	12.1	28.4	12.3	15.09	11
Poland	14.9	13.8	14.4	14.3	14.5	13.7	16.1	14.5	21.8	15.4	31.2	20.9		

Source: own compilation based on data from Central Statistical Office of 16.11.2022.

Considering the number of patents granted by the Patent Office of the Republic of Poland (UPRP), the Lublin Region, over the last 12 years, has been granted a total of 1,848 patents, which gives it seventh position compared to all regions in the country. In addition, over the last

five years (since 2017), the number of innovations introduced in the Lublin Region has been gradually increasing, but not exceeding a 10% share in Poland. The percentage of patents granted by the UPRP in all provinces in Poland is presented in Table 3.

Table 3.
Patents granted by the PPO between 2010 and 2021 - total (%)

Region	Year												Total (N)	Rank
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021		
Greater Poland	6.9	6.5	8.6	9.5	9.4	8.2	7.5	8.3	10.2	8.5	7.5	8.2	2506	5
Kujawsko-Pomorskie	2.5	4.0	3.0	3.3	2.5	3.3	3.1	3.2	3.2	3.3	3.0	3.1	944	11
Lesser Poland	11.8	8.4	8.1	8.8	10.3	10.4	10.4	11.7	11.9	10.7	12.8	11.2	3186	4
Lodz	6.8	6.9	6.4	7.4	7.6	6.3	6.5	7.1	6.4	6.8	7.6	7.0	2065	6
Lower Silesia	10.5	12.9	15.4	15.1	10.7	11.2	10.3	9.3	8.7	8.6	8.8	10.2	3218	3
Lublin	4.0	5.2	5.3	4.1	5.3	7.7	5.7	5.7	5.8	7.3	7.5	8.4	1848	7
Lubusz	0.5	1.0	0.5	0.7	1.3	1.0	0.7	0.8	1.2	0.9	0.8	1.1	266	16
Mazovia	23.5	20.7	21.0	19.6	20.4	20.5	24.1	22.3	18.4	19.0	17.2	17.3	6060	1
Opole	2.0	3.3	4.1	2.2	2.4	2.0	2.2	2.2	2.3	1.6	1.9	2.3	696	12
Podlaskie	0.8	0.6	1.1	1.4	1.2	1.4	1.5	1.0	1.5	2.2	1.6	2.0	431	14
Pomerania	5.8	4.4	4.6	4.2	5.2	4.6	5.0	4.7	4.7	5.4	4.9	3.7	1418	8
Silesia	16.8	16.1	11.5	12.7	15.0	12.4	14.2	12.6	13.0	11.6	13.7	12.7	4006	2
Subcarpathian	2.3	2.7	2.7	3.3	3.1	2.9	2.7	3.4	4.6	4.1	4.9	5.3	1083	10
Swietokrzyskie	1.8	2.4	2.1	1.6	1.3	1.3	1.5	1.5	1.4	2.1	2.1	1.8	516	13
Warminsko-Mazurskie	1.3	0.7	0.9	1.4	1.3	1.3	1.6	1.5	1.9	1.6	1.1	1.1	403	15
West Pomerania	2.5	4.4	4.6	4.6	3.1	5.3	3.1	4.9	4.9	6.3	4.7	4.3	1331	9
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Total (N)	1385	1989	1848	2339	2490	2404	3370	2795	2906	2947	2260	3244		

Source: own compilation based on data from Central Statistical Office of 16.11.2022.

In the latest edition of the survey "Millennium 2020 Index - Innovation Potential of Regions" (Maliszewski et al., 2020, pp. 5, 30, 46), the Lublin Region was ranked 8th, having fallen from last year's classification (Table 4.). The ranking was the sum of the results of five analyzed categories, which, according to the bank's experts, best reflect the innovation potential of the regions. The study took into account labor productivity (shows the current situation of enterprises), expenditure on research and development (is an indicator of innovative activity of enterprises), the number of students (information about the potential of the workforce), the number of people working in research and development (the intellectual base of the Region), as well as the number of issued patents (an indicator of the effectiveness of innovation creation). The cumulative index for the Lublin Region is 53 out of 100 possible points. The weaker result of last year is mainly due to a significant improvement in the potential of other competitive regions rather than a decline in the potential of the Lublin Region. It is mainly due to a worsening position in the criterion of patents obtained and a decrease in labor productivity (while retaining its position from last year's classification) in Lublin Region. It should also be noted that there is a slight difference between Silesia Region, holding the fifth position in the ranking (index equal to 55), and Lublin Region (index equal to 53).

Research conducted by Bank Millennium (Maliszewski et al., 2020, p. 30) also shows that the main driver of innovation in the Lublin Region is a solid academic center. Namely, the share of universities in the total value of expenditure on research and development activities in the

Region is the highest in Poland. In addition, although expenditure on research and development financed by the business sector is significantly lagging the national average (in minus), Lublin Region stands out from other regions with a high percentage of innovativeness-active businesses. It is also worth emphasizing that the Lublin Region has a relatively high percentage of enterprises undertaking cooperation for innovation, which creates a favorable climate for developing innovation potential in the Region.

Table 4.
Ranking of provinces in the Millennium 2020 Index

Specification	Innovation criteria*					Index	Ranking position**
	1	2	3	4	5		
Greater Poland	74	35	72	31	61	55	7 ↑
Kujawsko-pomorskie	69	30	60	28	38	45	12 ↓
Lesser Poland	66	100	97	68	82	83	2 =
Lodz	69	44	63	33	66	55	6 ↑
Lower Silesia	85	51	91	56	81	73	3 =
Lublin	51	48	72	29	66	53	8 ↓
Lubusz	72	23	29	15	22	32	16 ↓
Mazovia	100	93	100	100	100	99	1 =
Opole	71	30	47	21	56	45	11 ↑
Podlaskie	58	34	55	25	28	40	13 =
Pomerania	78	65	78	49	51	64	4 =
Silesia	82	34	55	32	72	55	5 ↑
Subcarpathian	53	52	48	38	41	47	10 =
Swietokrzyskie	57	26	40	14	29	33	15 ↑
Warminsko-Mazurskie	66	26	42	20	28	36	14 =
West Pomerania	76	26	51	20	61	47	9 =

Indications:
* Methodology for calculating index component values:
1. Labor productivity - gross value added generated by one employee (in thousands of PLN)
2. R&D expenditure - R&D expenditure to GDP ratio (in %)
3. post-secondary education - number of students per 10,000 inhabitants
4. employed in R&D - in the business sector per 1000 economically active persons
5. number of patents - arithmetic average of the last three years per 1 million inhabitants
All analyzed components have the same weight
The scale of marks 1-100 (where 100 is given to the best province in all criteria)

** Position relative to last year's classification:
= same position as last year's classification
↑ an increase on last year's classification
↓ decrease from last year's classification

Source: own compilation based on Maliszewski et al., 2020, pp. 4, 5, 46.

The largest city in Eastern Poland and the capital of the Lublin Region is Lublin, located between Warsaw and Poland's eastern border. It is one of the country's most attractive cities for business, which is why it is referred to as the "European Union's Gate to the East" (Lublin City Hall). It is the Region's leading economic, cultural, and administrative center. It is distinguished by a developed scientific and research sphere and a huge academic potential (Podstawka, Suchodolski, 2018, p. 10). The Lublin Economic Uplands strategy is based on cooperation in a quadruple helix (academic centers, public authorities, the business community, and NGOs). It enables the development of individual industries in the Region. In addition, the wide-ranging

exchange of knowledge and experience of the individual parties, the continuous use of their research and development potential, the Region's innovativeness, and the appropriate orientation of civic attitudes lead to the systematic development and improvement of the competitive position of enterprises operating in the Lublin Region (Żyśko, 2018, pp. 103-105).

In the latest report, European Cities and Regions of the Future 2022/23, prepared by fDi Intelligence (Foreign Direct Investment, 2022), belonging to the publishing group The Financial Times Ltd., 356 cities from Europe were studied, of which 14 represented Poland and ranked high in various rankings (they were in the top ten). The activity undertaken by fDi Intelligence is mainly benchmarking, focusing on predicting the profitability of long-term investments in Europe and the world. The results presented in the report covered large urban centers (over 250,000 inhabitants), medium-sized urban centers (100-250,000 inhabitants), and small urban centers (less than 100,000 inhabitants) separately and referred to five analyzed categories: economic potential, human capital, cost efficiency, accessibility, and business friendliness. Experts from fDi highlight the number of universities, a highly qualified workforce, the ability of cities to attract foreign investors, and innovation (cities investing in programmers, the IT sector, and future technologies, as well as supporting start-ups, are high on the ranking) (Polish Tourist Organization). In the ranking of small European cities, Lublin was ranked 9th in business friendliness and 6th in foreign direct investment (FDI) strategy, as presented in Table 5.

Table 5.
TOP 10 Small European cities of the future 2022/23 by business friendliness and FDI strategy

Rank	City	Country
Business friendliness		
1	Milton Keynes	UK
2	Reading	UK
3	Slough	UK
4	Cluj-Napoca	Romania
5	Cambridge	UK
6	Cork	Ireland
7	Gliwice	Poland
8	Warrington	UK
9	Lublin	Poland
10	Timisoara	Romania
FDI Strategy		
1	Doncaster	UK
2	Londonderry (Derry)	UK
=3	Plovdiv	Bulgaria
=3	Middlesbrough	UK
5	Braga	Portugal
6	Lublin	Poland
7	Cork	Ireland
8	Debrecen	Hungary
9	Kaunas	Lithuania
10	Gdynia	Poland

Source: compiled from Foreign Direct Investment, 2022, pp. 15, 23.

To sum up, in the Lublin Region, mainly micro-enterprises are being established. In addition, the share of innovative enterprises in the total number of enterprises increases yearly. Therefore, a successive increase in the number of introduced innovations is visible. The Lublin Region has a high percentage of innovativeness-active enterprises and those undertaking cooperation for innovativeness, the carrier of which is a solid academic center. The provincial city, Lublin, has been recognized internationally for its strategy of attracting investors and foreign investment and being a business-friendly place. As a result, Lublin is a region constantly developing its innovative potential and creating conditions for further investment activities.

4. Specifics of innovative organizations in the Lublin Region on the example of start-ups - results of own research

Lublin's start-up ecosystem is constantly growing. The province supports innovative entrepreneurs and is a friendly place to do business, according to the 2017 Startup Poland Foundation report (Beauchamp et al., 2017, pp. 78-79). A report from 2018 (Beauchamp et al., 2018, pp. 6, 24) shows that Lublin is among the top cities with a growing number of start-ups that focus mainly on big data and analytics. In the 2019 report (Krysztofiak-Szopa, Wisłowska, 2019a, pp. 6, 13, 39, 67, 69), Lublin achieved high positions in the leading rankings in the categories of cities with the largest start-up ecosystems in the country, cities with the highest concentration of start-ups, cities with the fastest pace of start-up development and regions with the highest chance of raising funding. In turn, according to the report "The Polish Tech Scene. 5 years" by the Startup Poland Foundation in 2019 (Krysztofiak-Szopa, Wisłowska, 2019b), Lublin ranked 4th among the most significant Polish start-up ecosystems. It also appeared in the top positions in the three subcategories of the report: first place as the Region with the highest perceived ability to raise funding by respondents, second place as the city with the highest growth in the number of start-ups, and third place in the subcategory related to the concentration of start-ups in terms of population.

Research in the Lublin Region in 2020-2021 targeted 350 start-ups. The sample was selected purposefully with the assumption that a start-up is an organization that has at least one distinguishing feature - it is at an early stage of development, goes through the first phase of its life cycle, introduces innovative solutions dynamically adapting to market changes, cooperates with the environment effectively using the synergy effect, and operates under conditions of extreme uncertainty taking a high risk. The survey questionnaire was anonymous, consisting of open and closed questions with a cafeteria of answers (where 1 - not important and 5 - very important) and using a five-point Likert scale (where 1 - strongly disagree and 5 - strongly agree). It was distributed to respondents via the Internet. Start-up founders were asked, among

other things, to indicate the number and type of innovations introduced in the regional, national, European, and international markets. Respondents were also asked to assess their start-up's innovativeness and the factors influencing it. The survey also asked about the importance of key performance indicators in the strategy of the surveyed start-ups. The research process yielded 97 correctly completed questionnaires.

Considering the innovation characteristics of start-ups in the Lublin Region (Table 6), the study shows that 66.8% of respondents have 1-3 innovations, and a much smaller percentage of start-ups introduce four and more innovations (3.2-1.6%). In comparison, 26.7% of respondents have not yet decided to implement any innovative solutions. Most innovations are introduced on the domestic market (36.5%), a smaller percentage is on the international (25.5%) and regional market (23.4%), and the least innovations are introduced on the European market (14.6%). Many of the founders of Lublin start-ups choose product innovations (55.6%), a smaller percentage introduce process innovations (24.9%) and marketing innovations (11.6%), and the smallest percentage introduce organizational innovations (7.9%). In general, most of the surveyed entities (73.6%) claim that their start-up is innovative (positive opinions), only 19.8% have a completely different opinion (negative opinions), and less than 7% are unable to assess the innovativeness of their company (6.6% - I have no opinion).

Table 6.
Characteristics of start-ups' innovativeness as assessed by respondents (N) in the Lublin Region

Specification	Specifics of the market				Total (N)	Total (%)
	Regional	National	European	International		
Number of innovations						
0 innovations	10	5	17	18	50	26.7
1-3 innovations	28	47	19	31	125	66.8
4-6 innovations	2	1	1	2	6	3.2
7-9 innovations	1	1	0	1	3	1.6
10 and more innovations	1	1	0	1	3	1.6
					187	100.0
Share of innovations introduced						
Total (N)	32	50	20	35	137	100.0
Total (%)	23.4	36.5	14.6	25.5		100.0
Type of innovation						
products	31	45	22	36	134	55.6
procedural	15	19	10	16	60	24.9
marketing	6	11	5	6	28	11.6
organizational	5	6	3	5	19	7.9
					241	100.0
My start-up is innovative*						
negative opinions	7	11	11	10	39	19.8
I have no opinion	0	2	4	7	13	6.6
positive feedback	39	45	29	32	145	73.6
					197	100.0

Explanations:
* negative opinions - "strongly disagree + rather disagree"; positive opinions - "rather agree + strongly agree".

Source: own compilation based on surveys conducted.

When selecting factors that have a significant impact on a start-up's innovativeness (Table 7), respondents most often indicated the high potential of the company's employees (mean 4.18), availability of qualified staff (mean 4.03), customers (mean 3.95), free internal communication (mean 3.95) and flexible organizational structure (mean 3.90). On the other hand, when considering factors that had the most negligible impact on innovation, founders of start-ups in the Lublin Region most often indicated a regional pro-innovation policy (mean score of 3.13), a national pro-innovation policy (mean score of 3.22), an incentive system supporting pro-innovation attitudes of employees (mean score of 3.24), availability of a market for materials (mean score of 3.33) and technical equipment of the company (mean score of 3.38).

Table 7.
Factors influencing the innovativeness of start-ups in the Lublin Region

Categories answers	Ratings* (%)					Average ratings**	Rank
	1	2	3	4	5		
Customers	3.1	10.3	10.3	41.2	35.1	3.95	3
Leadership qualities	1.0	6.2	39.2	27.8	25.8	3.71	8
High potential of the company's employees	2.1	2.1	17.5	33.0	45.4	4.18	1
Free internal communication	1.0	6.2	23.7	35.1	34.0	3.95	4
Flexible organizational structure	1.0	6.2	20.6	46.4	25.8	3.90	5
Enough financial resources	5.2	11.3	33.0	28.9	21.6	3.51	10
Technical equipment of the company	4.1	17.5	32.0	28.9	17.5	3.38	12
Marketing shaping demand for an innovative product	4.1	13.4	26.8	39.2	16.5	3.51	11
Access to the technology market	4.1	4.1	19.6	46.4	25.8	3.86	6
Access to the materials market	7.2	17.5	24.7	36.1	14.4	3.33	13
Availability of qualified staff	1.0	4.1	21.6	37.1	36.1	4.03	2
Cooperation with the scientific community	11.3	7.2	18.6	33.0	29.9	3.63	9
Regional pro-innovation policy	10.3	13.4	38.1	28.9	9.3	3.13	16
Pro-innovation national policy	11.3	9.3	36.1	33.0	10.3	3.22	15
Motivation system to support pro-innovative attitudes of employees	8.2	8.2	46.4	25.8	11.3	3.24	14
An innovation-friendly culture	1.0	6.2	30.9	42.3	19.6	3.73	7

Explanations:
* ratings: 1 - strongly disagree, 2 - rather disagree, 3 - no opinion, 4 - rather agree, 5 - strongly agree.
** rating scale: 1-5, where 5 - max.

Source: own compilation based on surveys conducted.

Respondents from the Lublin Region rated the importance of performance factors (Key Performance Indicators, KPIs) in their start-up's strategy very highly (over 74% each) (Table 8). Based on the collected information, it should be stated that the founders of the surveyed start-ups put the most significant emphasis on product development (92.8% of positive responses) and profitability (83.5% of positive responses). They put less emphasis on strengthening the motivation and development of employees (76.3% of positive responses) and strengthening the organizational culture (76.3% of positive responses). In comparison, the minor emphasis is on organizational development (75.3% of positive responses) and rapid growth (74.2% of positive responses).

Table 8.
Importance of key performance indicators in start-up strategy

Categories answers	Ratings* (%)		Average ratings**	Rank
	negative	positive		
Rapid growth	7.2	74.2	3.92	6
Profitability	5.2	83.5	4.20	2
Product development	1.0	92.8	4.47	1
Organizational development (processes, structures, communication, etc.)	5.2	75.3	3.99	5
Strengthening staff motivation and development	2.1	76.3	4.04	3
Strengthening the organizational culture (norms, values, etc.)	4.1	76.3	4.01	4

Explanations:
* negative evaluations "not important + rather not important"; positive evaluations "rather important + very important".
** rating scale: 1-5, where 5 - max.

Source: own compilation based on surveys conducted.

The surveyed start-ups were also asked to indicate the number of patents they had obtained. Unfortunately, only about 8% of them declared that they had a patent, mainly granted individually to the company. However, it should be emphasized that more than 70% of respondents plan to implement innovations in the next three years, mainly deciding on product innovations in the number of 1-3 innovations.

Given the above, it should be concluded that start-ups from the Lublin Region are constantly developing their innovative activity, focusing mainly on the domestic market and offering, most often, product innovations. Most of the surveyed founders claim that their start-up is innovative and, at the same time, makes this innovation dependent on the high potential of their employees, availability of qualified staff, and customers, free internal communication, and a flexible organizational structure. In the strategy of the surveyed start-ups, the most crucial focus is on product development and achieving satisfactory profitability. It should also be emphasized that the surveyed start-ups plan to implement innovative solutions, mainly in product innovation, in the coming years of their activities.

5. Conclusion

The innovative potential of a region is the ticket to the creation of hitherto unknown solutions by today's entrepreneurs. It encourages out-of-the-box decision-making, obliges the creation of innovative organizations bringing creative products/services to the market, and attracts wealthy and experienced investors. As a result, it contributes to socio-economic development, upgrades hitherto obsolete technologies, and thus ensures social well-being. The study shows that in the Lublin Region:

1. Mainly micro-enterprises are being set up.
2. The share of innovative enterprises in the total number of enterprises is increasing - a successive increase in the number of innovations introduced.
3. There is a high proportion of innovation-active enterprises and cooperation for innovation (supported by a solid academic center).
4. The provincial city of Lublin was recognized internationally for its strategy of attracting investors and foreign investment and being business-friendly.
5. Start-ups constantly develop their innovation activities (focusing on the domestic market and offering product innovations).
6. Start-ups depend for their innovation on the high potential of their employees, the availability of qualified staff, and customers, free internal communication, and a flexible organizational structure.
7. The focus on product development and achieving satisfactory profitability is paramount in the strategy of the start-ups surveyed.
8. Start-up founders say their business is innovative and plan to implement innovative solutions, mainly in product innovation.

Therefore, many initiatives supporting creative entrepreneurs setting up small businesses should be created in the Lublin Region. In turn, the entrepreneurs of the Lublin Region, in their strategy, should undertake actions favoring the local community. They should create solutions to improve social welfare and reduce the poverty level in the Region so that the least affluent part of society can access modern solutions and opportunities for personal development. In addition, entrepreneurs should also target foreign markets, which will contribute to the Region's international visibility.

The study shows that Lublin Region is constantly developing its innovative potential, thanks to the growing number of small, thriving companies focused on innovation. Despite the unfavorable economic conditions in Eastern Poland, Lublin Region creates conditions for further investment activities and favors new entrepreneurs.

The study is not exhaustive and is a premise for further in-depth research. The subject of this publication is of interest to the world of science, business, and public administration. Unfortunately, the publication also has some limitations, mainly related to acquiring empirical material. The research period coincided with the COVID-19 pandemic, meaning that entrepreneurs were mainly focused on survival and were not interested in participating in the study. The shift to remote working contacted them completely impossible. A further research area could be the analysis of the factors influencing innovation and thus success mainly for the dominant in the overall number of entities - micro-enterprises.

References

1. Adamczyk, M. (2015). Rola start-upów w procesie tworzenia innowacji. In: S. Wawak, M. Sołtysik (Eds.), *Współczesne trendy w outsourcingu* (pp. 201-208). Kraków: Mfiles.pl.
2. Beauchamp, M., Kowalczyk, A., Skala, A. (2017). *Polskie Startupy. Raport 2017 (Report)*. Warszawa: Fundacja Startup Poland.
3. Beauchamp, M., Kowalczyk, A., Skala, A. (2018). *Polskie Startupy. Raport 2018 (Report)*. Warszawa: Fundacja Startup Poland.
4. Berezowski, J., Kretek, H.A. (Eds.) (2016). *Zrównoważony rozwój – Debiut naukowy*. Racibórz: Państwowa Wyższa Szkoła Zawodowa w Raciborzu.
5. Chrzanowski, M., Zawada, P. (2018). *Otwarte innowacje i ich wykorzystanie w przedsiębiorstwach typu start-up.* Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
6. Czubała, A. (2015). Innowacje w sektorze usług w Polsce. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie*, *Vol. 26, No. 1*, pp. 35-45, doi: 10.25944/ znmwse.2015.01.3545.
7. Dimitrova, L. (2013). *Strategic Acquisitions by Corporate Venture Capital Investors*. London Business School.
8. Dolińska, M. (2010). *Innowacje w gospodarce opartej na wiedzy*. Warszawa: PWE.
9. Foreign Direct Investment (2022). *European Cities and Regions of the Future 2022/23 (Report)*. London: The Financial Times Ltd.
10. Janasz, W. (2011). Strategie organizacji innowacyjnych. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania*, *No. 21*, pp. 45-58.
11. Janczewska, D. (2012). Zarządzanie działalnością innowacyjną w mikroprzedsiębiorstwach w aspekcie wsparcia marketingowego. *Studia Ekonomiczne Regionu Łódzkiego. Wybrane aspekty zarządzania nowoczesną organizacją*, *No. 8*, pp. 11-29.
12. Jasiński, A.H. (1992). *Przedsiębiorstwo innowacyjne na rynku*. Warszawa: Wydawnictwo KiW.
13. Krysztofiak-Szopa, J., Wisłowska, M. (2019a). *Polskie Startupy. Raport 2019 (Report).* Warszawa: Fundacja Startup Poland.
14. Krysztofiak-Szopa, J., Wisłowska, M. (2019b). *The Polish Tech Scene. 5 years (Report).* Warszawa: Startup Poland.
15. Maliszewski, G., Gromada, M., Nasiłowska, M. (2020). *Indeks Millennium 2020 - Potencjał Innowacyjności Regionów (Report)*. Warszawa: Millennium Bank.
16. OECD. (2008). *Podręcznik Oslo. Zasady gromadzenia i interpretacji danych dotyczących innowacji*. Warszawa: Ministerstwo Nauki i Szkolnictwa Wyższego.
17. PARP (2007). *Społeczne determinanty przedsiębiorczości innowacyjnej*. Warszawa: PARP.

18. Pawlicz, A., Molski, A., Liszka, W. (2017). Wpływ wieku i wielkości przedsiębiorstw turystycznych na ich innowacyjność. *Studia Oeconomica Posnaniensia*, *Vol. 5, No. 4*, pp. 228-241, doi: 10.18559/SOEP.2017.4.11.

19. Podstawka, M., Suchodolski, B. (2018). Dochodowe uwarunkowania rozwoju powiatów województwa lubelskiego. *Zeszyty Naukowe UPH seria Administracja i Zarządzanie*, *Vol. 43, No. 116*, pp. 9-23. Retrieved from: https://czasopisma.uph.edu.pl/znadministracja/article/view/363.

20. *Polska Organizacja Turystyczna*. Retrieved from: https://www.pot.gov.pl/pl/pcb/news/polskie-miasta-w-rankingu-europejskich-miast-i-regionow-przyszlosci-fdi-2022-23, 16.11.2022.

21. Rothwell, R., Dodgson, M. (1991). External Linkages and Innovation in Small and Medium Sized Enterprises. *R&D Management*, *Vol. 21, No. 2*, pp. 125-138, doi: 10.1111/j.1467-9310.1991.tb00742.x.

22. Saura, J.R., Palos-Sanchez, P.R., Correia, M.B. (2019). Digital Marketing Strategies Based on the E-Business Model: Literature Review and Future Directions. In: *Organizational Transformation and Managing Innovation in the Fourth Industrial Revolution* (pp. 86-103). USA: IGI Global.

23. Skala, A. (2017). Spiralna definicja startupu. *Przegląd Organizacji*, *No. 9*, pp. 33-39, doi: 10.33141/po.2017.09.05.

24. Stawasz, E. (1999). *Innowacje a mała firma*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.

25. Urząd Miasta Lublin. *Dlaczego Lublin?* Retrieved from: https://lublin.eu/biznes-i-nauka/inwestorzy/lublin-destynacja-inwestycyjna/dlaczego-lublin/, 16.11.2022.

26. Żyśko, R. (2018). Lubelskie Wyżyny – ekosystemy gospodarcze Lublina. In: P. Maleszyk, M. Sagan (Eds.), *Lublin 2030 – europejska metropolia* (pp. 103-124). Lublin: Urząd Miasta Lublin. Wydział Strategii i Obsługi Inwestorów.

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 170

CHANGES IN THE TECHNICAL CONDITION OF VEHICLE BRAKES COMPARED TO 2014 YEAR

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Purpose: The purpose of the tests is to determine whether and to what extent there has been a change in the parameters of the car's braking system, assessed during the technical inspection.
Design/methodology/approach: Diagnostic tests were performed, braking force measurements on a roller device, the following were analyzed: differences in braking force on axle wheels, non-linear increases in braking force, deceleration of braking force, changes in the value of braking force.
Findings: Changes in the technical condition of vehicle braking systems in 2022 compared to 2014 were demonstrated.
Research limitations/implications: In the future, a trend line of changes in the technical condition of vehicle braking systems can be created.
Practical implications: In the course of the research, it was found that the technical tests made it possible to determine the direction of positive changes in the technical condition of the braking systems in the tested vehicles, which translates into vehicle safety in road traffic.
Originality/value: Changes in the condition of the brake system in 2022 compared to 2014.

Keywords: Safety and quality of transport, braking system, changes of conditions.

Category of the paper: Technical paper.

1. Introduction

The development of many different driver assistance systems in the area of traffic safety (Front assist, turn assistant, side assist etc.) (Kornacki, 2022), has not changed the brake system still remains a system that in the vast majority of road situations, determines the possibility of avoiding accidents.

According to the regulations (Rozporzadzenie Ministra Infrastruktury z dnia 31 grudnia…), vehicles moving on public roads must be equipped with a braking system that can be activated by at least two methods. Due to the methods of actuating the brakes in passenger cars, the following brake is distinguished:

- main - in most cases, foot operated by pressing the brake pedal. Braking only takes place while the brake pedal is depressed.
- emergency - the brake also works as a parking brake in order to prevent the vehicle from leaving the parking place. In case of a failure of the main brake, it is designed to brake the vehicle in an emergency. The emergency brake is activated by hand or foot, depending on the construction. It works from the moment it is turned on until it is turned off.

Testing the braking system during the annual technical tests of vehicles is a mandatory process and carried out in a strictly defined way (Dz.U. z 2015 r. poz. 776, Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 18 grudnia…).

According to the regulations, the acceptable methods of brake testing are roller stand and braking deceleration test. The results collected during the brake tests make it possible to calculate the so-called the braking rate.

Brake tests were carried out at a vehicle control station on another 100 passenger cars in 2014. Brake tests which a periodic technical inspection was carried out. The tests were carried out on a CARTEC BDE 3504 roller device. The tests were carried out with the use of a brake pedal pressure sensor.

The tests were carried out in the excatly described in the relevant Regulation (Dz.U. z 2015 r. poz. 776, Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 18 grudnia…).

The results obtained during the research were divided into nine groups. Eight groups of resulted from possible faults of the braking system, the occurrence of which necessitated the recognition of the system as out of order. The ninth group includes vehicles with the correct operation of the braking system. The collected results were as follows:

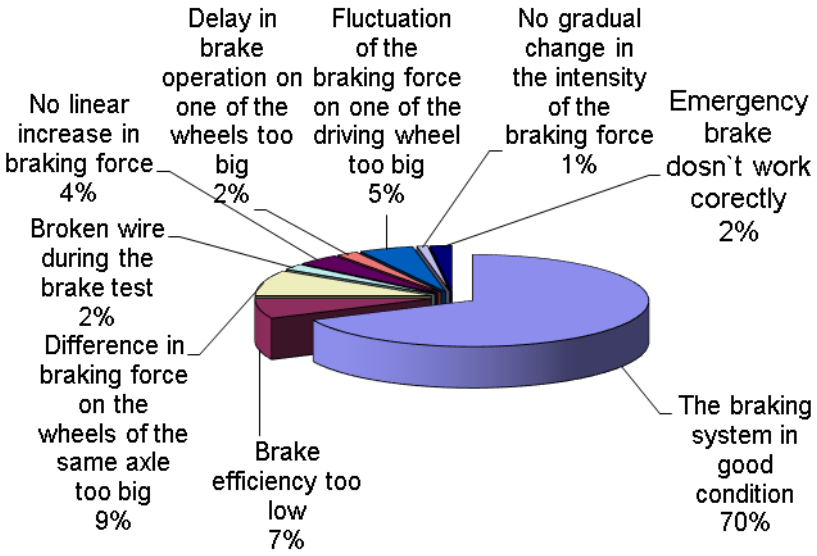

Figure 1. The results of the brake system test - the research carried out in 2014.
Source: Miros, 2014.

The testing of braking systems was extended to measure the boiling point of the brake fluid. The measurement was carried out in a brake fluid reservoir with the use of the WTM TPH-302 device.

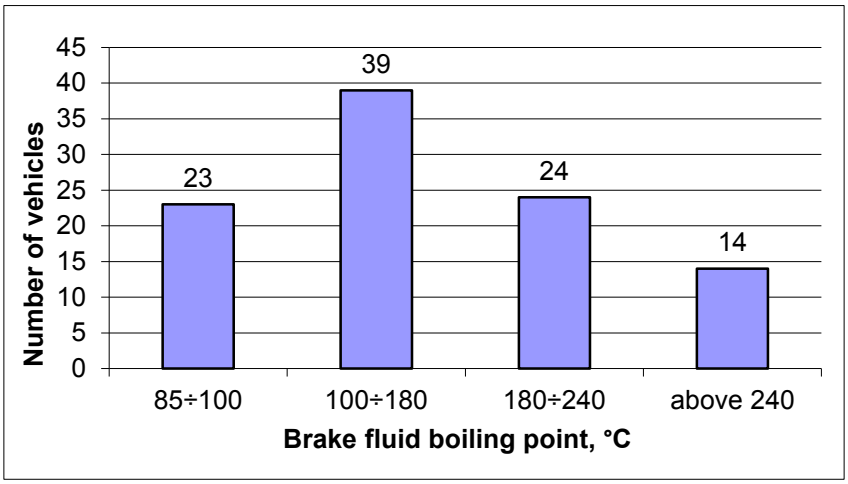

Figure 2. Brake fluid boiling point test - the research carried out in 2014.

Source: Miros, 2014.

A similar tests were carried out in 2022 at one of the Basic Vehicle Inspection Stations located in a medium-sized city in the Upper Silesian Industrial District.

2. Materials and research methods

The research carried out in the period from june to september 2022 was research, similarly to the research conducted and published in 2014, based on the guidelines for the operation of the braking system provided in the relevant Regulation (Dz.U. z 2015 r. poz. 776, Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 18 grudnia…).

The brakes were tested in a vehicle control station on 100 passenger cars, during periodic technical inspections were carried out. The tests were carried out on a CARTEC BDE 3504 roller device. The tests were carried out with the use of a brake pedal pressure sensor - with a brake pressure of 50 daN. The technical parameters of the roller stand are shown in Table 1.

Table 1.

Technical data of the CARTEC BDE 3504

Parameter name	Value
Max. axle load	130 kN
the diameter of the drive rollers	205 mm
the length of the drive rollers	1000 mm
the speed of drive rollers for vehicle inspection	5,2 km/h
the value of the slip of the wheel relative to the rollers	15 ÷ 40 %
measurement error the range in braking force	+/- 10

Cont. table 1.

coefficient of adhesion of tires to drive rollers: dry:	0,7
wet:	0,9
Ppermissible difference in the measurement of the left and right brake force measuring system	< 2%
braking rate max calculation error	-1%
measurement range	0-30/0-40

Source: Cartec-Poland information materials, *Manual of CARTEC BDE 3504.*

Before starting the brake test, the static wheel pressure on the ground was measured – it`s allowed to determine the actual mass of the vehicle at the time of the test. The braking force of individual wheels, obtained mass of the car during the test allowed for the calculation of the braking efficiency coefficient in accordance with the formula 1.

$$z = \frac{\sum T}{P} * 100 \tag{1}$$

where:

z – braking efficiency coefficient (%),

ΣT – braking force obtained from all wheels (kN) for the each type of brake,

P – force of gravity (pressure) from the permissible total weight of the tested vehicle (kN), assuming 1 kN = gravity force of 100 kg of mass for the calculation (for part vehicles, the permissible load of a given axle may be taken into account).

Assessment of the braking efficiency in accordance with the applicable regulation is based on the value of the braking efficiency coefficient and the relative difference of braking forces between the wheels of the same axle.

In accordance with the Regulation, the car's main brake should be considered defective if, among other things, it is noticed (Rozporzadzenie Ministra Infrastruktury z dnia 31 grudnia…, Dz.U. z 2015 r. poz. 776, Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 18 grudnia…):

- The braking force on one wheel is less than 70% of the greatest braking force measured on the other wheel on the same axle.
- No constant increase in braking force.
- Brake action at any wheel is too late to either wheel.
- Too large fluctuations in the braking force during each full rotation of the wheel.
- No gradual change in braking force.
- Efficiency lower than the minimum values contained in the Regulation of technical conditions (50 daN - for passenger cars).
- Too much corrosion of brake lines.
- Emergency brake doesn’t work properly.

As in the previous study (in 2014 year), the results obtained were divided into nine groups.

Eight groups concerned possible faults of the braking system, the finding of which made it necessary to recognize the system as inoperative.

The ninth group includes vehicles which the correct braking system was found. The results were as follows:

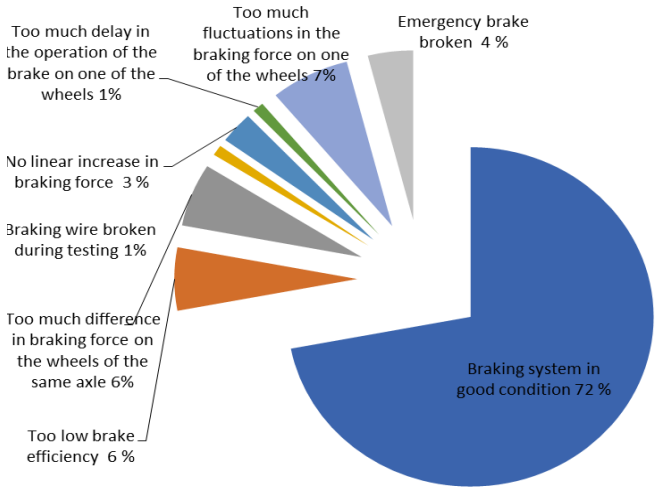

Figure 3. Results of investigations of the braking systems.

The results obtained in 2022 were compared with the results of the research conducted in 2014. Percentage changes in the results of individual tested parameters and the change in the number of properly functioning braking systems are shown in Figure 4.

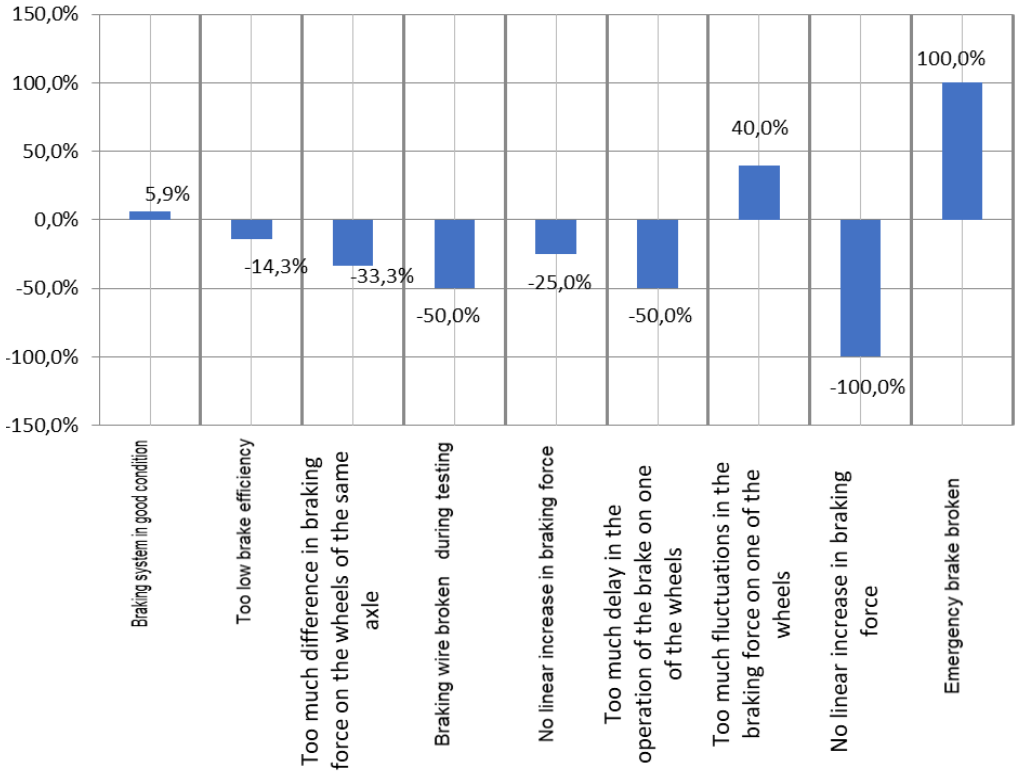

Figure 4. Percentage changes in the results of the tested parameters of the braking systems.

The above graph shows that the number of cars with a fully functional braking system has increased by almost 6%. This result was caused by a decrease in the number of all tested parameters indicating incorrect operation of the braking systems. It was also noticeable that two of the tested braking system performance parameters increased. These parameters were the no linear increase in the braking force - an increase by 40% compared to 2014, and incorrect operation of the emergency brake - an increase by 100%.

Just like in 2014. also in the current study, the boiling point of the brake fluid was checked.

The testing of brake systems was extended to include the measurement of the boiling point of the brake fluid. The measurement was carried out in the brake fluid reservoir using the WTM TPH-302 device. Selected technical parameters of the device are presented in table 2 (Cartec-Poland information materials, *Manual of the Brake…*).

Table 2.
Technical information of the WTM TPH-302 device

Parameter name	**Value**
Boiling point of measured fluids	85 do 300°C
Measurement accuracy	+/- 3%

Source: Cartec-Poland information materials, *Manual of the Brake Fluid Tester TPH-302 by WTM.*

The results of the brake fluid boiling point test were divided into 5 groups. The results are shown in Figure 5.

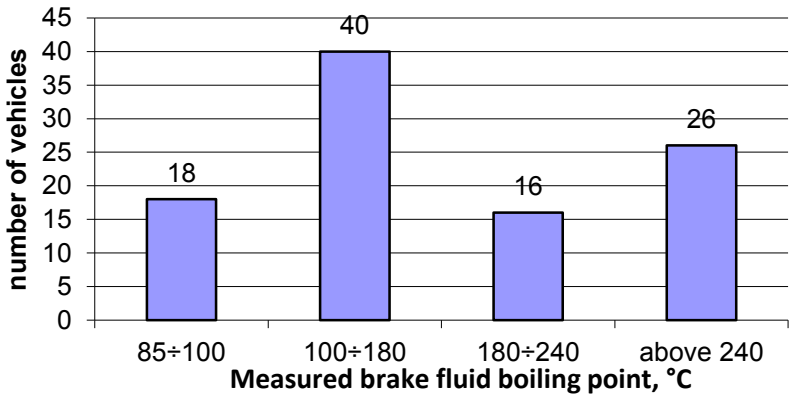

Figure 5. The results of brake fluid boiling point.

The results obtained in 2022 were compared with the results of the research conducted in 2014. Percentage changes in the results are shown in Figure 6.

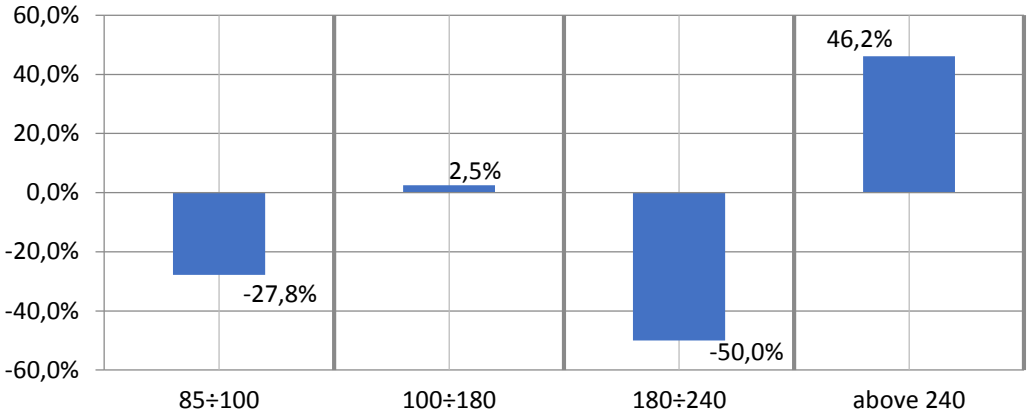

Figure 6. Percentage changes in the results of the tested brake fluid boiling points.

The collected information showed that more than 60% of the tested cars have a fluid in the brake system whose boiling point is below 180° C. The value of 180° C is the boundary boiling point of the brake fluid when measured in the tank (Cartec-Poland information materials, *Manual of the Brake…)*.

3. Summary

To sum up, it should be stated that a positive change in the technical condition of the braking systems in 2022 compared to 2014 has been noticed. The percentage share of brake system failures was lower in 2022 than in 2014. The conducted analyzes allowed the formulation of the following conclusions:

1. In 28% of the tested cars, defects of the braking system were found, which, according to the applicable Regulation, are defects qualifying the system as defective. The results showed a decrease in the number of cars with a damaged braking system by 2% compared to the research in 2014.
2. In 58% of the tested cars, the presence of brake fluid with too low a boiling point was found. The result shows a decrease in the number of cars with too low boiling point brake fluid compared to 2014 by 27.8%.

References

1. Cartec-Poland information materials, *Manual of CARTEC BDE 3504.*
2. Cartec-Poland information materials, *Manual of the Brake Fluid Tester TPH-302 by WTM.*
3. Dz.U. z 2015 r. poz. 776, Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 18 grudnia 2013 r. zmieniające rozporządzenie *w sprawie zakresu i sposobu przeprowadzania badań technicznych pojazdów oraz wzorów dokumentów stosowanych przy tych badaniach*, Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20130001675, 17.10.2022.
4. Kornacki, J. (2022). *Driver assistance systems increase our safety.* Automotyw.
5. Miros, M. (2014). *Efficiency of braking systems of passenger cars on Polish roads*. Zakopane: Conference materials SBO.
6. Rozporzadzenie Ministra Infrastruktury z dnia 31 grudnia 2002 r. *w sprawie warunków technicznych pojazdów oraz zakresu ich niezbędnego wyposażenia*. Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20160002022/O/D20162022.pdfgov.pl), 17.10.2022.

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

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ORGANIZATION AND MANAGEMENT SERIES NO. 170

DEVELOPMENT AND FINANCING OF INFRASTRUCTURE INVESTMENTS TO SHAPE SUSTAINABLE AND RESILIENT MOBILITY

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Purpose: The aim of the study is to identify the essential attributes that determine the development of a sustainable, innovative and resistant to disruption transport infrastructure and to answer two research questions: How to shape models for the development of sustainable and innovative transport infrastructure, while maintaining the logistic continuity of mobility and transport systems? and What actions should organizations take in the conditions of permanent change in order to maintain operational efficiency and cost-effectiveness of implemented investments, not only thinking about the possible return of the pandemic, but also about increasingly difficult access to resources, climate change and social needs?
Design/methodology/approach: The research methods and techniques used included, among others: content analysis, cause and effect analysis, selected methods of qualitative and quantitative analysis, which were used to present and discuss the results of the study.
Findings: Searching for methods of operationalization of the implementation of the assumptions of the new development paradigm, a conceptual framework for the model of sustainable development of transport infrastructure was developed. EU programs and instruments supporting the financing of activities in the field of development of sustainable, innovative and resilient transport infrastructure were reviewed. Attributes were indicated so that the development would strive for the simultaneous implementation of economic, social and environmental goals.
Research limitations/implications: The study did not measure the sustainability of infrastructure investments in transport. The precondition for successfully performing such a task is the availability of an accurate data set and the selection of appropriate measurement indicators. This has implications for future research.
Practical implications: One of the key challenges in cities is making decisions about investments in the development of economically effective, environmentally safe and socially important transport infrastructure. Hence, the development of algorithmic approaches that allow the use of the proposed qualitative model may contribute to improving the efficiency in making investment decisions.

Originality/value: The originality of the conducted research was achieved through its measurable character. The proposed model can contribute to the improvement of decision-making tools in the field of allocation of public and other funds for investments, so that they contribute to the sustainability of mobility systems.

Keywords: transport infrastructure, sustainable development, financial instruments.

Category of the paper: research paper.

1. Introduction

The initiatives adopted under the Sustainable and Smart Mobility Strategy (2020) and the "Fit for 55" package set out a number of actions for the development of sustainable, innovative and resilient mobility. Their implementation requires significant financial outlays in the short term and a comprehensive change in the approach to the functioning of the investment financing system in the entire value chain. In the face of weakening local budgets and rising national debt, the role of European Union (EU) funds and funding is undeniable. The current long-term EU support, in the 2021-2027 programming period, remains crucial to meeting the challenges of mobility in terms of sustainability and digitalization, while increasing transport demand. Taking into account the likelihood that public funds will be limited due to the scale and complexity of the projects, it will be important to increase investment in the sustainable mobility system by the private sector, including, among others, through "green" financial instruments. Responsibility for the development, financing and construction of transport infrastructure lies mainly with the EU Member States. EU funds, which must provide added value in the European dimension, should be subsidiary to private, i.e. market-based, sources of financing. Meanwhile, since 2008, expenditures, both from public and private funds, on transport investments have been gradually decreasing (European Commission, 2019). At the same time, the mobility system has changed radically in recent years and continues to transform rapidly. Driven by new technologies and changes in consumer behaviour, the mobility of the future will be more flexible, environmentally focused and based on 'use' rather than 'ownership' models. In the short and medium term, there are several main directions of activities related to the financing of solutions in the field of environmentally friendly and climate-neutral mobility.

Despite the adoption of new Sustainable Development Goals in 2015 and confirmed benefits related to social, economic and environmental aspects, the process of implementing sustainable mobility faces a number of challenges. Achieving zero net Greenhouse Gas (GHG) emissions by 2050, in line with the European Green Deal, requires the widespread availability of sustainable alternatives integrated into a fully integrated, efficient and resilient multimodal network EU transport infrastructure. Meanwhile, most countries are unable to provide the required quantity and quality of infrastructure investment. This reflects two fundamental and persistent barriers to investment. Firstly, countries are often unable to convert huge needs and

opportunities into a concrete set of projects, and much of the new investment is not as sustainable as it should be. This is due to the inherent complexity of transport development investments and political and institutional obstacles. Second, mobilizing long-term funding, taking into account the risk of the infrastructure project cycle and ensuring that funding is sustainable, remains a common challenge.

According to the adopted thesis, the development of a zero-emission, innovative and resilient economy requires the redirection of public and private capital to "sustainable" investments. Mobility plays an important role in this development. The main objective of the study, the results of which are presented in this article, is to identify the essential attributes determining the development of a sustainable, innovative and resistant to disruption transport infrastructure. For such a specific purpose, research questions were formulated:

- How to shape models for the development of sustainable and innovative transport infrastructure, while maintaining the logistic continuity of mobility and transport systems?
- What actions should organizations take in the conditions of permanent change in order to maintain operational efficiency and cost-effectiveness of implemented investments, not only thinking about the possible return of the pandemic, but also about increasingly difficult access to resources, climate change and social needs?

Investing in innovative and resilient transport infrastructure, taking into account environmental and social aspects, is a challenge, but also creates new business opportunities. Stakeholders are already recognizing the economic potential of the value chain of sustainable investments in transport and mobility infrastructure. The qualitative model of transport infrastructure development proposed in the article can contribute to the improvement of decision-making tools for the allocation of public funds and other sources for investments, so that they contribute to the sustainability of mobility systems.

2. Literature review

The issue of sustainable development is now an integral element not only of environmental policy, but also of economic and social policy. Along with the strengthening of the concept of sustainable development in economic activity, transport infrastructure is of particular importance, which is reflected both in the literature on the subject (Ahern, 2011; Bhattacharya, 2016; Cho, Choi, 2021), as well as in strategic documents (UN, 2015) and sectors of individual economies (White Pape, 2011). Infrastructure determines the proper functioning of the economy and society, and at the same time it can be a source of unintended negative effects of a long-term nature, in the closer and further environment. From the perspective of sustainable development, it is both a manifestation and a determinant of this development. It is therefore

crucial that the processes of designing, developing and operating transport infrastructure are both conditions and factors that strengthen the implementation of the concept of sustainable development (Yannis, Chaziris, 2022). At the same time, it should be noted that despite widespread acceptance, the concept is sometimes criticized, mainly in the context of problems in implementing the principles of sustainable development and the lack of measurable effects in practice. Czyżewski and Staniszewski (2018) argue that critical voices most often result from a rather general definition of the term "sustainable development", which often makes it abstract and ambiguous.

When analyzing the role of transport infrastructure as one of the key factors determining sustainable development, it should be emphasized that there are no completely unambiguous relationships between infrastructure investments and development. Particularly problematic are cases where, as a result of differences in the interpretation of sustainability, the actions taken to achieve it are contradictory. Transport infrastructure is an important factor in the competitiveness of regions and countries, but after reaching a certain level of saturation with infrastructure in geographical areas and supply networks, a further increase in expenditure on infrastructure investments may be economically unjustified, and even become a barrier to development. As Zaremba (2014) points out, indiscriminate investment of capital, unsupported by plans to use infrastructure, sometimes leads to a slowdown in economic growth, which is accompanied by a lower level of social development and an increase in environmental costs. In turn, Chen (2013) and Zhou et al. (2021), analyzing investment models, prove that the impact of infrastructure investments on development varies significantly in individual regions. They also indicate the need to take into account externalities for neighboring regions. It is therefore important to avoid, in the development of infrastructure, e.g. investment projects that primarily increase the transit importance of a given area (Polyzos, Tsiotas, 2020). This effect causes certain benefits in the economic dimension, while quite often being a source of local external costs, e.g. an increase in CO_2 emissions or migration of the labor force to a more attractive region.

The unanimity of views on the important role of infrastructure in the processes of economic growth and development is accompanied by an increasing awareness of the change in the perception of transport infrastructure as a result of the impact of the main trends in socio-economic development. The essential assessment criteria are not only the quantity, but above all the quality of the infrastructure, capacity for resilience, accessibility and impact on the environment. These criteria make it possible to assess both direct and indirect effects of infrastructure development, including social and environmental ones. Hence, shaping transport infrastructure in accordance with the new paradigm requires specifying the essence of sustainable infrastructure development and systematic research into the possibility of its effective implementation.

The concept of sustainable development of transport infrastructure is related to the conditions of stable socio-economic development, in which the activity of enterprises in the transport-forwarding-logistics (TFL) sector significantly contributes to the improvement of prosperity, while maintaining the need to respect the principles of rational resource management. The common ground of the new paradigm of the development of logistics infrastructure are activities at the intersection of the following dimensions: economic, social, environmental, spatial and legal and institutional. At the basis of the analyzed concepts is a systemic approach to the study of individual dimensions and the relationships between them. At the same time, Rogall (2010) emphasizes that each of the systems develops at a different pace, hence maintaining appropriate relations between economic, social, environmental, as well as spatial and legal-institutional development is a major challenge in shaping a coherent transport infrastructure. The complexity of this problem is exacerbated by the multidimensional understanding of infrastructure (Andreas et al., 2019).

Nowadays, the domain of almost all areas of economic and social life is striving to ensure sustainable socio-economic development, which undoubtedly depends on a coherent, complete and mature transport infrastructure, closely related to the use of individual capitals, i.e.: natural, tangible, human, social and political. Thanks to it, it is possible to effectively meet the needs of individual groups of stakeholders and to achieve short- and long-term goals, i.e. to achieve a state of sustainability. In the context of the role of transport infrastructure in the process of sustainable development, however, the natural environment cannot be overlooked as a "stakeholder" of infrastructure (Champagne, Dubé, 2023). In this aspect, the development of infrastructure should enable the reconciliation of economic, social and environmental interests.

It seems reasonable that the role of transport infrastructure in shaping the modern concept of sustainable logistics and sustainable supply chains can be presented in a similar context. Undoubtedly, elements of transport infrastructure are exogenous factors for the development of sustainable logistics and sustainable supply chains, which in a certain way can affect the formation of these processes, i.e. stimulate or limit their development. The essence of these relationships is reflected, for example, in overloaded urban transport systems. They are the effects of new infrastructural investments, which, in accordance with the strategy implemented until the end of the 1990s, were to mitigate the negative effects of the increase in demand for road transport. This approach did not bring the expected results, on the contrary, the systematic increase in the demand for passenger car travel resulted in the increasing phenomenon of transport congestion and the need to build further connections (Przybyłowski, Podbielska, 2017). Therefore, it remains a constant challenge to seek such paths of sustainable development of transport infrastructure that, within a given generation and on an intergenerational scale, will ultimately ensure an improvement in the quality of services provided and durability of infrastructure, without compromising the speed of investment implementation, taking into account the needs of all stakeholders, including the environment.

3. Methods

Selected research methods and techniques were used in order to achieve the assumed research objective and to answer the formulated research questions. The descriptive analysis was used to define the subject of the study and to identify the basic relationships within it. To systematize the current scientific achievements and the state of knowledge about the essence and motives of sustainable development of transport infrastructure, the method of analysis and criticism of the literature turned out to be useful. The review of the literature on the subject was carried out in accordance with the classic approach, i.e.: selection of sources, search by keywords, review and selection of articles, in-depth analysis of selected publications in relation to the subject of the study, taking into account, among others, latest publications and number of citations. The analyzed scientific articles are indexed in the following databases: Scopus, Web of Science, Science Direct and Google Scholar. Compact scientific publications, reports, scientific expertise and statistical data used in the study were published by recognized publishing houses as well as foreign and domestic institutions. A review of the literature on the subject identified a general gap in knowledge about an integrated approach to support investment decisions in the development of sustainable transport infrastructure.

Using the cause-and-effect analysis, the implications of sustainable development for shaping the logistics infrastructure were defined, the attributes of sustainable development of transport infrastructure and the challenges related to the processes of their implementation from the perspective of the functioning of transport and logistics systems were identified.

Using the analysis and logical construction as well as qualitative analysis, a conceptual framework for the model of transport infrastructure development was developed in accordance with the idea of sustainable development. Its application requires taking into account many variables, due to the complexity of the development of the mobility system. It is expected that it may contribute to the improvement of tools supporting investment decisions in the field of sustainable transport infrastructure development. Using the general assumptions of the qualitative model, a review of EU programs and instruments supporting financing activities in the field of development of sustainable, innovative and resilient transport infrastructure was made.

4. Results

4.1. Conceptual framework for sustainable development of transport infrastructure

The idea of sustainable development of transport infrastructure is most often considered as a concept of socio-economic development, which must meet four common criteria of the new development paradigm, i.e. economic, social, environmental and institutional. Implications for a broader approach to the essence of sustainable development of transport infrastructure are the works of, among others: Bhattacharya et al. (2015) and Weber et al. (2016). The research work carried out for over two decades focused primarily on improving the concept of sustainable infrastructure development and the idea of sustainable transport infrastructure. Their context varies depending on the adopted criterion and categorization of its impact on the new development paradigm, while deepening the understanding of the essence of investments in the development of sustainable transport infrastructure.

Along with the dissemination of the concept of sustainable development, the approach to planning and assessing infrastructure investments has changed. By adopting a hierarchy of functions and objectives, sustainable infrastructure development can be achieved by prioritizing specific strategic elements (Figure 1). In addition, to outperform what is currently common practice, logistics infrastructure operators should have clearly defined performance metrics and targets – not only in terms of economic performance but also environmental, social and institutional performance.

Sustainable development of logistics infrastructure is a very complex process. The current state of research in the field of shaping sustainable infrastructure confirms that in the pursuit of increasing sustainability, a properly selected set of features conducive to the development trajectory is decisive, i.e.: resilience, social inclusion, innovation as well as productivity and infrastructure flexibility to disruptions in a dynamically changing environment.

Infrastructure resilience can be treated as a derivative property of the system, which is the result of the investments made. Their implementation will help prepare the infrastructure for the increase in the frequency of extreme weather events caused by climate change. McKinsey Global Institute experts predict that over the next three decades the average global temperature is expected to increase between 1.5°C and 5°C, and the probability of an increase in extreme temperatures in the summer months is in the range of 15% to 30% (Climate risk, 2020). As a long-lived asset, transport infrastructure is particularly vulnerable to the effects of climate change.

Inclusivity and reliability in the social dimension is another target point of the process of changes constituting the essence of sustainable development of logistics infrastructure. It can be defined as "any infrastructure development that enhances positive social inclusion outcomes and ensures that no individual, community or social group is deprived of the benefits of improved infrastructure" (Stanley Jo., Stanley J., p. 2). Infrastructure facilities and services

must therefore be accessible, inclusive and beneficial to all. The features of increasing sustainability with regard to logistics infrastructure should also be associated with mutual benefit effects in terms of the implementation of new technologies, improved productivity and flexibility to disruptions in a turbulent environment.

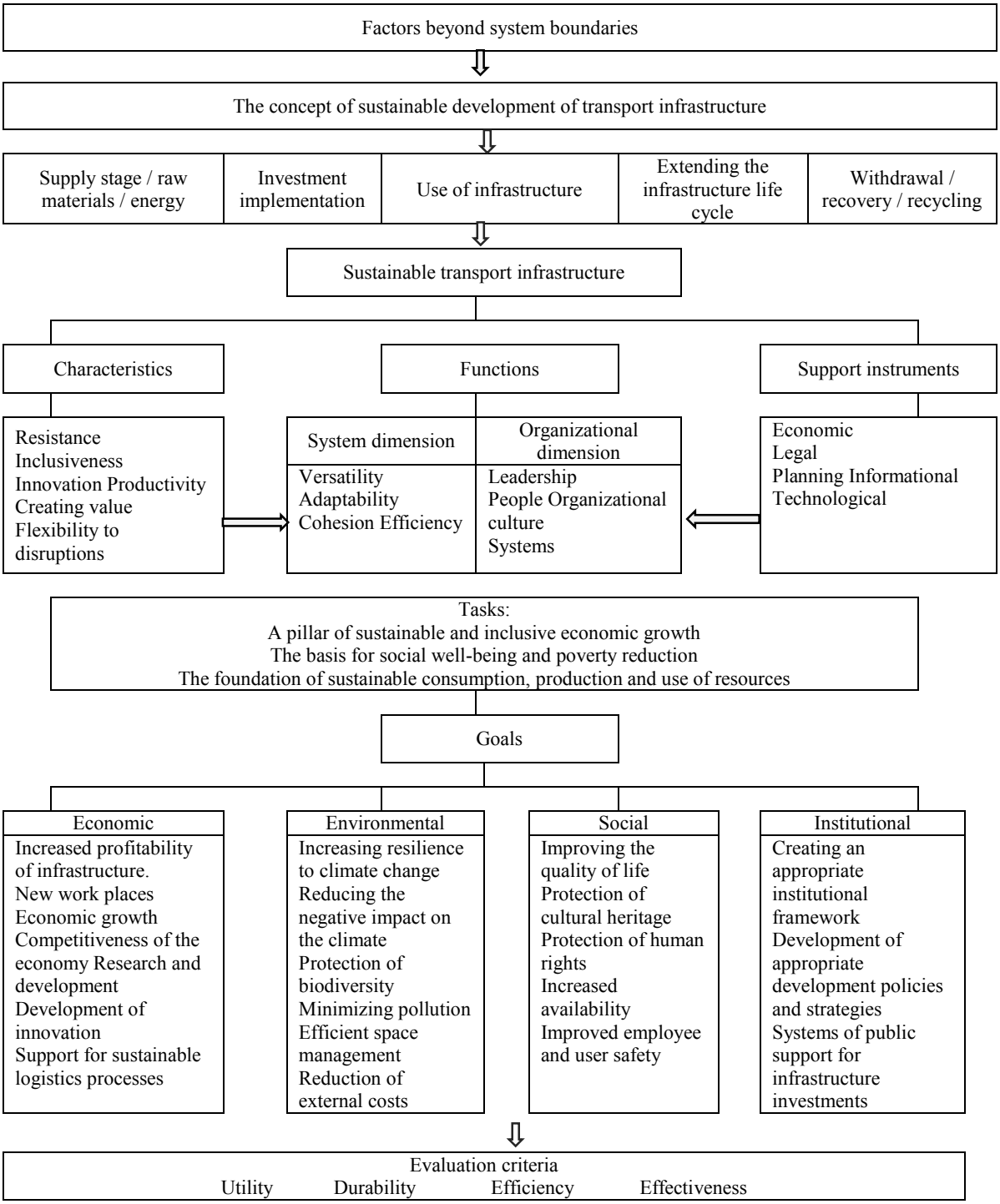

Figure 1. Conceptual framework of the model of sustainable development of transport infrastructure. Source: own study.

Technologies supporting the development of infrastructure have evolved at a rapid pace in recent years, from computer-aided design to digital solutions. At the current level of development, digital technologies are crucial in the sustainable transformation of logistics infrastructure in its myriad forms. Digital platforms can be used to improve transparency, streamline processes, and collaborate across phases of the infrastructure lifecycle to increase productivity and added value. In brownfields, they can also focus on creating value by reducing redundancy and leveraging the intelligent capabilities of infrastructure and data analytics and connectivity throughout the chain (Serrano, 2015). Digital solutions also determine the improvement of infrastructure flexibility, which should be able to cope with sudden and significant changes in demand, both predictable and unexpected.

The growing interest in sustainability and its implications for the development of logistics infrastructure confirms the perception of this process from an organizational and systemic perspective. Contemporary infrastructure development strategies and related economic models should take into account not only the expectations of individual stakeholders, but also of various participants providing this type of service. Taking into account the systemic approach to transport, sustainable development applies to linear, point and information infrastructure (Lipińska-Słota, Mutwil, 2019). On the other hand, in organizational terms, progress in development is determined by: leadership, organizational culture, human and social capital, and the organization of workstations. Enterprises are considered to be the main addressees of the principles of the new development paradigm, as they are the ones who benefit most from the following capitals: natural, economic, human, social and capital-integrating (institutional order) (Adamczyk, 2001). It can therefore be concluded that all forms of business activities related to the development and use of infrastructure, in accordance with the criteria of sustainable development, are conducive to the formation of a sustainable logistics infrastructure on a macroeconomic scale.

4.2. Directions of investments in the development of sustainable transport infrastructure

In the EU, in the context of recovering from the COVID-19 crisis and responding to a number of other threats, both environmental and geopolitical, it is necessary to implement decisive actions to increase the use of sustainable modes of transport and to develop alternative fuels. The modal shift has been recognized for years as the most effective means to decarbonize transport and achieve life-friendly "green" cities. Between 1990 and 2020, CO_2 emissions from transport increased by more than 33%, including international air transport, due to the increasing demand for passenger and freight transport. In 2020, transport accounted for 27% of total CO_2 emissions in the EU, of which 72% came from road transport (Greenhouse…, 9.09.2022). The decrease in emissions recorded in the first half of 2020 due to the COVID-19 pandemic was only temporary. Projections indicate that without the implementation of additional measures to decarbonize mobility, emissions from transport in 2030 could increase

by around 10% above 1990 levels. At the same time, according to data from the European Environment Agency (EEA), energy consumption in transport in 2020 was over 30% higher than in 1990. Oil-derived raw materials satisfied approx. 93% of transport energy needs. The greatest demand for oil derivatives was reported by road transport. In 2020, it was responsible for 71% of the total fuel needs of transport.

Sustainable logistics infrastructure, coordinating environmental, social and economic development, found support among participants of the World Economic Forum in 2021, in the context of a sustainable and resilient economic recovery after COVID-19 (OECD, 2020). Investing in innovative and resilient infrastructure, i.e. Infrastructure 4.0, and introducing improvements in the social and environmental dimensions was considered a priority. Estimates show that about 70% of the future increase in CO_2 emissions will come from infrastructure that has not yet been built (PwC, 2022). According to the concept and the formulated 13 recommendations, Infrastructure 4.0 is a future-proof infrastructure that uses technologies and information to ensure high-quality environmental, economic and social effects and functions as a technical system within wider human and natural systems (World Economic Forum, 2021). Future infrastructure investments should therefore focus on measures to reduce carbon consumption, shift from fossil fuels to renewable energy sources (RES), encourage cleaner and greener construction methods, and promote environmentally friendly means of transport. In other words, recovery efforts are designed to create the conditions to accelerate the transition to a climate-neutral, innovative and resilient economy. For the transport system this means:

- adaptation of infrastructure to new mobility patterns (i.e. modernization and construction of new elements),
- making new investments in infrastructure development for emission-free alternative fuels,
- adopting a new approach to network design and business model development.

The directions of development of sustainable and innovative transport are in line with the goals of the currently applicable strategic documents, which are the United Nations 2030 Agenda (UN, 2015) and the Paris Agreement on Climate Change (EU and the Paris Climate…, 2018). Intensifying climate and environmental changes have prompted the EU to take urgent and ambitious action under the European Green Deal. In the communication adopted in December 2019, a commitment was made to achieve climate neutrality by 2050, including the "green transition" in key cross-cutting programs and sectoral policies (European Green Deal, 2019). However, a net-zero society and economy will not be possible without a more sustainable, innovative and resilient transport system. It is estimated that achieving climate neutrality will require a 90% reduction in transport emissions by 2050. Sustainable transport investments have been identified as one of the strategic elements of the transition to a zero-emission, safe and smart mobility network. The importance of a holistic approach to investment planning was emphasized in the context of the development of a coherent multimodal system,

taking into account the local dimension and the need for the appropriate development of alternative fuels infrastructure.

The Strategy for Sustainable and Smart Mobility (EUSSSM) of 9 December 2020 contains specific milestones in the pursuit of a smart and sustainable future for the transport sector. They concern three main areas of activity, within which the development of a coherent multimodal system is treated as a priority. In order to achieve a systemic change in the scope of zero CO_2 emissions from transport, it is necessary to:

- make all modes of transport more sustainable,
- ensure the wide availability of sustainable alternatives in the multimodal transport system,
- implement the right incentives to support the transition.

In total, the strategy sets out 82 initiatives in 10 key areas and concrete actions to significantly reduce the current dependence on fossil fuels, increase the use of sustainable transport modes and internalize external costs, in particular for access to infrastructure and through CO_2 charging mechanisms. The overview of the initiatives and the specific tasks accompanying them show that all modes of transport need to become more sustainable, with green alternatives widely available and appropriate instruments to support the acceleration of the decarbonization of the mobility system. With regard to transport infrastructure, the development of affordable alternatives to increase the demand for zero-emission vehicles, the use of digital technologies to support the functioning of an integrated, multimodal transport network enabling the transport of people and cargo, and "green" financing to increase the resilience of transport infrastructure have been identified as priorities.

A greener, fairer, digital and resilient Europe is one of the EU's key priorities setting strategic directions for investment in the context of socio-economic development after the COVID-19 pandemic (Commission Work, 2021). In July 2021, the European Commission presented a package of proposals for the EU "Fit for 55", aimed at reducing GHG emissions by at least 55% by 2030 compared to 1990 levels and achieving climate neutrality by 2050. One of the important directions of action planned under the "Fit for 55" package are investments for the development of an innovative, sustainable and resilient multimodal mobility system in a way that saves resources and energy.

4.3. Financing investments in the development of sustainable transport infrastructure in the European Union

The EU mobility funding structure for 2021-2027 has two main pillars. The first is the 2021-2027 Multiannual Financial Framework with a budget of EUR 1.2 trillion, which is funded by the EU's own resources. The second pillar is Next Generation EU, a EUR 806.9 billion short-term recovery facility, funded by periodic capital markets borrowing. The greatest investment needs, apart from energy and buildings, are identified in the transport sector.

In the current decade, private and public investment needs for sustainable mobility are estimated at almost EUR 230 billion per year. According to the estimates of the European Commission, the total value of investments necessary for the development of TEN-T infrastructure and urban infrastructure is around EUR 130 billion per year. The needs for funds for investments in the development of the core network are estimated at around EUR 500 billion in 2021-2030. Taking into account the financial needs of the comprehensive network and other investments in transport infrastructure in the calculations, this amount increases to approx. EUR 1.5 trillion (Delivering TEN-T…, 2017).

In the 2021-2027 programming period, support to entities involved in the development of sustainable, innovative and resilient transport infrastructure mainly under the Recovery and Resilience Facility (RRF), the Connecting Europe Facility Facility (CEF), the InvestEU programme, the European Structural and Investment Funds (ESIF), including in particular the Cohesion Fund (CF) and the European Regional Development Fund (ERDF), as well as Horizon Europe and LIFE (Table 1).

The Investment Plan for a Sustainable and Climate-Neutral Europe aims to mobilize sustainable public and private investment over the coming decade. Mobilizing at least EUR 1 trillion requires a combination of funds made available under the EU budget, as well as further public and private investment mobilized by these funds. An important role in attracting private and public investments for the "green" transformation of mobility is planned for the InvestEU Fund, the Innovation Fund and the European Investment Bank (EIB).

Some of the investments needed to make the green transition involve greater risks that the private sector cannot bear alone. In such cases, public funding under the InvestEU Fund can be used to reduce project risks and create a leverage effect to attract private finance. By providing guarantees from the EU budget to partially cover the risks of financial and investment operations, InvestEU is expected to mobilize around EUR 279 billion in private and public climate and environmental investments between 2021 and 2030. The Fund can provide support through loans, guarantees, capital market instruments, credit enhancement instruments, direct and indirect equity and quasi-equity (EU funds and financing…, 2022). Investments in sustainable, safer and smart mobility projects are eligible under the Sustainable Infrastructure Policy Window. EUR 9.9 billion, i.e. 38% of the Fund's total guarantee, was allocated for their implementation. At least 30% of the InvestEU guarantee is dedicated to climate-related objectives, with a figure of 60% in the policy window on sustainable infrastructure. The InvestEU Fund includes the possibility to combine its support with EU grants and financial instruments from sectoral programs and is correlated with the RRF.

Highly technologically innovative infrastructure projects with European added value that can contribute to significant reductions in CO_2 emissions may apply for financial support from the Innovation Fund budget. Support is available for projects located in all EU Member States, Norway and Iceland. The Fund streamlines the sharing of project risks by granting more funding more flexibly through a simpler selection process. It's about sharing risks with project

promoters to help showcase highly innovative pioneering projects. This may concern innovative, high-risk projects in the development of zero-emission vehicles and transport networks, together with innovative infrastructure for alternative means of transport. The Innovation Fund will support up to 60% of the additional capital and operating costs of large-scale projects and up to 60% of the capital costs of small-scale projects. The fund, operating outside the long-term EU budget, co-finances projects through part of the proceeds from the auctioning of CO_2 emission allowances under the emissions trading system (Sustainable Europe Investment…, 2020).

Table 1.
Programs for financing European Union investments in the development of sustainable transport infrastructure in 2021-2027

Programs/Instruments	Financial assistance	Scope of support
Recovery and Resilience Facility (2021-2023)	EUR 723.8 billion - total EUR 72.2 billion – investments in sustainable and green mobility	Green and digital transformation of transport Territorial cohesion The use of low-emission and zero-emission technologies in transport Railway infrastructure and urban transport
"Connecting Europe"	EUR 42.30 billion - total EUR 25.81 billion CEF Transport including: EUR 242.2 million - research on sustainable transport infrastructure	European TEN-T transport network European alternative fuel charging infrastructure network Ecological means of transport, Transport infrastructure for civil and military needs
Cohesion Fund and the European Regional Development Fund	EUR 11.29 billion - total EUR 1.69 billion – civil and military infrastructural investments	Financing trans-European networks in the area of TEN-T transport infrastructure Support for cross-border, regional, local and urban mobility Ecologically "clean" vehicles Improving the safety of bridges and tunnels Vehicles, aircraft and vessels designed and built or adapted for use by civil protection and fire services
Horizon Europe	EUR 95.5 billion – total, including EUR 5.4 billion from the European Recovery Instrument EUR 15.3 billion - Cluster 5: Climate, Energy and Mobility	Clean Hydrogen Partnership Green Aviation Partnership Partnership for European Railway Connected and automated mobility Batteries Emission-free road transport Emission-free water transport Built4People partnership Transformation towards clean energy Partnership for the transformation of urban areas
LIFE Programme	EUR 5.5 billion - total	Projects targeting sustainable mobility, including measures for local public transport Sustainable mobility in road transport Actions supporting the transition to zero-emission mobility
Digital Europe Program	EUR 9.2 billion - total	Digitization of mobility and the use of artificial intelligence

Source: own study based on Regulation (EU) 2021/1058 of the European Parliament and of the Council of 24 June, 2021; Horizon Europe (2021).

The EIB is also playing a key role in financing the transition to sustainable, CO_2-neutral mobility. This bank's role in financing the sustainable transition will increase as it becomes the EU's climate bank. Its aim is to accelerate the implementation of sustainable transport solutions by mobilizing private investment while ensuring sustainable regional development. As part of its lending policy in the field of transport, the EIB provides long-term financing, mainly in the form of loans and guarantees, as well as financial and technical advice. The transport sector accounts for more than 25% of the total EIB portfolio and more than EUR 10 billion of new investments annually. EIB loans can cover up to 50% (75% for TEN-T projects) of the total investment costs. In addition, intermediary loans, innovative financial instruments and private equity funds are used to stimulate and catalyze private capital by investing in equity funds dedicated to transport infrastructure. The EIB can also support priority projects (up to EUR 300 million) with a high risk profile under the structured finance facility.

The EIB supports transport projects through many instruments and initiatives. The Cleaner Transport Facility (CTF) is an initiative of the EIB and the European Commission, launched in December 2016, to support investment by both public and private entities in low- and zero-emission transport projects. The aim of the CTF is to use the EIB's technical and financial capabilities to support the accelerated deployment of alternative fuels and infrastructure needs. Eligible projects can receive credits covering up to 50% of project costs. For some innovative projects, loans amount to EUR 7.5 million, but direct loans are usually above EUR 25 million. The CTF funding instruments are (Kwasniok, 2022):

- loans, capitals and guarantees as well as new financial instruments directed to the InnovFIN programme,
- life cycle costing models including risk-sharing financial instruments that mobilize private sector funds.

An EIB loan of EUR 50 million has, for example, enabled the financing of a new bus rapid transit system (known locally as MetroGuagua) in Las Palmas de Gran Canaria, Spain. In addition to the construction of new bus lanes, the project includes the purchase of 17 new electric or hybrid buses and the construction of three new charging stations, 17 bus stops and a traffic control center. The project also includes the creation of a new bicycle lane and the improvement and widening of sidewalks next to the new bus lanes. Pursuant to the contract, works under the project were carried out in the period 2017-2021 (Las Palmas saves…, 2022).

Together with the European Commission, the EIB is also responsible for implementing the ELENA (European Local Energy Assistance) instrument. ELENA provides subsidies up to 90% of eligible costs and technical assistance for investments in energy efficiency and renewable energy, including innovative urban and regional transport. Typically, ELENA supports mobility investment programs above EUR 30 million. In addition, the EIB offers support opportunities under the thematic Future Mobility Facility, which provides investments in high-risk projects in the transport sector. To date, contracts have been signed to finance projects in the field of mobility of the "future" amounting to approximately EUR 141 million.

The Gap Fund, launched by the World Bank and the EIB in September 2020, is a new partnership supporting the development of innovative and sustainable cities in developing and emerging economies, including transport projects. The fund provides grants and free technical assistance to cities in the early stages of project planning and preparation to facilitate investment preparation and improve the quality of projects.

4.4. Selected financial market instruments for projects supporting the sustainable development of mobility

The new EU Sustainable Finance Strategy sets out several initiatives to address environmental challenges in the financial market (Strategy for Financing …, 2021). The Fit for 55 package and the Smart and Sustainable Mobility Strategy have identified it as a key means of leveraging private investment for the EU's financial transformation towards a multimodal sustainable mobility model. In the Action Plan on Financing Sustainable Growth, the EU introduced three core elements of a Sustainable Finance Framework (Action Plan, 2018):

- a classification system or "taxonomy" of sustainable activities,
- a disclosure framework for non-financial and financial companies,
- investment tools, including benchmarks, standards and labels.

The new strategy aims to stimulate sustainable finance and green investments, including transport investments, by better aligning with the EU taxonomy regulation and implementing a common reporting standard (Regulation EU 2020/852…, 2020). In addition, the strategy proposes a European standard for green bonds.

The technical classification criteria in the Taxonomy Regulation define the conditions for transport under which an investment qualifies as making a significant contribution to climate change mitigation or adaptation, and whether this type of transport activity causes significant harm to any from other environmental objectives (Commission Delegated Regulation…, 2021). For example, for urban and suburban passenger transport, they state that an activity is compliant if direct CO_2 emissions from vehicles or infrastructure are zero. It could be argued that since public transport is essentially a low-carbon and sustainable mode of transport, all types of projects should be eligible for consideration. Encouraging private sector investment in urban and suburban passenger transport will ensure a faster modal shift in EU cities. It will also facilitate public-private investment in complex and innovative projects, which often have relatively higher economic risks.

On July 6, 2021, the European Commission presented a proposal for a Regulation on European Green Bonds, the so-called European standard for green bonds (Proposal for a Regulation … 2021). It aims to set a "gold standard" on how companies and public authorities, including the public transport sector, can use green bonds to raise funds in capital markets to finance ambitious large-scale investments, while meeting sustainability requirements and investor protection. The standard will use the detailed criteria of "green" economic activity contained in the EU taxonomy to define green investment.

Green bonds are the most popular form of debt financing for sustainable development projects. A wide catalog of project categories that can be financed with funds from the issue includes, among others: emission-free transport. The country that leads European countries in terms of the volume of green bond issues in the EU is France. In 2021, an issue of green bonds was carried out by the city of Łódź, co-organized by Bank Pekao S.A. It was the first issue of green bonds by the local government in Poland. PLN 50 million obtained from the issue of green bonds was used to finance two investments, i.e. low-emission transport and water and sewage management. The reconstruction of one of the main streets in the south of Łódź - Przybyszewskiego Street, related to the implementation of the low-emission transport network project, estimated at PLN 34.5 million, is to be completed in 2023. The next issue of green bonds is planned for 2023. (Zielone obligacje…, 25.10.2022).

With access to sustainable finance, individuals, households and small and medium-sized enterprises can play an important role in the transformation of mobility towards a sustainable model. Opportunities for green retail loans and green mortgages offer an opportunity to accelerate green transport investments (e.g. purchase of zero-emission vehicles) among retail investors and small businesses.

5. Discussion

Taking into account the adopted main goal and research questions, the results of the analyzes carried out indicate several important findings that confirm the thesis contained in the article.

Sustainable development of transport infrastructure is an evolving concept that differs from the idea of a conventional approach to infrastructure development and management. The concepts of traditional infrastructure investment management focused on identifying and quantifying their value to the economy. The importance of infrastructure as a factor determining economic growth and development, or a factor increasing the efficiency of management, was confirmed, among others, by in exogenous growth concepts, the most famous of which is the Solow and endogenous growth models by Barro, Shioji, as well as Ott and Turnovky, or Duggal et al. (Zaremba, 2014).

The driving force behind the evolution of the essence of infrastructure in the economy was and still is the increasing range of issues related to the ongoing process of networking infrastructural investments. Since the concept of sustainable development was developed at the UN Forum in 1997 and given the official status of a global development strategy, infrastructure has ceased to be directly related to economic growth. In scientific research, there has been a systematic increase in interest in the issue of measuring the size of transport infrastructure in the context of its value for the economy, society and the environment. In the last 25 years,

researchers have increasingly agreed on the need to value the goods resulting from the use of this infrastructure (Eadie et al., 2013; Munyasya, Chileshe, 2018). The measurement of transport and telecommunications infrastructure should reflect such results as, for example, increased innovation, time savings or increased security (information, road traffic). At the same time, it was emphasized that the real reflection of the impact of infrastructure investments on development generates many problems. Hence, the analyzes carried out for the purposes of investments are a big challenge for investors in relation to the goals of the new development paradigm.

Currently, discussions of representatives of science and supranational organizations on the issue of sustainable infrastructure have highlighted the need to adopt an integrated approach to infrastructure investments and to take into account long-term aspects, including external effects in the project life cycle. A common feature of all dimensions of this approach is the consideration of the long-term benefits of infrastructure investments. Taking into account the growing spatial sensitivity and the already visible effects of climate change, as well as the need to preserve and restore natural capital, a number of innovative solutions have been proposed as part of the existing strategic documents, programs and sectoral policies.

Actions aimed at accelerating the development of sustainable and resilient transport infrastructure require regulatory, economic and institutional changes. The scale and complexity of challenges in terms of investment and advisory needs in relation to the development of sustainable transport infrastructure exceeds the financial and organizational capabilities of EU countries. It is necessary to raise private capital and appropriate changes in the financial sector that will support sustainable financing of transport investments. Although financial support for the development of sustainable infrastructure is increasing, current progress is unsatisfactory (Crossing the Bridge…, 2017). Among the key barriers that reduce the likelihood of private investment, they indicate, among others: lack of a coherent, universally applicable definition of sustainable logistics infrastructure. This state can be associated with multidimensionality in relation to the nature of infrastructure and connotations with sustainability. At the same time, it should be emphasized that the development of sustainable logistics infrastructure requires the conscious participation of all stakeholders, including social acceptance, in order to ensure their broad participation in socio-economic development. In this context, logistics infrastructure is of particular importance due to the contribution it can make to sustainable development. This is due to both the dynamics of its growth and the role it plays in the economies of individual countries.

6. Conclusion

A key challenge facing the transport sector is to significantly reduce CO_2 emissions and make the sector more sustainable. At the same time, these challenges represent an opportunity to improve the quality of life and modernize European industry in all value chains, to develop innovative products and services and to strengthen the resilience of the mobility system to disruptions. Due to the complexity of the concept of sustainable transport infrastructure development in the EU, it can be concluded that its implementation will be a gradual and long-term process, requiring an integrated approach. The measurable nature of the decisions made can be obtained by implementing the assumptions of the qualitative model presented in the article. At the same time, it should be taken into account that the effectiveness of the implemented activities and their significant effects may appear in the longer term. At the same time, obtaining them will require the implementation of specific actions under national and local policies, aimed not only at the development of sustainable transport infrastructure, but also at increasing social awareness for new solutions. The development and modernization of transport infrastructure is an important element in shaping a zero-emission, innovative and resilient EU economy.

The transformation towards a sustainable and climate-neutral mobility system, in line with the assumptions of the Paris Agreement, the UN 2030 Agenda and the European Green Deal strategy, will require the full commitment and support of all actors operating in the transport sector, as well as a significant increase in green investments from the public sector and private. The way to ensure sustainable infrastructure development remains a priority is a combination of grants, green bonds, financial guarantees, state aid, equity and private funds. Sustainable infrastructure investments therefore require a more substantial and stable funding framework as well as better targeting of funds to ensure their overall effectiveness.

References

1. Action Plan: Financing Sustainable Growth, Communication From The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions. COM(2018) 97, (2018).
2. Adamczyk, J. (2001). *Koncepcja zrównoważonego rozwoju w zarządzaniu przedsiębiorstwem.* Kraków: Wydawnictwo Akademii Ekonomicznej w Krakowie.
3. Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning, vol. 100, Iss. 4,* pp. 341-343, doi: 10.1016/j.landurbplan.2011.02.021.

4. Bhattacharya, A., Meltzer, J.P., Oppenheim, J., Qureshi, Z., Stern, N. (2016). *Delivering Sustainable Infrastructure for Better Development and Better Climate.* Washington: The Global Commission on the Economy on Climate.
5. Bhattacharya, A., Oppenheim, J., Stern, N. (2015). Driving Sustainable Development Through Better Infrastructure: Key Elements of a Transformation Program. *Program Working Paper, 91.* Washington: Global Economy and Development.
6. Champagne, M., Dubé, J. (2023). The impact of transport infrastructure on firms' location decision: A meta-analysis based on a systematic literature review. *Transport Policy, vol. 131,* pp. 139-155, doi: 10.1016/j.tranpol.2022.11.015.
7. Chen, Z. (27.08.2013). *Spatial impact of transportation infrastructure: a spatial econometric CGE approach.* The 53rd European Regional Science Association Congress, Palermo, Italy.
8. Cho, S., Choi, K. (2021). Transport accessibility and economic growth: Implications for sustainable transport infrastructure investments. *International Journal of Sustainable Transportation, vol. 15, Iss. 8,* pp. 641-652, doi: 10.1080/15568318.2020.1774946.
9. *Climate risk and response. physical hazards and socioeconomic impacts* (2020). Washington: McKinsey Global Institute, pp. 1-164.
10. Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing technical screening criteria to determine the conditions under which a given economic activity qualifies as making a significant contribution to mitigation climate change or adaptation to climate change, as well as determining whether this economic activity does not cause serious damage to any of the other environmental objectives, EU L 442 (2021).
11. Commission Work Programme 2022. Making Europe stronger together, Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions, COM(2021) 645, (2021).
12. Connecting Europe Facility. Retrieved from https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/connecting-europe-facility_en, 20.10.2022.
13. Crossing the Bridge to Sustainable Infrastructure Investing: Exploring Ways to Make it Across. (2017). Washington DC: Mercer and Inter-American Development Bank.
14. Czyżewski, A., Staniszewski, J. (2018). Dylematy operacjonalizacji paradygmatu zrównoważonego rozwoju rolnictwa z wykorzystaniem pojęcia ekoefektywności. *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Problemy Rolnictwa Światowego, tom 18(XXXIII), zeszyt 2,* pp. 44-56, doi.10.22630/PRS.2018.18.2.33.
15. *Delivering TEN-T: Facts & figures* (2017). Brussels: DG MOVE.
16. Eadie, R., Browne, M., Odeyinka, H., McKeown, C., McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: an analysis. *Automation in Construction, vol. 36,* pp. 145–151, doi: 10.1016/j.autcon.2013.09.001.

17. EU and the Paris Climate Agreement: Taking stock of progress at Katowice COP, Report From The Commission to The European Parliament and The Council, COM(2018) 716 (2018).
18. EU funds and financing for resilient local mobility, to climate change (2022). EU Policy Paper.
19. European Commission (2019). Transport in the European Union: Current Trends and Issues.
20. European Green Deal, Communication from the Commission to the European Parliament, 2019, the European Council, the Council, the Economic and Social Committee and the Committee of the Regions, COM(2019) 640 (2019).
21. Greenhouse gas emissions from transport in Europe (2022). Retrieved from: https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport, 9.09.2022.
22. Horizon Europe (2021). *Research & Innovation. EU Program for 2021-2027.* European Commission. Retrieved from: http://ec.europa.eu/horizon-europe, 20.10.2022.
23. Kwasniok, R. *European Investment Bank (EIB). Changing Transport. Facilitating climate actions in mobility.* Retrieved from: https://changing-transport.org/european-investment-bank-eib/, 21.10.2022.
24. Kyriacou, A.P, Muinelo-Gallo, L., Roca-Sagalés, O. (2019). The efficiency of transport infrastructure investment and the role of government quality: An empirical analysis. *Transport Policy, vol. 74,* pp. 93-102, doi: 10.1016/j.tranpol.2018.11.017.
25. *Las Palmas saves the climate one MetroGuagua at a time* (2017). Retrieved from: https://www.eib.org/en/stories/las-palmas-metroguagua.htm, 23.10.2022.
26. Lipińska-Słota, A., Mutwil, A. (2019). *Elementy infrastruktury systemów logistycznych*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
27. Marcinek, K. (2018). Infrastruktura zrównoważona – rozważania o istocie i cechach w kontekście zrównoważonego rozwoju. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, nr 374*, pp. 92-110.
28. Munyasya, B.M., Chileshe, N. (2018). Towards sustainable infrastructure development: Drivers, barriers, strategies, and coping mechanisms. *Sustainability, vol. 10, no. 12*, 4341, pp. 1-18, doi: 10.3390/su10124341.
29. OECD (2020). *Building back better: A sustainable, resilient recovery after COVID-19.* Paris: OECD Publishing.
30. Polyzos, S., Tsiotas, D. (2020). The Contribution of Transport Infrastructures to the Economic and Regional Development: A Review of the Conceptual Framework. *Theoretical and Empirical Researches in Urban Management, vol. 15,* pp. 5-23, doi: 10.2307/26868292.
31. Proposal for a Regulation of The European Parliament and of The Council on European green bonds, COM(2021) 391 (2021).

32. Przybyłowski, A., Podbielska, M. (2017). Publiczny transport zbiorowy w Gdańsku w kontekście równoważenia rozwoju miast. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania Uniwersytetu Szczecińskiego, nr 47, tom 2*, pp. 253-264.
33. PwC (2022). *Global infrastructure trends*. Retrieved from: https://www.pwc.com/gx/en/industries/capital-projects-infrastructure/publications/infrastructure-trends.html, 11.12.2022.
34. Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investments, amending Regulation (EU) 2019/2088, EU L 198 (2020).
35. Regulation (EU) 2021/1058 of the European Parliament and of the Council of 24 June 2021 on the European Regional Development Fund and the Cohesion Fund, UE L 231/60 (2021).
36. Rogall, H. (2010). *Ekonomia zrównoważonego rozwoju. Teoria i praktyka*. Poznań: Wydawnictwo Zysk i S-ka.
37. Serrano, W. (2015). Big Data in Smart Infrastructure. In: Y. Bi, S. Kapoor, R. Bhatia (eds.), *Intelligent Systems and Applications* (pp. 703-732). London: Springer.
38. Stanley, Jo., Stanley, J. *Everyone aboard: Integrating social inclusion values into planning transport projects*. Retrieved from: https://www.gihub.org/articles/everyone-aboard-integrating-social-inclusion-values-into-planning-transport-projects/, 2.03.2022.
39. Strategy for Financing the Transition to a Sustainable Economy, Communication From The Commission to The European Parliament, The Council, The European Economic And Social Committee and The Committee of The Regions, COM(2021) 390 (2021).
40. Sustainable and Smart Mobility Strategy – putting European transport on track for the future, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2020) 789 (2020).
41. Sustainable Europe Investment Plan. European Green Deal Investment Plan, Communication From The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions, COM(2020) 21 (2020).
42. Transport infrastructure: EUR 292.5 million of EU funding for projects contributing to greener mobility. European Climate Infrastructure and Environment Executive Agency. Retrieved from https://cinea.ec.europa.eu/news-events/news/transport-infrastructure-eur-2925-million-eu-funding-projects-contributing-greener-mobility-2022-09-12_en, 20.10.2022.
43. Transport infrastructure: projects receive EUR 425 million in EU funding to boost green mobility and to adapt the network for dual civil/defence use. European Climate, Infrastructure and Environment Executive Agency. Retrieved from: https://cinea.ec.europa.eu/news-events/news/transport-infrastructure-projects-receive-eur-425-million-eu-funding-boost-green-mobility-and-adapt-2022-04-08_en, 9.08.2022.

44. UN (2015). Resolution Adopted by the General Assembly on 25 September 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. A/RES/70/1.
45. Weber, B., Alfen, H., Staub-Bisang, M. (2016). *Infrastructure as an Asset Class: Investment Strategy, Sustainability. Project Finance and PPP*. Wiley: Chichester, UK.
46. White Paper. Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System, 2011, COM(2011) 144 (2011).
47. World Economic Forum (2021). Retrieved from: https://www.theglobaleconomy.com/rankings/roads_quality/, 17.03.2022.
48. Yannis, G., Chaziris, A. (2022). Transport System and Infrastructure. *Transportation Research Procedia, vol. 60,* pp. 6-11, doi: 10.1016/j.trpro.2021.12.002.
49. Zaremba, T. (2014). Inwestycje infrastrukturalne w teorii makroekonomii i badaniach ekonometrycznych. In: J. Gajewski, W. Paprocki (eds.), *Dylematy rozwoju infrastruktury* (pp. 26-47). Gdańsk: Instytut Badań nad Gospodarką – Gdańska Akademia Bankowa.
50. Zhou, J., Raza, A., Sui, H. (2021). Infrastructure Investment and Economic Growth Quality: Empirical Analysis of China's Regional Development. *Applied Economics, vol. 53, Iss. 23,* pp. 2615-2630, doi: 10.1080/00036846.2020.1863325.
51. Zielone obligacje przyciągają ekologiczne inwestycje (2021). *PFR dla miast*. Retrieved from: https://pfrdlamiast.pl/baza-miejskich-innowacji/zielone-obligacje-przyciagaja-, 17.10.2022.

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ORGANIZATION OF REVERSE ENGINEERING USING MODERN CALCULATION METHODS IN THE PROCESS OF REPRODUCING A GEARS

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Purpose: The main purpose of this article is to present modern possibilities for the reproduction of a machine element. If there are no replacements for the damaged part, and there is no technical documentation, then the only options is to use reverse engineering (RE) methods to reproduce it.
Design/methodology/approach: On the example of a damaged gear, the process of measuring the wheel and manufacturing a physical model using 3D printing. An additional step has been added to the classic reverse engineering process to modify the model to improve its strength.
Findings: Strength analysis was carried out in the Abaqus program using the finite element method (FEM). Based on the results obtained, it was proposed to change the tooth profile of the gear, which will improve its durability.
Research limitations/implications: An extension of the proposed scheme may be a modification of the production process in order to implement the reverse engineering method to the serial production of machine elements.
Practical implications: The use of a modified reverse engineering (RE) process will not only allow the components to be reproduced but will also allow extended uptime of the components, and this will reduce production costs.
Originality/value: The proposed new reverse engineering process can be successfully used to reconstruct machine components with even very complex shapes. The digital model obtained as a result of scanning has been used to improve the geometry of the toothed rim, but it can be successfully used for other analyses, research, or calculations.

Keywords: reverse engineering (RE), rapid prototyping (RP), finite element method (FEM), reconstruction process, gear.

Category of the paper: Research paper.

1. Introduction

Reverse engineering (RE) aims to obtain a digital form of a physical model and then produce a copy of it with the same or expected geometrical and strength parameters. This process consists of two main stages, including the digitization of the real object and the production of a physical model. Digitization can be realized with using optical scanners or with the help of contact measurements, depending on the availability of devices and the expected accuracy. Then the obtained measurement result is checked and corrected in CAD programs until a geometrically correct, digital CAD model of the reproduced element is obtained. On its basis, it is possible to create a physical copy of the output model, e.g. using rapid prototyping (RP) methods.

Such a basic scheme of the reverse engineering process is in many cases enough for the reconstruction of machine elements that cannot be made using a classical method (Pacana et al., 2018). In addition, the undeniable advantage of this process is the fact that as a result of scanning, a digital model of the element is obtained, which can be modified. Therefore, it was proposed to change the basic RE process by extending it to the CAD model modification stage. A diagram of the extended reverse engineering process is shown in Figure 1, and the added RE process step is highlighted in grey. Modifying a digital model can involve simple dimensional changes, but it can be the result of extensive material, strength, or thermal analysis. CAD models obtained as a result of scanning in the first stage of the reconstruction process can be used to perform numerical calculations of kinematic simulations and to evaluate their durability and reliability. The introduction of the CAD model modification stage significantly expands the possibilities of using reverse engineering methods in production and reproduction processes of even geometrically complicated machine elements.

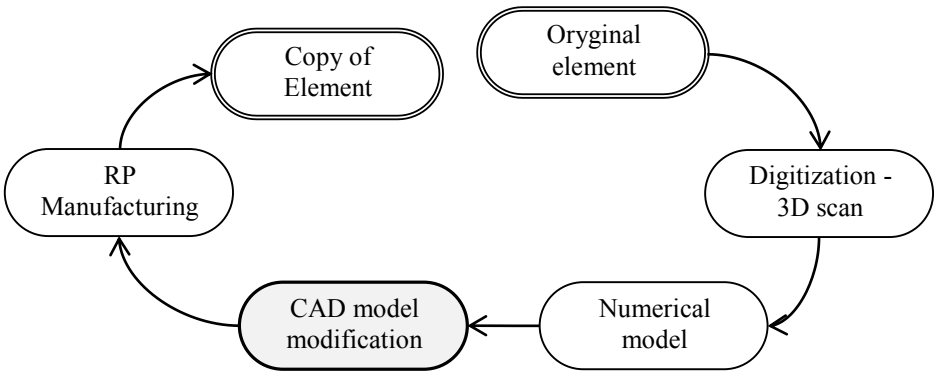

Figure 1. Diagram of the RE process with the CAD model modification step (Kachel, 2011).

An example of parts with complicated construction and difficult working conditions are gears. They are used most often in drives and then have an involute profile of teeth, but they are also successfully used in pumps, valves, or control mechanisms (Müller, 1970). The basic line of involute can be subject to multidirectional modifications of geometric parameters in order to increase tooth strength, improve cooperation conditions, quiet running or vibration reduce. Gears usually are made of steel using machining techniques. However, wherever they do not transfer powerful loads, gears made of polymer materials are successfully used. Because then they are made by injection into molds, they often have atypical tooth profiles, difficult to reproduce with classic machining. In the event of gear damage, the correct procedure is to replace the damaged element with the same new one. If the production of substitutes has already been ended or they are not available, it is usually not possible to make a gear with the same geometrical parameters using machining methods. With the development of measurement techniques and additive manufacturing methods, the possibility of making precise copies of damaged gears at a relatively low cost has just appeared (Budzik, 2007). By restoring a corrupted element, can be correct its geometry to increase durability or functionality. This procedure is presented later in the article.

2. Digitize the gear model

The reconstruction and modification process of the model was presented on the basis of a gear being part of a household appliance. The gear wheel was made of polymer plastic and was originally mounted in a meat mincer. Unfortunately, during use, there was a situation in which the teeth of this gear were broken. An ad hoc solution to such a situation was to replace the damaged gear with a new one. However, since it was not possible to buy a new gear due to the end of its production, it had to be reconstructed on the basis of the damaged element. In the first stage, it was necessary to scan the used gear in order to obtain its numerical model. This was done using the contact scanning method on a Roland MDX-40 coordinate measuring machine using a special ZSC-1 measuring head.

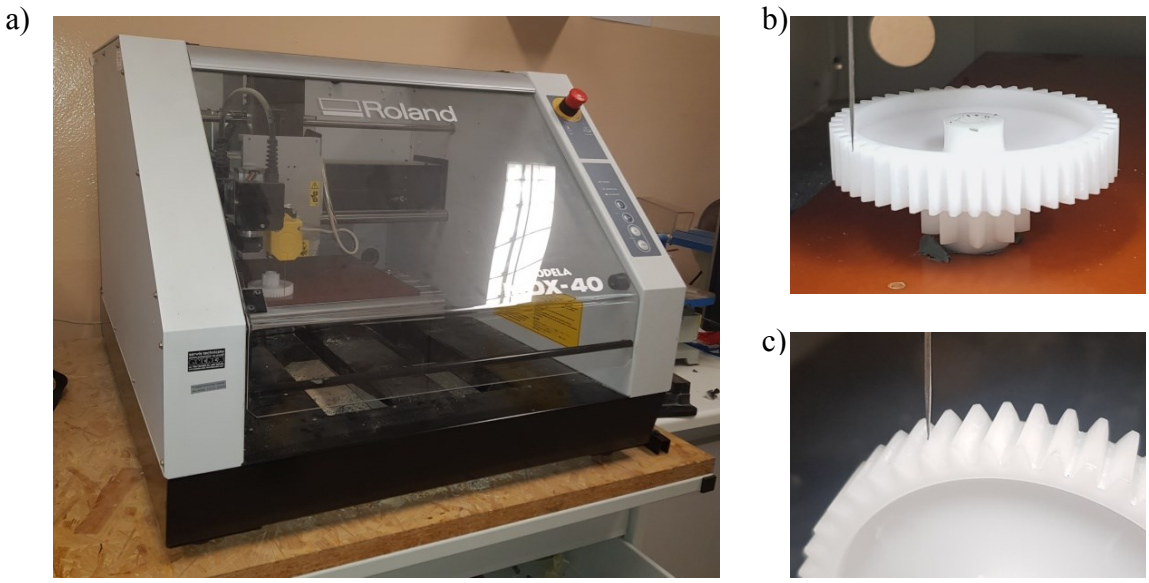

Figure 2. Digitization of the model using the contact method: a) Roland MDX-40 measuring machine, b) gear geometry measurement, c) tooth profile scanning.

Since the measuring tip of the head had a very small radius, it was possible to digitize the gear model with high accuracy. In the first step, general measurements of the geometry of the model were made regarding diameters, thicknesses, or rounding radius. This was done in two gear mounts, first where its main axis was parallel to the axis of the measuring tip (Fig. 2b). The second phase of the measurements concerned the measurements of the tooth outline in the direction perpendicular to the model axis (Fig. 2c). For some correct teeth, measurements were made with the highest machine precision possible of 0.04 mm.

Thanks to the contact measurements, both the surface model of the gear and the tooth profiles were obtained (Fig. 3b). The automatically received measurement results had the format of a point cloud and required minor correction. The acquired surfaces had node errors and discontinuities, which were removed directly in the program used to made the measurements. Some errors of the acquired surface for the digitized gear can be observed in the area of its hub (fig. 3).

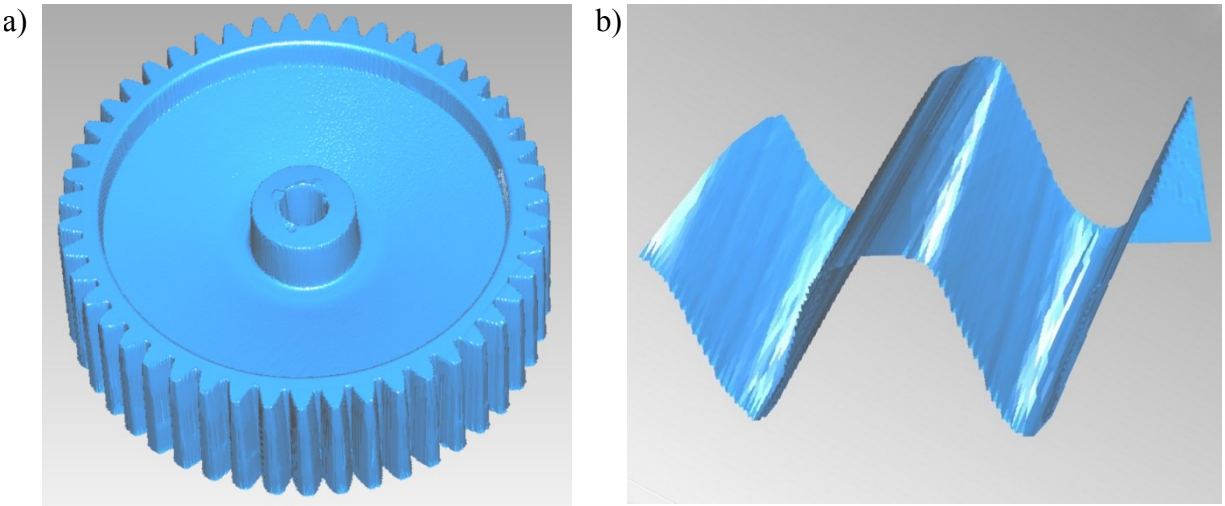

Figure 3. Gear scan result: a) digitized surface model, b) profiles of the selected tooth.

The next work on the model concerning its smoothing, connection, matching, and modification was performed in the Autodesk Inventor program. The gear model in places of damage was also supplemented by copying the correct geometry from adjacent teeth. However, the final correction of the toothed rim will be made only after additional strength calculations have been solved. In Autodesk Inventor program, the surface model resulting from scanning was also transformed into a solid model that will be used to produce a new gear using the incremental method.

This program was also used for preliminary measurements of the tooth profiles and the surface of the whole gear. On their basis, the nominal geometric parameters of the toothed rim were determined, and the final shape of the gear was assumed. The tooth module was found to be 2 mm, the number of teeth is 47, and the width of the rim is 12 mm. Comparison of the outline obtained in the measurements with the theoretical ones confirmed that there are teeth in the circle with an outline angle of $\alpha = 20°$. This was not evident results, because the original gear was made by moulding, so the technology did not force the use of tools with this most popular angle of tooth profile for the production of the gear.

On the outer surface of the model was also found information about the material used in its production. It was a commonly used acrylonitrile-butadiene-styrene polymer (ABS). The result of the successful process of reconstructing the gear geometry was its solid model, which can be freely modified in the CAD program.

3. Modification of the tooth profile

The goal of modifying the tooth profile is to obtain a gear with greater strength. Changes in the contour of the gear teeth can proceed in different ways, which has been repeatedly described in publications. In the case of the analysed gear, it was assumed that the changed parameter would be the angle of the tooth outline. Such a corrections do not bring too many modifications in the geometry of the tooth rim, but also do not change the axis distance, which would force changes in the entire device. Therefore, for the reproduced gear, numerical calculations were performed using the FEM in the Abaqus program. It is a driven wheel that is part of the meat mincer drive mechanism of the meat mincer. Because this gear was damaged, an attempt was made to improve its strength by changing the profile of the teeth. Three variants of the model were analysed, which differed only in the angle of the involute profile. The value set for the damaged gear of 20° was assumed to be the initial variant. In the next calculation variants the angle of the value of the involute profile angle was increased to 25° and 30°.

The analysed element is cylindrical gear wheel with a tooth line parallel to its axis, therefore calculations can be conducted using two-dimensional models. The calculation model is the cross section of the gear, perpendicular to its axis, created in the middle of the width of the

toothed rim. Due to this limitation of geometry, the problem analysed can be defined as a flat stress state (Rusiński, Czmochowski, Smolnicki, 2000). In subsequent calculation variants, only the tooth profiles were changed, the remaining dimensions of the gears were unchanged. For FEM calculations, it was assumed that: the width of gears is small in relation to its diameter, the external loads of gears are evenly distributed over their entire width and that they work only in the plane of a cross-section. The defined assumptions and procedures allow with sufficiently high accuracy to perform calculations of gears differing only in the profiles of the teeth. Calculations for all models were solved under the same fixation and load conditions for each model.

In the FEM calculations, it was assumed that the analysed models would be made of ABS plastic, just like the original gear. For this material, the basic properties were in accordance with the manufacturer's recommendations: Young module 2400 MPa, yield strength 90 MPa, Poisson number 0.4. This material was chosen, also because it is easy to select the technology for making such gears. In production conditions, wheels can be mass-produced by injection moulding, while maintaining constant quality parameters. This material also allows the manufacturing of functional gear models using rapid prototyping techniques. Wheels made by 3D printing can be prototypes for experimental research or be a cheap, and quick to manufacture, replacement for the original part.

Only fragments with seven teeth were used for the calculations in order to limit the calculation time. Models prepared in this way are enough to correctly simulate the meshing of several pairs of teeth. An example view of the computational model of a gear prepared for FEM calculations is shown in Fig. 4.

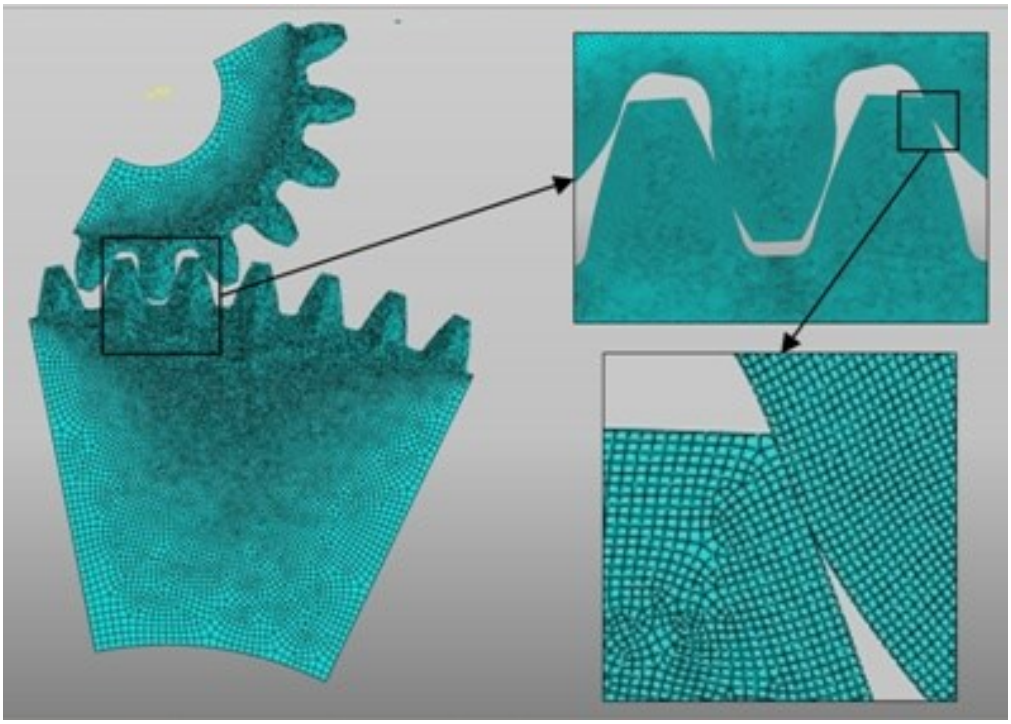

Figure 4. Gear calculation model prepared for FEM calculations in the Abaqus program.

In the defined computational model, the wheels could only rotate relative to their axis, defined by reference points (RP). The linking of models with their centre of rotation was realised by means of rigid links. For the transmission model, a forced rotation around its axis was performed at an angle of w = 0.5 rad. This allowed the cooperation of six pairs of teeth for each wheel to be traced. The gear load was realized by a torque amounting 4 Nm in the axis of the pinion model. Such a relatively low torque value was assumed because the analysis includes gears made of polymer plastic.

Due to the use of contact surfaces on the teeth, the real interaction of the wheels was simulated. The width of the gears analysed prepared for the calculations was 12 mm. The defined boundary conditions allow to obtain the required stiffness of the models and correctly determine the stresses in the tooth along the path of contact (Pacana, Kozik, Budzik, 2010; Wiktor, 2004).

The created flat model was discretised in the Abaqus preprocessor using finite quadrangular elements. The most precise division was defined on the toothed rims due to the expected high stress values in these areas. In the rest of the model, a much less dense mesh was specified, which is clearly visible in Figure 4. As a result of the division of the wheel, 87328 were obtained, while for the pinion 52169 finite elements.

4. Results of the analysis

The calculations allowed to obtain correct solutions for all prepared calculation models.

In all analysed models, higher stress values were located at the teeth contact of the both gears, and at the root of the tooth. Areas of increased bending stresses at the root of the tooth occur on the side opposite its load. This stress distribution is known from the literature and maximum stress values can be determined analytically based on ISO 6336-1:2006. Taking for calculations models with several teeth, it was possible to observe meshing conditions at various stages of tooth cooperation. This allows complete conclusions about the load on the teeth and the resulting stresses. It is possible to smoothly trace the cooperation of the teeth along the path of contact, both in a single-pair and two-pair contact.

Although a two-dimensional model was calculated, a high mesh density was used, so the accuracy of the obtained results was high. This allowed for precise processing of the results, and detailed analysis for all examined tooth profiles. They were compared to choose the most advantageous one for use in the reproduced model. It was observed that the lowest stress values were observed for an involute profile with 30° angle, and the highest for teeth with 20°. These differences are caused directly by the shape of the tooth, and especially its width at the root. For all three profiles, the single tooth begins cooperation at the same time, but the lengths of individual phases of cooperation (single and two-pair) are different for each of them.

The involute outline with 30° angle remains the shortest in the meshing of all the subjects, and has the longest duration of single-pair cooperation.

In the same way as for the reproduced gear, an analysis for the pinion model was conducted, but in this element it is not a problem and it is working correctly. For the pinion, the lowest values of bending stresses at the tooth root were also for the gears with a 30 ° angle of the tooth profile.

Qualitative analysis of various tooth profiles also concerned the determination of contact stresses on the flank of the tooth. Their maximum values occur in the area of contact between the teeth of the gear and the pinion. But this point during the meshing of the drive changes its position by moving along the path of contact. When reading the results of stresses on the flank of the tooth, in subsequent time steps of the calculations, the maximum values of contact stresses were sought. The stress distribution on the flank of the tooth always looked similar to Figure 5. An example of single-pair cooperation of involute gears with an angle of $\alpha = 30°$ is presented. On the horizontal axis, the length of the tooth flank is determined counting from the root to its apex, while on the vertical axis, the contact stress values are determined. The graph shows a very clear local increase in stress values, which corresponds to the place of single-pair cooperation of the tooth pair. With this method, the maximum contact stress values were read for all the calculation steps in order to compare the results for different tooth profiles. The graphs for all calculation models had a similar shape, but differed in the level of stress depending on the tooth profile used.

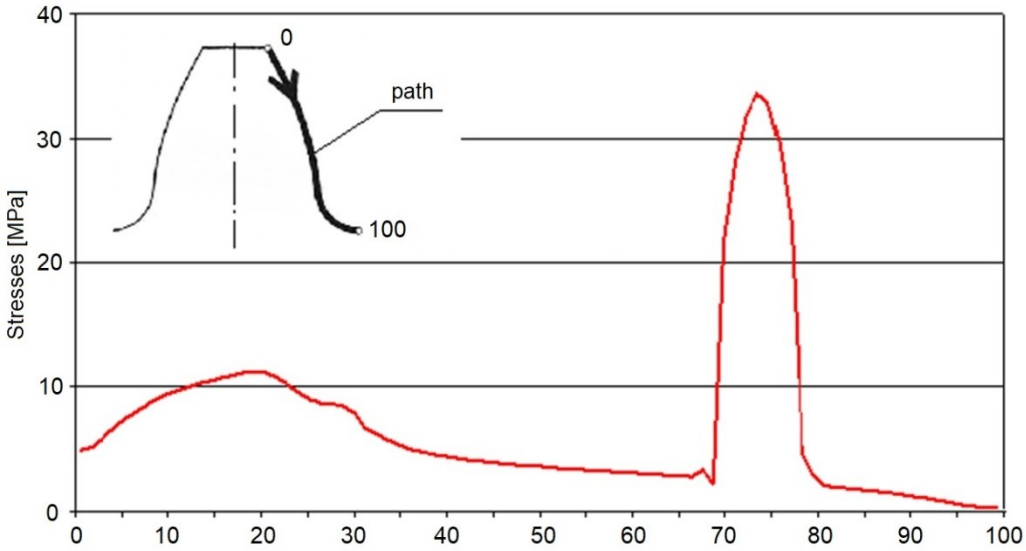

Figure 5. Method of reading the results on the flank of the pinion tooth.

Figure 6 shows the maximum contact stress values on the tooth surface for different profiles. The presented values are the maximum stresses recorded for each tooth faces for all anlysed profiles.

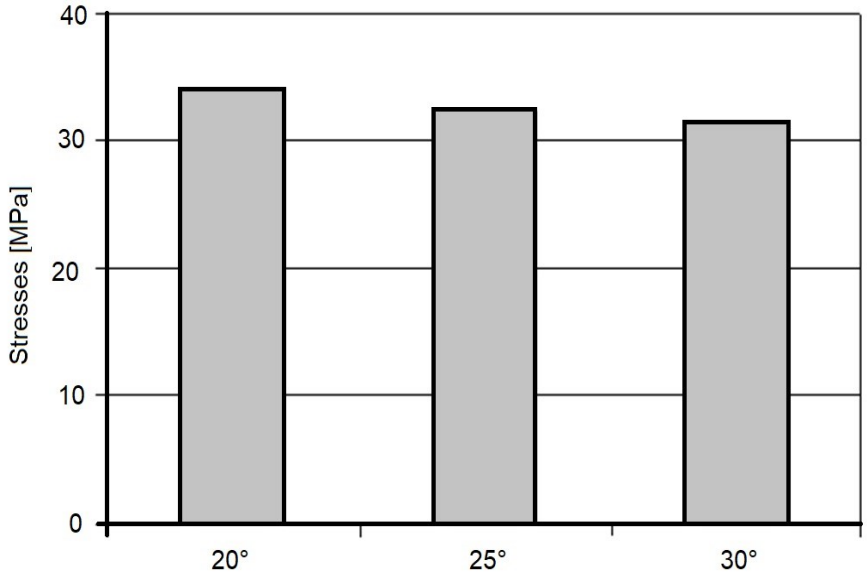

Figure 6. Contact stresses on the teeth surface of gears with different involute profiles.

In each of the calculation models, the maximum contact stress values were located at the end of the single-pair cooperation. The highest contact stresses were observed for models with a profile angle of 20° (36.34 MPa), while the lowest were observed for teeth with 30° angle of (35.67 MPa). The difference between the extreme values does not exceed a few percent, so it did not clearly indicate the benefits of using any of the design variants.

5. Fabrication of models

For three involute profiles, a reduction in the value of contact stresses was noticed as the angle of the profile increased. A similar trend occurred for the bending stresses at the root of the tooth, where the 30° profile also had the lowest stress values.

However, it should be noted that the choice of tooth profile should not always be determined only by maximum stress values. In this case, it should also be noted that as the angle of the tooth outline increases, it narrows at the apex, which can cause damage during work under load. The decision of the choice of the most advantageous solution in a specified situation should be made after a more in-depth analysis or on the basics of experimental research.

In the absence of other premises, it was assumed that the reconstructed gear will have a tooth outline $\alpha = 30°$, and the remaining parameters of the tooth rim will remain unchanged.

For this, the solid gear model was modified in the CAD program to the new geometry. The change in the its design consisted in removing the original toothed rim and replacing it with a new one generated in the CAD program, for the changed tooth profile. To better match the gear model to other assembly elements, the central hole in the hub was also made again.

Then, on the basics of solid CAD models, a physical model of the gear was made using the incremental method. To produce the prototype, the FDM (fused deposition modeling) method which consists of the layered construction of a model from molten polymer extruded from a heated nozzle. The material for the construction of the model was ABS in the form a filament, previously included in the FEM calculations.

The model preparation and the printing process were performed in the UpStudio program, and the printing was performed on the Up Box Plus printer (Fig. 9). Since the minimum available print layer thickness of 0.1 mm and the maximum fill density of the model were assumed, the printing process took a long time, over 5 hours.

After the printing process, it was still necessary to remove supports created only for the needs of the print itself and clean the resulting product. The physical model obtained in the 3D printing process is complete and fully functional, and also ready for assembly in the machine.

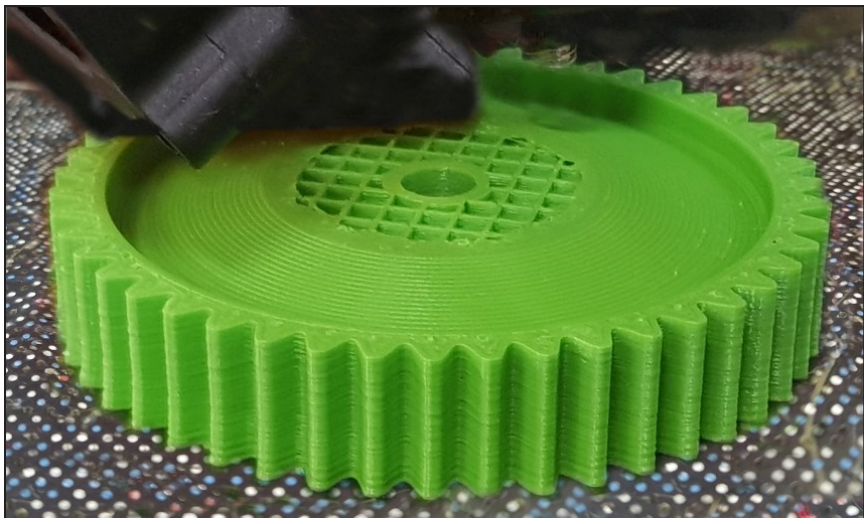

Figure 7. View of the gear during printing.

The correct work and durability of the gears are influenced not only by the parameters of the tooth rim, but also by their correct assembly. Therefore, the material and manufacturing technology was chosen, which allows for additional correction of geometry through machining. In this case, an additional reaming of the central hole was performed so that the gear wheel could be mounted on the shaft of the machine with precision and with the required clearance.

6. Summary

Reverse engineering allows us to make a copy of the original element while keeping its geometrical and strength parameters. In this article is presented how this process proceeded for the gear that is part of the drive of a meat mincer. The analysed gear was made of ABS polymer plastic, and was often damaged by breaking a single tooth. Since it was not possible to replace

the damaged gear with a new one, reverse engineering methods were used to reconstruct it. The standard reproduction process was extended for an extra step involving the modification of the geometry for copied element. Changes in the design of the gear were aimed at improving its durability, and especially increasing the bending strength of the teeth. Therefore, the numerical model obtained as a result of contact measurements was subjected to numerical analysis using FEM. The calculations concerned different variants of gears that differed in the value of the profile angle of the involute tooth. Three angle values of 20°, 25° and 30° were tested. Preliminary evaluation of gears with different tooth profiles showed disparities in their load capacity. In none of the calculation variants, the determined level of bending stress values at the root of the tooth did not exceed the acceptable values, so they can be successfully used. The lowest stress values at the root of the tooth occurred for the profile angle $\alpha = 30°$. Also for this tooth profile, the lowest contact stress values occurred on the flank of the mating teeth. On the basis of these results, it was assumed that the original shape of the teeth with a profile angle of $\alpha = 20°$ will change into an involute with an angle of $\alpha = 30°$. After applying this modification, a copy of the gear was made using FDM 3D printing. So, the entire reverse engineering process of the gear was conducted, extended by its modification resulting from an additional numerical analysis of the FEM.

References

1. Budzik, G. (2007). *Synteza i analiza metod projektowania i wytwarzania prototypów elementów o skomplikowanych kształtach na przykładzie wirników turbosprężarek*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
2. Kachel, S., Kozakiewicz, A., Łącki, T., Olejnik, A. (2011). Zastosowanie inżynierii odwrotnej do procesu odtwarzania geometrii układu wlotowego silnika RD-33 w samolocie MIG-29. *Prace Instytutu Lotnictwa*, *213*, pp. 66-84.
3. Müller, L. (1970). *Przekładnie zębate. Projektowanie.* Warszawa: Wydawnictwa Naukowo-Techniczne.
4. Pacana, J., Kozik, B., Budzik, G. (2010). Naprężenia u podstawy zębów o zarysie BBW wyznaczane z zastosowaniem metody MES. *Czasopismo Techniczne, z. 107/7, t. 1-M*, pp. 81-88.
5. Pacana, J., Pacana, A., Woźny, A., Bednarova, L. (2015). Application of reverse engineering in the manufacturing process of machine parts. In: M. Majerník, N. Daneshjo, M. Bosák (Eds.), *Production Management and Engineering Sciences* (pp. 517-522), Londyn: CRC PRESS/BALKEMA.

6. Rusiński, E., Czmochowski, J., Smolnicki, T. (2000). *Zaawansowana metoda elementów skończonych w konstrukcjach nośnych*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej.
7. Wiktor, J. (2004). *Analityczno-numeryczne metody analizy parametrów geometrycznych, zakłóceń ruchu i wytrzymałości przekładni walcowych*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.

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TRUST AS A PARTICIPANT IN THE ADAPTATION OF TECHNOLOGICAL CHANGES

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Purpose: Trust is an important relational element in everyday social life and influences the efficiency of the communication process of the whole society. In the literature on the subject, there are different definitions of this concept. Most often, trust is described as an element of the personality formed at the beginning of life. This thesis examines the concepts of trust and trust in technology. It discusses the differences, connections, and dependencies between them, which determine the process of adaptation of technology recipients to its advanced development.
Design/methodology/approach: In the content of the paper, the authors focused on a review of the literature on the selected issue. The content attempts to refer to the aspects of trust that emerge during the implementation and adaptation of new technologies.
Findings: The analysis of the research carried out by individual authors allows us to conclude that the concepts of interpersonal and technological trust are not identical, but complementary. Due to technological progress and the fact that it plays an increasingly important role in society, trust in technology is gaining in importance. There is also a growing need on the part of manufacturers to provide trustworthy IT solutions, as audience trust is crucial in the sense of user acceptance of technological solutions and thus their turnover in the market.
Social implications: The development of new technologies changes the shape and perception of reality. Technology determines the progress of development as well as the dynamics of functioning in this technological reality of society. New technologies throw many challenges at the social level, one of them is the issue of trust in what technology can change as a causal effect.
Originality/value: In its content, the article tries to cross the horizon of current events in the dimension of technological changes. Many futurologists like Y.N. Harrari is trying to see possible scenarios that will be a consequence of implementing the technology. It is important to emphasize that technology itself is not deterministic, it is programs of use, common sense, trust and human morality that determine the ultimate agency and use of technology.

Keywords: technology, trust, adaptation.

1. Introduction

Trust is an important relational element related to interpersonal interactions occurring in everyday social life and influencing the efficiency of the communication process of the whole society. In the literature on this subject, one can find various definitions of this concept. Most often, trust is described as an element of the personality of a given individual, formed in the initial period of life, concerning his tendency to certain actions. This article examines the concepts of trust in technology and trust as a whole. It discusses the differences, connections, and dependencies between them, which determine the process of adaptation of technology recipients to its advanced development.

2. Trust

The key factor in the process of any social interaction of significant importance, which undoubtedly influences the behavior of every human being, is trust. This phenomenon is responsible for the pace and dynamics of created mutual behavior and determines the speed of information exchange in any social environment (Smith, Barclay, 1997). Trust is reinforced by the circumstances which, as a result of the occurrence, characterize cooperating individuals as dependent on each other by being oriented towards achieving a previously defined, common goal.

Due to the meaning of the term in various disciplines (e.g. social psychology, sociology, and economics), trust is defined in many different ways. Some researchers view trust as an aspect of a person's personality - similar to a tendency to trust or dispositional trust - that develops early in life and remains relatively stable (Rotter, 1967; Webb, Worchel, 1986).

Trust usually involves the ability of another person to do something in a certain scenario. As a result, it is widely accepted in the literature on this topic that trust is essentially a three-place predicate (Castelfranchi, Falcone, 2010; Hawley, 2014; Simpson, 2011). Usually, this will mean a trust attitude analysis in which entity A trusts entity B with respect to some action of X. Trust seen in such a model is a matter of performing some action in a specific situation or domain of interaction.

Interpersonal trust is an inherently relational concept and is often cited as the underlying principle for optimal performance in society as a whole. It is commonly defined as the willingness to rely on someone else's actions when at risk (Mayer et al., 1995; Williams, 2001). But trust also underlies other key aspects of relationships, such as someone's perception of their ability to be helpful (Gambetta, 1988) and the willingness to reveal confidential information (Krackhardt, Hanson, 1993). As trust reduces the need to monitor another person's behavior

and thus the need for formalized procedures or contracts, it provides the necessary link that organizations need to become more efficient and effective (Powell, 1990). A different perception of trust appears as a set of beliefs and expectations about the characteristics, intentions, and behaviors of the other party (Cook, Wall, 1980; McAllister, 1995). There are researchers in the scientific community who treat trust as a psychological state or willingness to be vulnerable based on beliefs and expectations of the other party (Mayer et al., 1995; Rousseau et al., 1998).

It is also worth remembering that the scientific community also distinguishes the approach to trust, where trust is seen as a synonym of cooperative behavior or risk taking (Gambetta, 1998). Such complexity in the interpretation of the term can lead to misunderstandings about how to correctly define trust.

The literature on the subject consists of extensive collections of scientific works that lead to wide-ranging discussions about the role of trust (Dirks, Ferrin, 2001; Schoorman et al., 2007). However, it does not raise any doubts and it is not a controversial statement that trust is the glue, which in its success, defines human-human interaction and is necessary on the way to the success of interpersonal relationships.

Among many studies on trust between human beings, research on the role of human trust in new technologies is gaining importance. The initiating motivation to carry out research in this area is undoubtedly the new information technologies which, with their development, have crossed the horizon of events in the field of human-to-human communication. Current experience is enough to show the multitude of benefits of this way of communicating with other people through technology. However, this difference in the way we communicate through the broadly understood lower quality way of communication may be what, in its effect, will inhibit the development of trust between people. Taking the above as an argument, it becomes justified to carry out research into the relationship between trust and interpersonal trust in technology.
The conducted research allowed to establish that interpersonal trust influences trust in technology, which in turn influences the behavior related to cooperation. Both types of trust influence intentions to continue interpersonal interactions and intentions to use technology in the future, but interpersonal trust has a stronger impact on both intentions. The results of the study help us understand how trust functions in a technology-mediated environment. Future research should focus on examining how interpersonal trust and trust in technology develop over time (Miller, 2015).

Trust plays an integral role in the communication process. Recent research has begun to analyze the nature of the construct of trust in human-machine interactions and human trust in technology. In many disciplines, trust in technology has attracted a lot of attention from both the research and applied communities, providing support for its theoretical and practical relevance (McKnight et al., 2011).

Research on trust in the literature has been the interest of many scientists. Among the many different studies, there are studies that linked trust with the communication process (Boss, 1980; De Dreu et al., 1998; Dirks, 1999; Kimmel et al., 1980; Mellinger, 1959; Smith, Barclay, 1985; Zand, 1972), trust with the behavior of an individual in an organization (Konovsky, Pugh, 1994; McAllister, 1995), trust and the negotiation process (Kimmel et al., 1980; Schurr, Ozanne, 1985), trust and conflict (De Reu et al., 1998; Porter, Lilly, 1996; Zaheer et al., 1998), trust and other behaviors (Dirks, 1999; Spreitzer, Mishra, 1999), trust and individual efficiency (Earley, 1986; Oldham, 1975), trust and satisfaction (Boss, 1978; Brockner et al., 1997; Driscoll, 1978) and other research on trust (Benton et al., 1969).

3. Trust in Technology

In the field of research, trust in technology has become a meaningful subject. The multitude of definitions that try to develop this issue treats trust in technology in a way where the interpretation is translated as the belief that a specific technology has the attributes necessary to operate as expected in a given situation where negative consequences are possible (McKnight et al., 2011). When talking about trust in technology, we can distinguish identical levels that develop this trust. Among other things, there is a relationship between trust and whether a given technology will be adopted by its user (Gefen et al., 2003; Davis, 1985; Ajzen, 1975). There is also an aspect of trust in automation (Lee and See, 2004) and services provided by technology (such as e-administration, e-banking, or e-commerce).

Often, when trust is discussed in the context of human-technology interaction, it refers to human dependence and the use of a particular technology. After all, technology is often developed to reduce human error in the system.

In the literature, there are many models that deal with technology acceptance models, noting a lot of constructs that are a catalyst or an inhibitor of technology implementation. Scientists are looking in many different directions, but the aspect of trust is not popular in the context of dealing with technology. However, trust is what binds any social relationship, it is the beginning of every business, the whole functioning world is based on it. The technology-driven world invites machines to cooperate with humans, with which humans enter into relationships through multiple communication opportunities. Technology allows for new ways and methods of human-to-human communication.

This allows for the conclusion that the role of trust in technology is an element of the context of using information and communication technologies (Kuriyan et al., 2010). Today's mechanisms, which powering a functioning economy, are nothing more than technology. This technology, taking the form of various tools, provides man with a way to carry out complex tasks more efficiently than ever before, in other words, technology provides services that form

the pillar of the multi-level functioning of the economy, politics, economy - life. Therefore, trust in technology is related to technology adaptation, and response of target users making trust in technology a matter of broad interest.

The profile of trust research can have different backgrounds. For clarification, the example of trust research is of interest to scientists who are focused on a field of science that looks towards information systems. In this environment, the conducted research and conclusions suggest that trust in technology depends on how the user perceives a given technology and on institutional mechanisms ensuring the security of human-technology interactions (Rajalekshmi, 2008). This issue is of interest to an organization that wants to develop because of the fact that the reliability of technology is a key aspect of the reliability of a modern organization (Tworek et al., 2020).

4. Research on Trust and Technology

In the context of understanding the nature of trust in technology, a study was conducted by L. Xin, R. Guang, B. Jason (2012). The researchers believe that there is a lack of basic understanding of how technology trust relates to traditional trust and its role. Their work suggests that technology trust differs from an interpersonal trust (i.e., trust in people) due to different basic characteristics of trustees. To explore these differences, the authors first develop and validate a measure of technology trust consisting of technology-specific belief sources. They then develop a research model that compares and contrasts technological trust and interpersonal trust. This study provides evidence that trust in technology is related to, but distinct from, interpersonal trust. The authors found that trust in technology plays a dual role, exerting direct and indirect effects on trust outcomes. Rather than suggesting that trust in technology replaces interpersonal trust, the findings suggest that trust in technology complements interpersonal trust by influencing intention to use technology.

Research on trust in technology is rooted in theories of social reactions to computers (Reeves, Nass, 1996; Nass, Moon, 2000), which assume that people treat computers and computer technologies as social actors and apply social rules to them. As a result, many studies simply extend theories of interpersonal trust and transfer definitions and models from the interpersonal context to the technological context. For example, consistent with interpersonal trust research, IS research often defines trust in technology as people's multidimensional beliefs about the trustworthiness of a particular technological artifact, including benevolence, competence, and fairness, when performing important tasks (Wang, Benbasat, 2005; Vance, Straub, 2008). However, the characteristics of social actors and information technologies differ. For example, even when personified as agents of human actors, technologies generally lack the volitional control and moral capacities of human beings.

Given the existing differences between trust in people and trust in technology, researchers point to the need to identify an appropriate set of attributes that are unique to trust in technology.

In the era of development, the profile of scientists and the profile of business practitioners should treat the subject of development carefully. Scientists and managers in a responsible way should look for solutions that will take into account the good and fate of man. Undoubtedly, technology is the direction in which all units for which development and growth matter are oriented. For this reason, the aspects of ethics that stimulate the development of trust in technology should be studied by scientists to determine the moral responsibilities of those responsible for implementing the technology. Nowadays, the thesis that technology shapes our world is not controversial, so it is also necessary to recognize the fate of man, who may ultimately be replaced by this technology.

Table 1.
selected definitions of trust

Concept	Definition	Reference
Trust	The willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a specific action important to the trustee, regardless of the other party's ability to monitor or control the other party	Mayer et al., 1995
Trustor	A party in a fiduciary relationship that trusts	
Trustee	A party in a trust relationship that receives trust	
Trustworthiness	The features and actions of the trustee that make the person more or less trusted	Gefen, 2002
Trusting beliefs	The trustees' insights into the trustworthiness characteristics of the trustee to form a trust	Gefen et al., 2003; Kim, Benbasat, 2009
Interpersonal trust	People's beliefs about the credibility of another human actor in a relationship	Mayer et al., 1995; McKnight et al., 2002; Gefen et al., 2003
Interpersonal Trust Belief - Competence	The ability of the trustee to do what the trustee needs	
Interpersonal Trust Belief - Benevolence	The care and motivation of the Trustee to act in the interest of the Trustee	
Interpersonal Trust Belief - Integrity	Trustee’s honesty and promise keeping	
Technology Trust	People's beliefs about the reliability of an IT department in carrying out a task	Ratnasingam et al., 2005; McKnight, 2005
Institution-Based Trust	Belief that structural conditions are needed to increase the likelihood of a successful outcome to the trust venture	McKnight et al., 2002; Pavlou, Gefen, 2004

Source: Xin, L., Guang, R., Jason, B. (2012). Does Technology Trust Substitute Interpersonal Trust?: Examining Technology Trust's Influence on Individual Decision-Making, Journal of Organizational and End User Computing; Hershey Tom 24, Nr/edition 2, (2012): 18. DOI:10.4018/joeuc.2012040102.

In a study conducted by Alesina and Ferrara, the researchers note that the determinants of trust are rooted in individual and community characteristics. The researchers indicate that both individual and community characteristics contribute to the selection of trust by factors that reduce trust: recent traumatic experiences, membership in a racially discriminated group, low income or education, and high racial or income inequality in communities. They also found that religious beliefs and ethnicity do not significantly affect trust (Alesin, Ferrara, 2000).

5. Conclusion

The analysis of the research carried out by individual authors allows us to conclude that the concepts of interpersonal and technological trust are not identical, but complementary. Due to technological progress and the fact that it plays an increasingly important role in society, trust in technology is gaining in importance. There is also a growing need on the part of manufacturers to provide trustworthy IT solutions, as audience trust is crucial in the sense of user acceptance of technological solutions and thus their turnover in the market. It is also important that many currently available solutions, by reducing the risk of error, contribute to the efficiency of teams and thus consumer trust in the company itself.

Undoubtedly, in future years, scientists should pay attention to the agency of technology in terms of ethics that affects society. More and more technologies powered by artificial intelligence make the fate of man in the world of business questionable. Already today, the world of science and the world of business cannot predict what professions will be dominant on the labor market and what will actually be expected from the employee in terms of his skills and knowledge.

Technology powered by artificial intelligence puts humans in a position that is impossible to compete with. Algorithms are immeasurably ahead of the effect of human work. Situations like this should guide scientists and world governments to make wise decisions and build programs for proper technology implementation so that confidence in technology can grow.

Using the latest reports on tools and technologies that function thanks to artificial intelligence, such as generating images after entered words (Dalle-2) or creating ready-made essays on any given topic (chatGPT) is what starts asking important questions in which direction this is coming, as well as what it may lead to as a result.

If today there are algorithms that are able to create graphics much more efficiently, replacing the graphic designer's working hours - will it not be possible in the future to establish the entire production process based on algorithm calculations that will determine the entire process-flow, noting bottlenecks and potential quality defects? In this case, the work of countless people is directly at risk. Such technology without the right framework based on morality, ethics and trust can lead to negative scenarios.

And as scientists and business practitioners realize, technology is gaining momentum, making economically developed countries even larger economies of the world. However, there is a huge risk that countries with much lower economic development in this race may, according to Y.N. Harrari, become a 'useless class'.

References

1. Alesina, A., Ferrara, E. L. (2000). The Determinants of Trust. National Bureau of Economic Research, Inc, *NBER Working Papers: 7621S.*
2. Benton, A., Gelber, E., Kelley, H., Liebling, B. (1969). Reactions to various degrees of deceit in a mixed-motive relationship. *J. Personality Soc. Psych., 12,* 170-180.
3. Boss, R.W. (1978). Trust and managerial problem solving revisited. *Group Organ. Stud., 3,* 331-342.
4. Brockner, J., Siegel, P., Daly, J., Tyler, T., Martin, C. (1997). When trust matters: The moderating effect of outcome favorability. *Admin. Sci. Quart., 42,* 558-583.
5. Castelfranchi, C., Falcone, R. (2010) *Trust theory: a socio-cognitive and computational model.* Wiley series in agent technology Chichester, West Sussex, UK: J. Wiley.
6. Cook, J., Wall, T. (1980). New work attitude measures of trust, organizational commitment and personal need non−fulfilment. *Journal of Occupational and Organizational Psychology, 53(1),* 39-52.
7. De Dreu, C., Giebels, E., Van de Vliert, E. (1998). Social motives and trust in integrative negotiation: The disruptive effects of punitive capability. *J. Appl. Psych., 83,* 408-423.
8. Dirks, K.T. (1999). The effects of interpersonal trust on work group performance. *J. Appl. Psych., 84,* 445-455.
9. Dirks, K., Ferrin, D. (2001). The role of trust in organizational settings. *Organizational Science, 12(4),* 450-467. DOI: 10.1287/orsc.12.4.450.10640.
10. Earley, P.C. (1986). Trust, perceived importance of praise and criticism, and work performance: An examination of feedback in the United States and England. *J. Management, 12,* 457-473.
11. Gambetta, D. (1988). Can We Trust? In: D. Gambetta (ed.), *Trust, Making and Breaking Cooperative Relations* (pp. 312-237). London: Basil Blackwell.
12. Gefen, D., Karahanna, E., Straub, D.W. (2003). Trust and TAM in online shopping: An integrated model. *MIS Quarterly, 27(1),* 51-90.
13. Hawley, K. (2014). Trust, Distrust and Commitment. *Noûs, 48(1),* 1-20. DOI:10.1111/nous.12000.
14. Kimmel, M., Pruitt, D., Magenau, J., Konar-Goldband, E., Carnevale,, P. (1980). Effects of trust, aspiration, and gender on negotiation tac-tics. *J. Personality Soc. Psych., 38,* 9-22.
15. Kuriyan, R., Kitner, K., Watkins, J. (2010). ICTs, development and trust: An overview. *Information, Technology, and People, 23(3),* 216-221. DOI: 10.1108/0959384101069130.
16. Lee, J., See, K. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 46,* 50-82.
17. Mayer, R.C., Davis, J.H., Schoorman, F.D. (1995). An integrative model of organizational trust. *Academy of Management Review, 20(3),* 709-734.

18. McAllister, D.J. (1995). Affect-and cognition-based trust as foundations for interpersonal cooperation in organizations. *Academy of Management Journal, 38(1),* 24-59.
19. McKnight, D.G., Carter, M., Thatcher, J.B., Clay, P.F. (2011). Trust in a specific technology: An investigation of its components and measures. *ACM Transactions on Management Information Systems, 2(2),* 12-32.
20. Mellinger, G. (1959). Interpersonal trust and communication. *J. Abnormal Soc. Psych., 52,* 304-309.
21. Miller, E. (2015). *Trust in People and Trust in Technology: Expanding Interpersonal Trust to Technology-Mediated Interactions*. University of South Florida.
22. Mishra, A., Spreitzer, G. (1998). Explaining how survivors respond to downsizing: The roles of trust, empowerment, justice, and work redesign. *Acad. Management Rev., 23,* 567-588.
23. Nass, C., Moon, Y. (2000). Machines and mind lessness: Social responses to computers. *The Journal of Social Issues, 56(1),* 81-103. doi:10.1111/00224537.00153.
24. Oldham, G. (1975). The impact of supervisory characteristics on goal acceptance. *Acad. Management J., 18,* 461-475.
25. Paska, M. (2021). *The Aspect of Ethics Determined by Technological Impact*. Conference: Hradec Economic Days 2021, DOI: 10.36689/uhk/hed/2021-01-062.
26. Powell, W.W. (1990). Neither market nor hierarchy: Network forms or organization. In: L.L. Cummings, B.M. Staw (Eds.), *Research in organizational behavior, Vol. 12* (pp. 295-336). Westport, CT: JAI Press.
27. Reeves, B., Nass, C. (1996). *The media equation: How people treat computers, television, and the newnmedia like real people and places*. Cambridge, UK: Cambridge University Press.
28. Rotter, J.B. (1967). A new scale for the measurement of interpersonal trust. *Journal of Personality, 35(4),* 651-665.
29. Rousseau, D.M., Sitkin, S.B., Burt, R.S., Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of Management Review, 23(3),* 393-404.
30. Schoorman, F.D., Mayer, R.C., Davis, J.H. (2007). An integrated model of organizational trust: Past, present, and future. *Academy of Management Review, 32(2),* 344-354.
31. Schurr, P., Ozanne, J. (1985). Influences on exchange processes: Buyers' preconceptions of a seller's trustworthiness and bargaining toughness. *J. Consumer Res., 11,* 939-953.
32. Simpson, T.W. (2011) Robots, Trust and War. *Philosophy & Technology, 24(3),* 325-337. DOI:10.1007/s13347-011-0030-y.
33. Smith, J.B., Barclay, D.W. (1997). The effect of organizational differences and trusting on the effectiveness of selling partner relationships. *Journal of Marketing, 61*, 3-21.
34. Tworek, K., Bieńkowska, A., Zabłocka-Kluczka, A. (2020). *Organizational reliability: Human resources, information technology and management.* Routledge.

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THE IMPACT OF THE ORGANIZATION OF THE WORKING DAY ON PRODUCTION EFFICIENCY IN THE LABORATORY OF PLANT TISSUE CULTURES

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Purpose: The aim of the study was to rate the employee's productivity on different work day organization and to indicate the most optimal work schedule.
Design/methodology/approach: For the research presented in this paper, strong literature review was done. We showed why human workforce is so important in tissue culture laboratory and why proper work organization is essential for increasing competitiveness of companies. Literature in the field of overtime work and short, elastic hours of work was also presented. Our research design checked effectiveness of work of ten employees of tissue culture laboratory in five different workday schedules. First combination was control and four other investigated influence of six hour work on main task in different arrangements on productivity. Data was statistically analysed with Kruskal-Wallis ANOVA. Productivity Index and Labour Productivity Index were also used for better results processing.
Findings: The highest employees productivity is concentrated in the middle of work day. In conventional eight hour workday, the highest productivity is just after fifteen minute break. Six hour workday has big potential in increasing work, especially when main task is not interrupted by other activities and when work starts at the beginning of workday.
Research limitations/implications: In future, research should be expanded on employees efficiency in work with bioreactor and costs analysis of plant production in such system.
Practical implications: Our results are directed to plant tissue culture companies and others where employees are essential and their work requires concentration during repetitive activities. We suggest solutions increasing work efficiency.
Originality/value: Our work presents hour after hour analysis of work efficiency in different workday organization in plant tissue culture company.

Keywords: day schedule, productivity, work organization, work effectiveness.

Category of the paper: Research paper.

1. Introduction

Employees are essential in many companies and they still cannot be replaced by machines in some professions. Mass production of *in vitro* plants in tissue culture laboratory is such a profession. It requires accuracy, precision and the ability to make the right decision. Tissue culture technology, for plant clonal propagation, was introduced in the mid 1960's (Thorpe, 2007). Although traditional methods have been around in commercial usage for more than 50 years, it has been automated to a small extent and then only in medium preparation and dosage. It is relatively easy because of the extremely developed dosing technology used in other industries. The only challenge is to maintain asepticity and the use of frequently occurring short series of media. Short media series occurs when a laboratory is not specialised in a narrow amount of plant species growing in the same medium. So offering a wide range of species causes difficulties and then an efficient human workforce is very important.

In vitro protocols for plant propagation are presented for many species. These protocols start from simple methods ranging up to advanced bioreactor production, but there is little information about productivity and the cost of plant propagation used within *in vitro* techniques. Taking into consideration the fact that *in vitro* laboratories are currently developing and increasing production, studies on cost calculation and cost reduction proposals should be carried out Souza et al. (2015), Chiachung Chen (2016), Saraswathi et al. (2016), Pożoga et al. (2019), focused on research in this field. The researchers describe variable costs of production or costs of total laboratory investments in certain species production. Still there is a lack of production of plants in bioreactor cost analysis. Very often the workforce is a considerable cost for production companies. Pożoga et al. (2019) indicated that 48% of variable costs of Paulownia tree (*Paulownia tomentosa* × *Paulownia fortunei* hybrid) *in vitro* production is connected with labour. According to Chiachung Chen (2016) labour is more than 60% of the total cost of production of orchid (*Phalenopsis)* plants. That is why studies on human workforce productivity should be provided. By increasing human productivity companies can achieve better results and decrease production costs. The increase, can be done in many ways. It can be stimulation using music (Lesiuk, 2005; Haake, 2011), light intensity (Karlikova et al., 2016), environmental quality and employee satisfaction (Vischer, 1989; Staw, Barsade, 1993; Garris, Monroe, 2005). Moreover Street et al. (2019) indicates that stress is also a crucial factor of productivity and labour cost reduction. Reducing stress among employees can significantly increase an enterprise's results.

The fast development of technologies, especially connected with communication, has created a '24-hour society' over the recent years. Employees are always ready to pick up the phone or answer an email when they have finished work. People spend evenings trying to achieve goals set by employer's. A sharp line between time of work and a time for relaxation is not so obvious nowadays. Very often people have to work overtime (Golden, 2012).

But how is this continuous readiness to work affect productivity? O'Conner, L.V. (1969) and Haneiko, J.B. and Henry, W.C. (1991) showed that working overtime brings a loss in efficiency. Firms see this issue and try to solve this problem. There are a lot of companies doing private research indicating that working fewer hours increases productivity. This can include working fewer hours in a day or working less hours during the week. Also flexible working hours can increase productivity (Kossek, Van Dyne, 2008; Kossek, Lee, 2008). It is also important to introduce shorter work conditions as stated in Parkinson's Law. It states that 'work expands so as to fill the time available for its completion' (Parkinson, 1955). This means that the closer we are to the deadline the higher productivity becomes. So duties on an eight-hour work day can be done faster. This can be achieved by properly planning work and encouraging employees and for sure this is worth some attention.

This study was conducted among ten employees of Plant Research Laboratories located in Warsaw, Poland. The employees were male and female within the age range of 20-35 and were responsible for different tasks in the laboratory. Research was repeated three times for each combination and each employee. The plant used in the experiment was an ornamental alternantera plant (*Alternanthera dentata)*.

The working day for the people responsible for transplanting of plants starts at 9 am and ends at 5 pm. Employees arrive a few minutes earlier to prepare for work. At 9 am they sit at their workplace, spray it with 70% ethanol solution and transfer 20 containers with a culture medium, 4 containers with mother plants, sterile paper plates, tweezers and scalpels to laminar flow hood. All these objects are prepared by a different person who is responsible for work organization, and not included in the study. There are always 3 pairs of tools. One pair of tweezers and scalpels is used for cutting plants, the second is in a glass bead steriliser and the third in an ethanol solution. Tools for cutting are changed after completion of transplanting of mother plants from one container. Hand used tools are transferred to a glass bead steriliser, hot tools from the steriliser are moved to ethanol and cool tools from ethanol can be used for further work.

Plant cultures are kept in polypropylene 350ml containers. The cutting of plants is done on a sterile paper plate.

The workplace is always organised in an optimal way. Tools, such as tweezers and scalpels, paper plates for cutting, containers with mother plants and containers with the medium are located near to each other and can be easily grabbed with a highly reduced possibility of contamination. All the equipment can be reached with body movement reduced to a minimum (Figure 1A). Chairs for employees are comfortable, do not cause back pain and are in accordance with the principles of health and safety at work. The LED lighting of the workplace used meets requirements. Employees work in gloves.

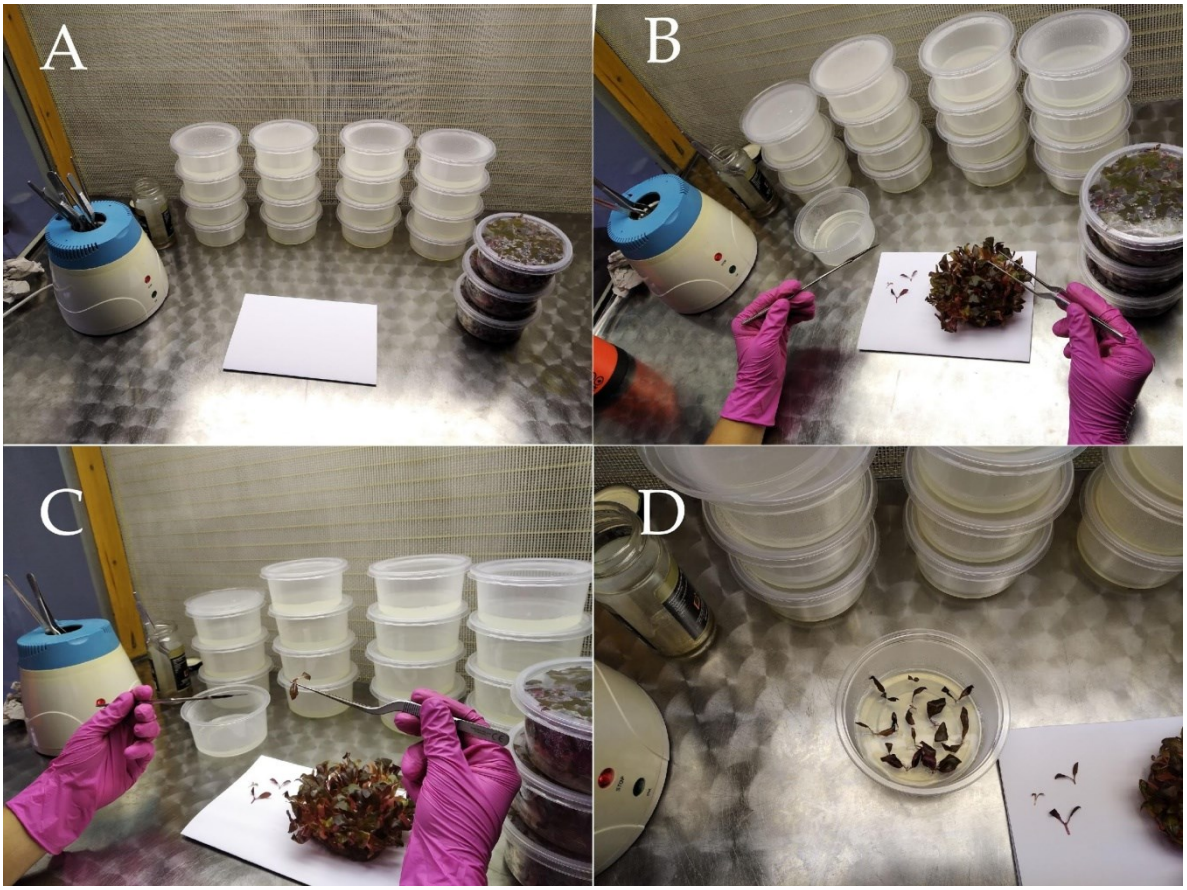

Figure 1. Workplace organization. (A) Location of cups with plants and medium. (B) Cutting off the explants. (C) Selecting explants. (D). Explants placement in medium.

Source: own elaboration.

The duties of employees during the transplanting included: opening a container with mother plants, moving all plants onto a sterile paper plate, cutting an accurate amount of explants (proper fragment of plant for propagation) that can be transplanted without drying too much, opening a container with the medium, transplanting of plants, closing the lid, opening the next one. Repetition of these steps until the total use of all plant material is complete, replacing containers with explants on containers with the medium, removing empty mother plant containers on completion and adding new ones to the laminar flow hood (Figure 1B-1D).

At the end of the day the workplace is cleaned and prepared for work on the next day. Cleaning consists of tweezers and scalpels being removed from the laminar flow hood and placing them on the trolley standing next to the workplace, spraying 70% ethanol solution inside the laminar flow hood and a thorough wiping down. Tweezers and scalpels are replaced with sterile ones the next day, before the start of the working day.

The experiment consisted of examining the work efficiency of five combinations. Firstly – the control combination C1 consisted of an eight-hour work day with plant transplanting, whilst another combination C2-C5 consisted of a six-hour plant transplanting in various systems and two hours of other work activities (Table 1). During these two hours employees were not supposed to transplanting plants. Instead they were doing other necessary activities such as:

preparing medium for the next day, sterilisation, removing contaminated cultures from the growth room and had a 15 minute break.

At the end of each hour the number of plants cut were recorded. The whole 15 minute break took place at the end of the fourth hour of work, 12:45-13:00, within an eight-hour work combination. The break in a six-hour transplanting work combination took place when employees were not working with plant transplanting. During the examination of the six-hour transplanting working day, examination of efficiency consisted of four cases when employees worked: 11 am to 5 pm (C2); 9 am to 11 am and 1 pm to 5 pm (C3); 9 am to 1 pm and 3 pm to 5 pm (C4) and 9 am to 3 am (C5). Table 1 shows the scheme of the work day in different combinations.

Table 1.
Scheme of work day in different combinations

<table>
<tr><th>Work hour</th><th>Combination C1</th><th>Combination C2</th><th>Combination C3</th><th>Combination C4</th><th>Combination C5</th></tr>
<tr><td>9:00-10:00</td><td rowspan="8">plant transplanting with 12:45-1:00 break</td><td>other activities and break</td><td>plant transplanting</td><td rowspan="3">plant transplanting</td><td rowspan="4">plant transplanting</td></tr>
<tr><td>10:00-11:00</td><td rowspan="4">plant transplanting</td><td rowspan="2">other activities and break</td></tr>
<tr><td>11:00-12:00</td></tr>
<tr><td>12:00-1:00</td><td rowspan="3">plant transplanting</td><td>other activities and break</td></tr>
<tr><td>1:00-2:00</td><td rowspan="2">plant transplanting</td></tr>
<tr><td>2:00-3:00</td></tr>
<tr><td>3:00-4:00</td><td>plant transplanting</td><td>other activities and break</td></tr>
<tr><td>4:00-5:00</td></tr>
</table>

Source: own elaboration.

In time series analysis ANOVA Kruskal-Wallis test was used to elaborate data above. P-value is $\alpha = 0{,}05$.

The following hypothesis were adopted:

H0 – there are no significant statistical differences between the employees work performance in each hour and the way the work is organised.

H1 – at least in one of the organization's of work combination, average hourly work efficiency differs significantly from the others.

Apart from this in time series analysis, taking the number of cut plants obtained in the first hour after starting work as 100%, the changes in dynamics of productivity were calculated. The coefficient of variation, as a quotient of the standard deviation and the arithmetic mean of plants produced within each hour was also calculated and in each combination for three repeatition's for ten employees. For determing the number of plants produced in individual hours arithmetic average was used.

The research conducted also allowed for an estimation of Productivity Index PI according to the followed formula:

$$PI = \frac{PRESENT\ PRODUCTIVITY}{BASE\ PRODUCTIVITY}$$

Present productivity is the number of plants that an employee cuts during one hour. The base productivity is the number of plants that each employee should produce in a single hour. PI > 1.0 indicates that productivity is better than the base, planned productivity. PI < 1.0 indicates that productivity is less than planned. Base productivity was determined on the basis of the average highest number of plants produced within a standard 8-hour workday.

The Labour Productivity Index LPI was also calculated. LPI shows the efficiency of services and goods production. It is a ratio between the production of goods and the total number of work-hours or total employment (Freeman, 2008).

$$LPI = \frac{VOLUME\ MEASURE\ OF\ OUTPUT}{MEASURE\ OF\ IN\ PUTUSE}$$

The volume measure of output is the amount of goods and services produced by the workforce. The measure of input use reflects the time and effort of the employees. The measure of labour input is made by the total number of hours worked by all employees.

3. Results

The analysis shows that regardless of the combination, including the control combination C1, the highest work efficiency was between the fourth and sixth hour of the working day. In each combination the best efficiency of work was obtained in the middle of the working day (fig. 2, fig. 3). Even in the C3 combination in which work was started after two hours of completing other tasks, in the fifth hour of work the efficiency of transplanting was as much as 30% higher than in the first hour of work. In combination C2 in which work on plant transplanting started from the third hour of the working day, efficiency in the fifth hour was 25% higher compared to the first hour of work. In C4 and C5 combinations in the fourth working hour, work efficiency was 22.9% higher compared to the first hour, then it gradually declined. It is worth noting that even in the case of a two-hour change of tasks and a return to transplanting, labour productivity at the end of the working day is much higher than in the first or second hour. For example, in the C4 combination, in the eighth hour of the working day, the efficiency was 10% higher than in the first hour of the day, and in the case of the C3 combination 15% higher.

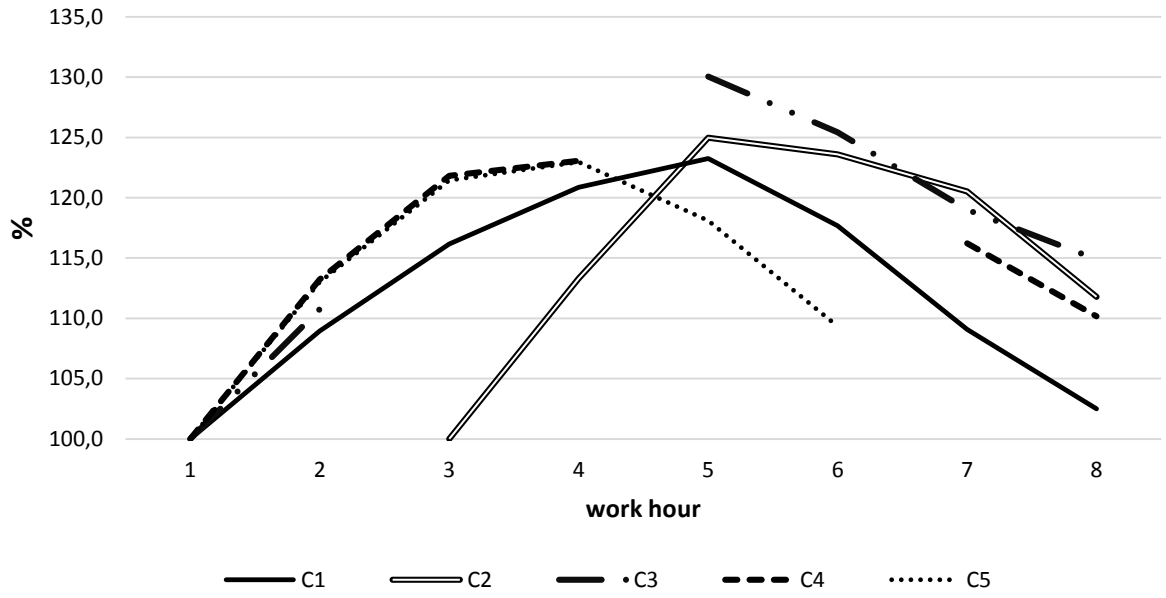

Figure 1. The dynamics of work efficiency during transplanting in five combinations. Work efficiency in the first hour of starting work = 100%.

Source: own elaboration.

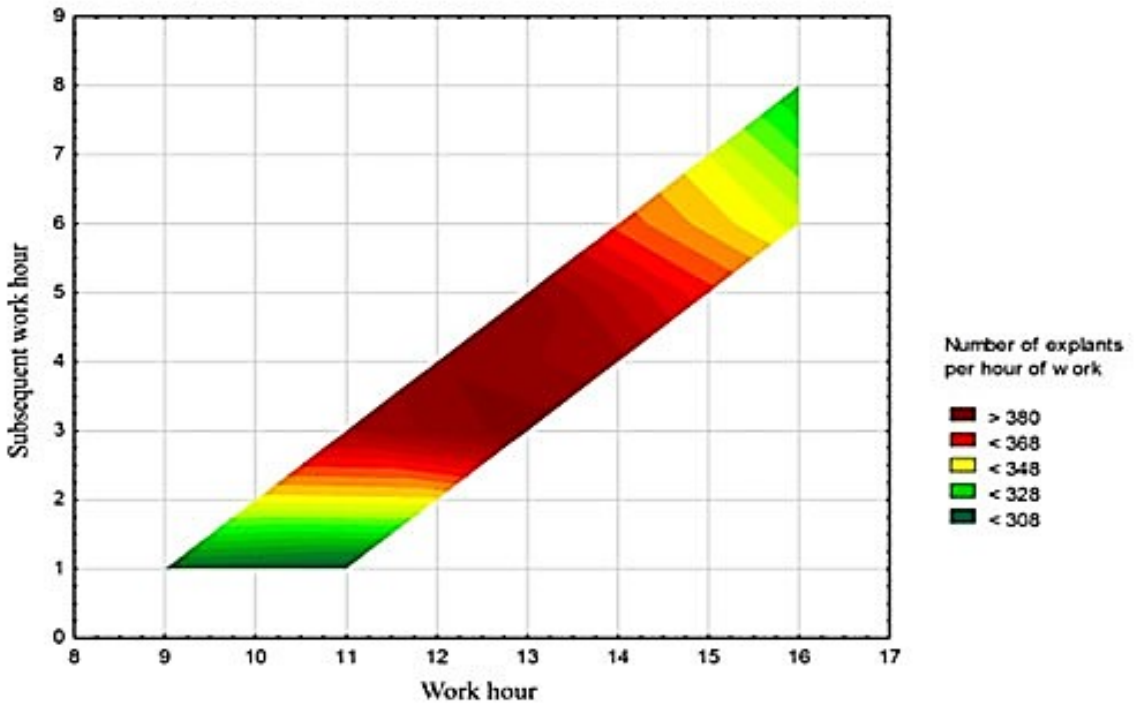

Figure 3. Number of explants per hour of work in subsequent work hour.

Source: own elaboration.

The results presented above were in addition conducted by statistical analysis. The value of all coefficients of variation for the combination C2 to C5 was 58%. The coefficients differed only in decimal values, whilst the coefficient of variation for the combination C1 was 7.1%. The variability for C2 to C5 is higher because work on other duties (other than plant

transplanting) were calculated as '0'. However, regardless of the zeros, the coefficient of variation in all combinations was the same.

The analysis showed that regardless of the organization of work during the day, there are no statistically significant differences in work efficiency. Graphic presentation of the phenomenon described is shown in figure 4. The p-value calculated for individual combinations was 0.9595, whilst the value of statistics H = 0.3029. Because p-value was higher than the assumed significance level $\alpha = 0.05$ therefore, the hypothesis 0 (H0) which stated there are no significant statistical differences between the employees work performance in one hour and the adoption of the way the work is organized.

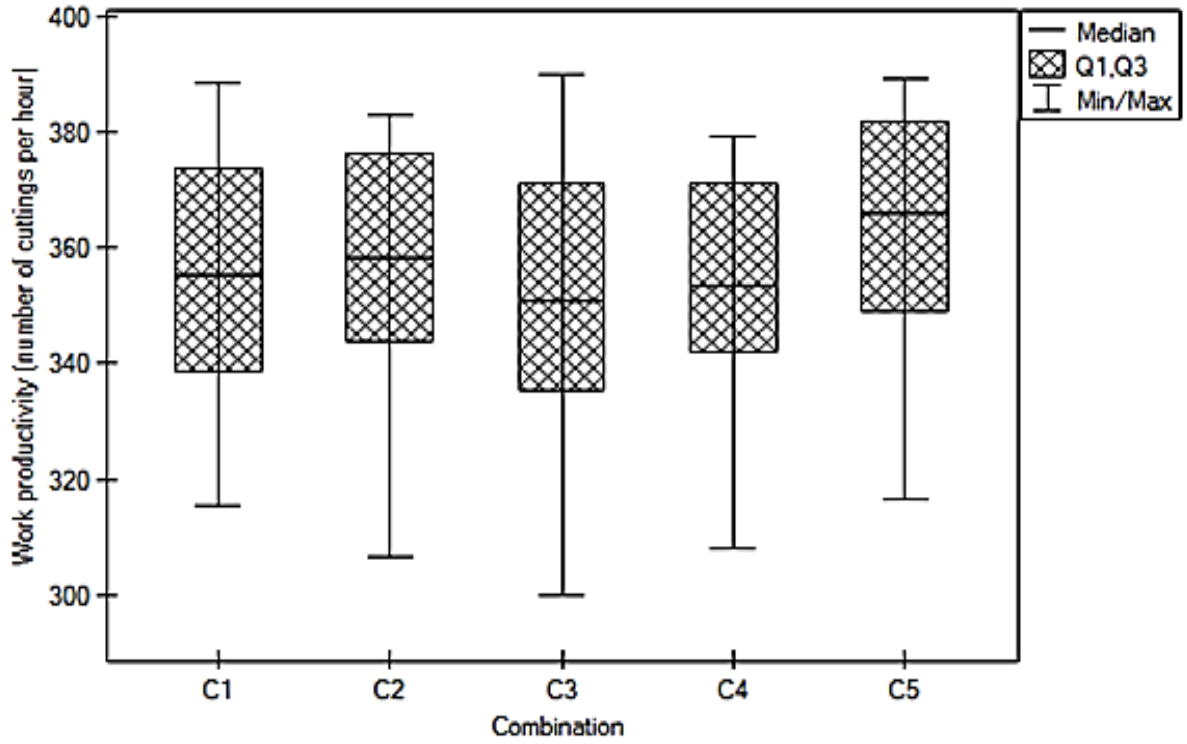

Figure 4. Hourly work efficiency and the work organization during the day based on the Kruskal Wallis ANOVA test*.

Source: own elaboration.

An examination was also conducted into which hour of work employees achieved the highest productivity (highest number of plants) in the control combination C1. Employees gained the highest productivity in the fifth hour, which resulted in 388.67 plants. This result was obtained after just 15 minutes of break from plant transplanting. This number of plants was used as the base productivity for further calculations concerning the Productivity Index. Among all combinations the largest number of plants 389.33 was gained in the fourth hour of work in C5, whilst the worst result, 294.90 plants, was obtained in the first hour in combination C3 (fig. 5).

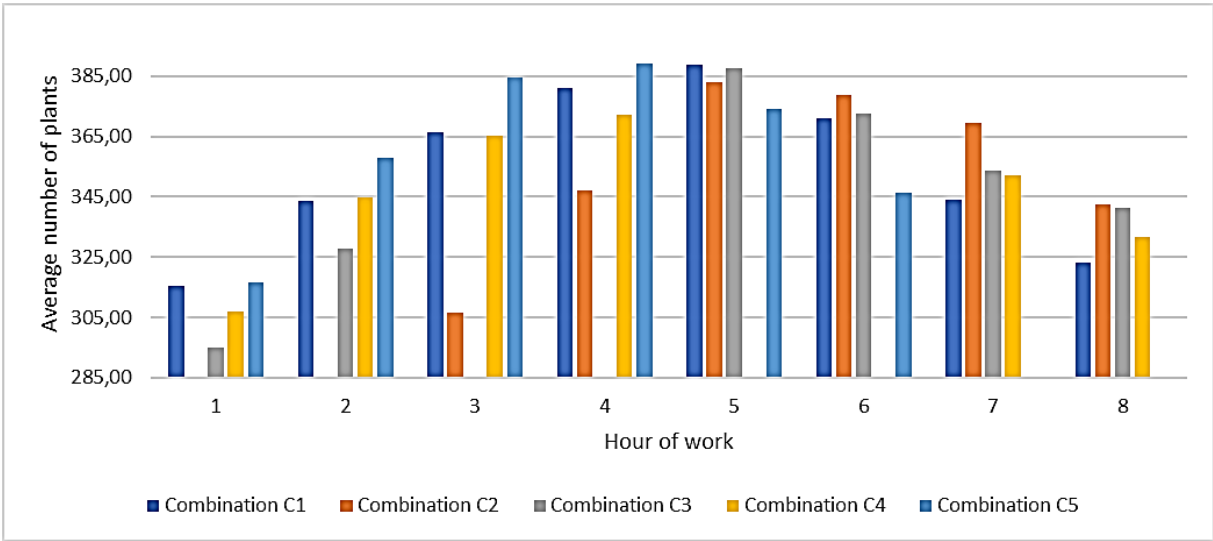

Figure 5. Arithmetic average number of plants produced in individual hours.

Source: own elaboration.

Exploring the Productivity Index the highest result for combination 1, 2 and 3 was in the fifth hour. A slight difference was observed in combination 4 and 5 where the highest PI was in the fourth hour. Whereas the lowest Productivity Index was obtained in the first hour of combination 3 and it was 0.76. In all combinations the Productivity index increased after the first hours to the middle hours of transplanting, after which it began to decrease (fig. 6).

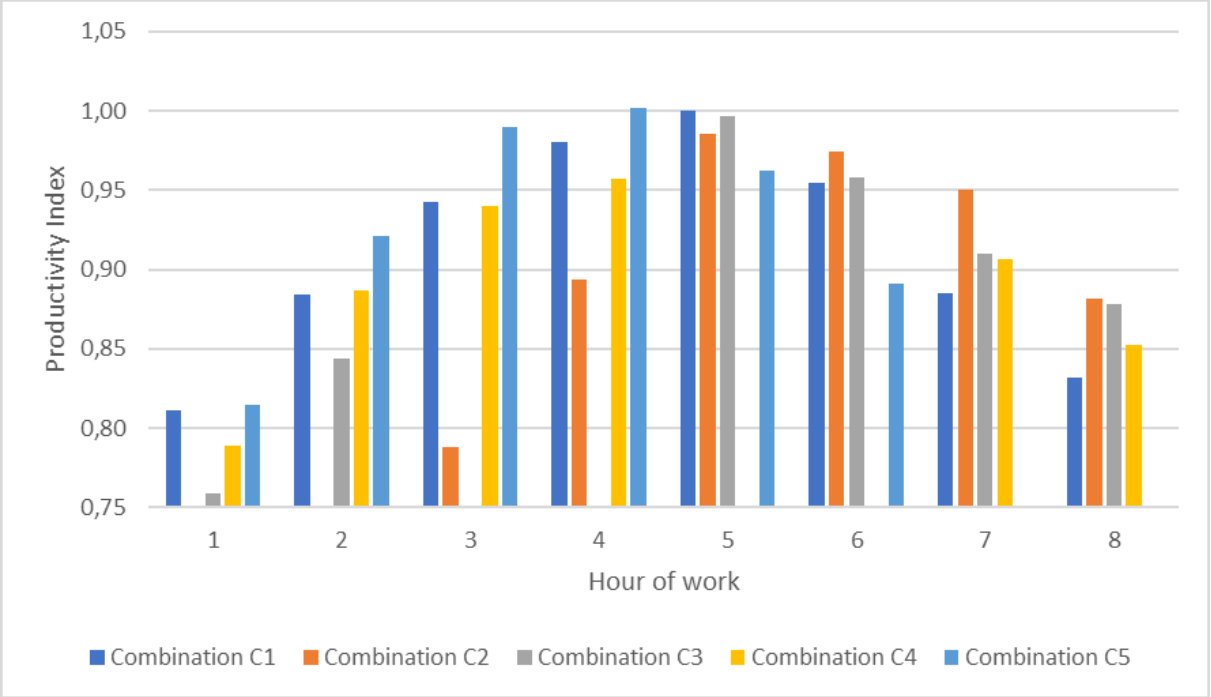

Figure 2. Productivity Index for combination C1-C5.

Source: own elaboration.

The Labour Productivity Index is a great tool used to indicate production efficiency per unit of time. In this study the most effective combination that occurred was C5. Starting the working day with six hours of plant transplanting resulting in LPI 361.44. This means that the average number of plants produced each hour in C5 was 361. The worst LPI was in C4 which was 345.42. A similar result was in combination 3. Disrupting plant transplanting procedures with other activities in combination C3 and C4 during work day leads to a decline in productivity (fig. 7).

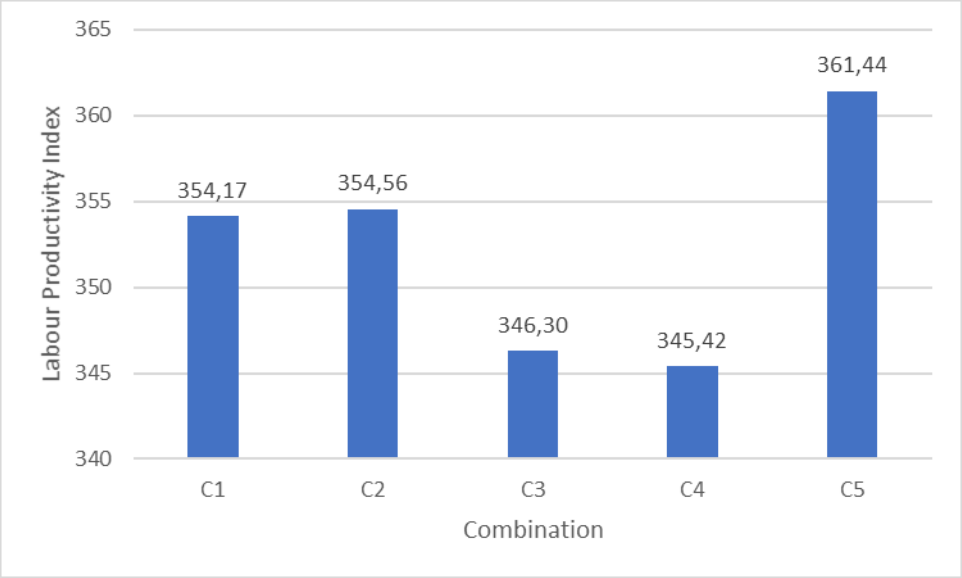

Figure 3. Labour Productivity Index (LPI) reffering to five combination in experiment. Source: own elaboration.

4. Discussion

Nowadays, when competition among companies is big, new innovative solutions are implemented to increase performance and profits. Because robots and computer programs still can not replace many human activities it is important to find solutions enhancing human productivity. In our study the proposal of six-hours work on the main task during an eight-hour workday was proposed. The study showed that LPI was the biggest when employees spent their first six hours of work on the main task and a further two hours were reserved for other duties. It suggests focusing on the main task in shorter, non-disrupted time which brings better effects. There is a trend for shortening the working day in the corporate environment, especially in offices. It is said to have a positive influence on work by reducing work time but there is little scientific research on its effects. Studies available show a reduction of productivity during extended working hours. It is supported by reliable measurements that show working overtime brings lower productivity. Shepard and Clifton (2000) indicated that in 18 manufacturing

industries overtime lowered average productivity. Similar results can be found across a number of industries. On average a 2.4% decrease in productivity was observed when a 10% increase in overtime was introduced. Working too many hours can lead to mental and physical problems, especially cardiovascular, diseases (Bosma et al., 1997; Stansfeld, Candy, 2006; Street, Lacey, 2018). Mental problems may be related to lower productivity. A good mental condition and avoiding stress can be essential for high performance at work. Street and Lacey (2018) showed that employees of a mining company in Queensland experienced stress during work have 19% lower productivity than employees who did not feel stress at work. So working less hours and in a good atmosphere can truly influence good performance in a company. On the contrary Collewet and Sauermann (2017) proved through an experiment on a call centre company that call quality does not decrease with growth of worked hours during the day. What is more it slightly improves.

Research on productivity should also be supported by the assessment of the reduction of labour costs. As mentioned in the literature review, the workforce can even absorb 60% of the total cost of production. There is a possibility of the reduction in this significant cost through proper workday organization and in this paper the proposal of such a solution was proposed. Our study proved that the middle of the working day is the most effective. This is a signal that during this time the most demanding task can be entrusted to the workers. The effect of higher efficiency in the middle of the day can be explained by assuming that just at the beginning of work the employee needs some time to increase their own work efficiency. In the next stage there is maximum efficiency moment. When employees sense the end of the working day efficiency decreases. A similar dependence was described by Bryson and Forth (2007) but over a period of a week. Monday and Friday occurred to be the less effective days of the week. On these days the smallest number of hours during the workday were really spent on work. Whereas on the middle days of the week, performance was the highest. The reasons for such similarities during weekly and daily changes in productivity are probably the same and are caused by free time after work and weekend rest. At the start of work in daily and weekly routines, rested people need time to re-gain the special co-ordination required to perform tasks which are often lost after rest time. Also similarly, faced with the feeling of the weekend approaching people focus more on plans for entertainment rather than on high performance at work.

5. Conclusions

1. The middle of the workday is characterised by the highest efficiency, so at this time of the workday the most demanding tasks should be entrusted. At the beginning and at the end of work, when performance is lower, less demanding tasks can be completed. These can include employees performing various duties, work in tissue culture laboratories should be organised as mentioned above.
2. In an eight hour workday combination the best productivity is gained in the fifth hour just after a fifteen minute break. The lowest productivity is gained when the main task (plant transplanting) is interrupted a by other duties for two hours.
3. The highest productivity is achieved in a combination when the main task was completed for six hours (starting from the first hour) during an eight hour working day.
4. However, it should be emphasized that hypothesis H0 which stated that there are no significant statistical differences between the employees work performance in each hour and the way the work is organized was confirmed.

References

1. Bosma, H., Marmot, M.G., Hemingway, H., Nicholson, A.C., Brunner, E., Stansfeld, S.A. (1997). Low job control and risk of coronary heart disease. *Whitehall II (prospective cohort) study*, *314*, pp. 558-565.
2. Bryson, A., Forth, J. (2007). Productivity and days of the week. Discussion Paper. *Royal Society for the encouragement of Arts, Manufactures & Commerce.*
3. Chiachung, C. (2016). Cost analysis of plant micropropagation of Phalaenopsis. *Plant Cell Tiss Organ Cult*, *126*, pp. 167-175.
4. Collewet, M., Sauermann, J. (2017). *Working hours and productivity. Discussion paper series.* IZA Institute of Labor Economics.
5. Freeman, R. (2008). Labour productivity indicators. Comparison of two OECD databases productivity differentials and the Balassa-Samuelson effect. *OECD Statistics Directorate Division of Structural Economic Statistics.*
6. Garris, L.B., Monroe, L.K. (2005). The Color Factor. *Journal of Buildings*, *99(10),* pp. 72-73.
7. Golden, L. (2012) The Effects of Working Time on Productivity and Firm Performance, Research Synthesis Paper. *Conditions of work and employment series*, *33*.
8. Haake, A.B. (2011). Individual music listening in workplace settings: An exploratory survey of offices in the UK. *Musicae Scientiae*, *15(1),* pp. 107-129.

9. Haneiko, J.B., Henry, W.C. (1991). Impacts to construction productivity. *Proceedings of the American Power Conference, 53-II,* pp. 897-900.
10. Karlikova, R., Pinosova, M., Hricova, B. (2016). Lighting quality and its effects on productivity and human health. *International journal of interdisciplinarity in theory and practice ITPB*, *10*, pp. 8-12.
11. Kossek, E.E., Lee, M.D. (2008). Implementing a Reduced-Workload Arrangement to Retain High Talent: A Case Study. *The Psychologist-Manager Journal, 11, No. 1,* pp. 49-64.
12. Kossek, E.E., Van Dyne, L. (2008). Face time matters: A cross-level model of how work-life flexibility influences work performance of individuals and groups. *Handbook of work-family integration: Research theory and best practices*, pp. 305-330.
13. Lesiuk, T. (2005). The effect of music listening on work performance. *Psychology of Music*, *33(2),* pp. 173-191.
14. O'Conner, L.V. (1969). Overcoming the problems of construction on large central station boilers. *Proceedings of the American Power Conference*, *31*.
15. Parkinson, C.N. (1955). Parkinson's Law. *The Economist*.
16. Pożoga, M., Olewnicki, D., Jabłońska, L. (2019). In Vitro Propagation Protocols and Variable Cost Comparison in Commercial Production for Paulownia tomentosa × Paulownia fortunei Hybrid as a Renewable Energy Source. *Appl. Sci.*, *9*, 2272.
17. Saraswathi, M.S., Uma, S., Kannan, G., Selvasumathi, M., Mustaffa, M.M., Backiyarani, S. (2016). Cost-effective tissue culture media for large-scale propagation of three commercial banana (Musa spp.) varieties. *The Journal of Horticultural Science and Biotechnology, 91, 1*, pp. 23-29.
18. Shepard, E., Clifton, T. (2000). Are Longer Hours Reducing Productivity in Manufacturing? *International Journal of Manpower*, *Vol. 21, No. 7,* pp. 540-553.
19. Souza, C.A., Rocha, J.F., Araújo, L.V., Espindula, C., Rondônia, E. (2015). Comparison of Economic Efficiency between in Vitro and Field Methods for Vegetative Propagation of Coffea Canephora. *Australian Journal of Basic and Applied Sciences*, *9(20),* pp. 1-7.
20. Stansfeld, S., Candy, B. (2006). Psychosocial work environment and mental health—a meta-analytic review. *Scand. J. Work Environ. Health*, *32*, pp. 443-462.
21. Staw, B.M., Barsade, S.G. (1993). Affect and managerial performance: A test of the sadder-but-wiser vs. happier-and-smarter hypotheses. *Administrative Science Quarterly*, *38*, pp. 304-33.
22. Street, T.D., Lacey, S.J. (2018).Accounting for Employee Health: The Productivity Cost of Leading Health Risks. *Health Promot. J. Aust.*, *30(2),* pp. 228-237.
23. Street, T.D., Lacey, S.J., Somoray, K. (2019). Employee Stress, Reduced Productivity, and Interest in a Workplace Health Program: A Case Study from the Australian Mining Industry. *Int. J. Environ. Res. Public Health*, *16*, 94.

24. Theorell, T., Hammarström, A., Aronsson, G., Träskman Bendz, L., Grape, T., Hogstedt, C., Marteinsdottir, I., Skoog, I., Hall, C. (2015). A systematic review including meta-analysis of work environment and depressive symptoms. *BMC Public Health*, *15*, 738.
25. Thorpe, T.A. (2007). History of plant tissue culture. *Mol. Biotechnol.*, *37*, pp. 169-180.
26. Vischer, J.C. (1989). *Environmental quality in office*. New York: Van Nostrand Reinhold.

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A NEW APPROACH TO PURCHASE IN DOMESTIC SMES

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Purpose: The main objective of the paper is to determine the way purchases are carried out in small and medium-sized domestic enterprises. In particular, the following research questions are asked: (1) in which activities do they use the Internet? (2) How willing are they to use electronic tools in purchases? (3) Have supply chain problems arising primarily from the COVID-19 pandemic and the war in Ukraine changed the buying habits of companies?
Design/methodology/approach: SMEs were selected as the subject of the research. The questionnaire study was quantitative in nature.
Findings: The specificity of purchasing in SMEs results mainly from a different way of managing organisations and often from a different approach to cooperation with suppliers. Research results show that small and medium companies are using the Internet increasingly in particular phases of the purchase process. They are becoming convinced (albeit slowly) of the electronic solutions available in the area of purchasing and appreciate their advantages. Supply chains and consumerization of B2B purchasing contribute to changing the approach of SMEs and popularising electronic tools.
Research limitations/implications: The article contains a preliminary study. In the future, additional research is planned on a comparison of the use of electronic solutions in the procurement of SMEs in individual industries and in different countries.
Originality/value: The article presents a detailed analysis of the reasons for the specificity of SMEs' purchase. In addition, the results of research on the use of electronic tools on the Internet in the purchasing process are discussed. The conclusions of the research are important for domestic SMEs and organisations that support the development of this sector.

Keywords: purchasing, electronic tools, supply chains, SME sector.

Category of the paper: Research paper.

1. Introduction

Purchasing is defined as a function responsible for the acquisition of materials, components (semi-finished products), parts, and services by purchasing, leasing, or otherwise legally in order to use them for production or resale (Lysons, Farrington, 2020). The effective functioning

of the supply sphere in the company not only affects the level of customer service, product quality, and costs of the entire logistics system, but also gives rise to a competitive advantage (Kowalska, 2005). Procurement is a strategic function that impacts operations, supply chain, quality, cost, and profits of manufacturing companies. Depending on the industry, companies can spend between 45% and 70% of sales revenue on the procurement of raw materials and professional services (Nitychoruk-Brzeska, 2018).

In recent years, much attention has been paid in the literature to the topic of purchasing in the B2B market. There are many publications on how companies buy and what new solutions they introduce in this area. However, descriptions of changes in sourcing tend to concern large enterprises. In this context, the topic of medium- and small-sized enterprises is relatively rarely discussed in the literature. As a result, little is known about the state of purchasing activities and supply management within SMEs, and it happens despite that SMEs play a very important role in a nation's economy.

Many different reasons for this situation are mentioned. First, the assumption that companies in the SME sector buy in the same way as large companies. Second, the conjecture is that most of them do not feel the need for changes in the area of supply and also do not have sufficient resources to carry out such activities. Third, due to many constraints in companies of this size, they are often described as ‘normative’ or ‘conservative’ buyers. This also concerns adoption of the solutions related to using the information and communication technology (ICT) in purchases – some publications indicate that SMEs are lagging in implementing modern solutions in their businesses.

This article aims to fill the gaps mentioned above; its main objective is to determine how small and medium-sized domestic enterprises use ICT in purchasing and what changes have recently taken place in their purchasing. In particular, answers to the following research questions are sought: (1) In what activities do they use the Internet? (2) How willing are they to use electronic tools in purchases? (3) Have the supply chain problems resulting from the COVID-19 pandemic and the war in Ukraine changed the buying habits of companies?

These answers were obtained through analysis of domestic and foreign literature and the author's own research conducted in domestic companies in the SME sector. The author conducted a survey among 126 small and medium enterprises in the Lower Silesia Region. It aimed to learn their preferences on how to use particular tools in the purchasing process and the rate of usage of individual solutions.

This paper is structured as follows. Section 2 describes the theory concerning the purchases in small and medium enterprises, including the specificity of SMEs (Section 2.1), the reasons for the changes, and the effects of those changes (Section 2.2). Section 3 concerns issues related to the use of electronic tools in SMEs purchasing (the description of tools, the benefits of use, and the level of use). The methodology and results of the research are presented in Section 4, and Section 5 summarises the discussion and final implications of the study.

2. Purchasing in small and medium enterprises

2.1. Specificity of purchases in SMEs

Micro, small, and medium enterprises (SMEs) significantly affect the economies of many countries (Sila, Dobni, 2012). They represent approximately 99% of all companies in the European Union and make a key contribution to the economy in terms of employment innovation and growth. In 2022 99.8% of 2.26 million companies in Poland belong to SMEs – 97% of them are micro, 2.2% are small, and 0.6% are medium (PARP, 2022).

Purchases in SMEs, contrary to appearances, are not conducted in the same way as in large enterprises and differ only in scale. Differences in approach are related to both different needs, a different way of managing smaller organisations, and limited possibilities of investments in this area (Ramsay, 2001).

Management in small and medium enterprises differs from activities carried out in this area in larger organisations. The main difference is the independence of the entrepreneur (owner), who not only manages and supervises, but also usually contributes capital to it. It establishes the principles on which the company is to operate and the goals it is to pursue. Who is responsible for making decisions and, consequently, is the sole risk associated with them, which often has a strong impact on the operation of the company (Gabryszak, 2008). The advantages of such one-person decision-making are the speed and ease of their implementation, but excessive centralisation and the lack of the ability to delegate tasks can become a significant obstacle in the development of the company when there is an increase in employment.

The management staff in SME companies is generally small. In small businesses, most activities, including those related to purchasing, are carried out by the owner. With the development of the organisation, a certain specialisation takes place, and some tasks are transferred to new employees; however, most of them are also responsible for several functions (Janczewski, 2016; Wagner et al., 2003). Managers focus on the most important tasks, so operational decisions are an important part of their daily management routine. Their time available for strategic thinking is limited, and they usually do not have enough time to analyse opportunities to improve the way they operate in particular areas (Paik et al., 2015).

SME sector companies operate most often on the local or regional market. The condition for success is good (often personal) contacts with contractors, which create a climate of mutual trust and allow for a better exchange of information. The consequence is a chance to react quickly to changes taking place on the market, especially since the simple organisational structure allows for a quick flow of information and appropriate response to signals coming from the environment (Safin, 2002; Smolarek, 2015).

Another issue is the approach to suppliers, who often have been cooperating with a given enterprise for a long time, and it is not a common practise to undertake activities related to the assessment of suppliers or seeking and obtaining new sources of supply. However, having long-term relationships with customers and suppliers, shaped over the years of activity, can constitute a competitive advantage in a situation where it is an asset that distinguishes the company from the competition. Often organisations do not even try to cooperate with foreign suppliers because they lack the necessary resources to search for purchasing solutions on a global basis (Quintens et al., 2005).

Small and medium-sized enterprises also often have a conservative approach to purchasing and are reluctant to introduce any changes in this area. This was visible, among others, in the low level of use of IT solutions that could speed up and simplify some activities. Often the reason is also the lack of knowledge about such tools. Statistics Poland's 2018 research on success factors in SMEs showed that information solutions and systems were perceived as important or very important by only less than 40% of entrepreneurs. There is a visible difference in the opinions of small and medium-sized entities: the larger ones are almost twice as likely to consider software as an important or key determinant of success (Statistics Poland, 2018).

However, research conducted in 2015 showed that of 120 entrepreneurs, only 12 mentioned the lack of specialised programmes and applications that facilitate online shopping as a barrier to the development of online commerce. At the same time, only three organisations used the possibilities to make electronic purchases. (Bartczak, 2016).

The biggest problems in supplying SMEs include (Jukowski, 2021; Mushanyuri, 2014):

1) Lack of awareness that the effective implementation of purchases can affect the profitability of the company. The consequence may be the low importance attributed to the purchasing function in the organisation.
2) There are no procedures specifying how the purchasing process should be conducted and the people responsible for it – everything is decided by the owner or, on the contrary, there are many people making purchases, and each of them is guided by their own rules.
3) Delegating responsibility for managing the purchasing process to random employees without education or experience in this area.
4) Lack of proper cost control, resulting in a dilution of financial responsibility.
5) Reluctance to use external help (training, consultants) – the reason is the belief in the uniqueness of the problems occurring in the organisation, the ability to solve them on their own, and the fear of intercepting the company's know-how by the competition.
6) No use of IT tools that could support the implementation of the purchasing process. The problem is usually caused not by the availability of such solutions but by the lack of willingness to organise the purchasing process, which is necessary when implementing such a tool.

2.2. Reasons for changes in SME purchasing

In the last few years, there have been significant changes in the situation of enterprises. The COVID-19 pandemic and the war in Ukraine have disrupted global supply chains. Supply problems in 2020 were experienced by 36% of companies in Poland, and on a global scale, this situation was declared by up to 58% of companies (PARP, 2020).

Small and medium enterprises were particularly affected - according to the SME Scanner report from the third quarter of 2022, up to 47% of the 500 companies surveyed from the SME sector felt the negative consequences of interrupting supply chains. The most burdensome effects included reduced sales (34%), as well as a decrease in profits and the need to look for substitutes and new suppliers (32% each). In response to these problems, companies began paying more attention to the location of suppliers and avoid single-sourcing solutions. A new trend, which occurs in almost every third company, is the creation of inventories. This action is primarily caused by the need to guarantee materials for future production (73%) and the fear of further increases in raw material prices (56%) (eGospodarka, 2022). However, a high level of stock, in turn, generates maintenance costs and requires adequate storage space and a team of employees who will handle them.

The latest problem is inflation. The results of the 'Company purchases' survey conducted in August 2022 among Polish micro and small enterprises show that up to 95% of them stated that the costs of their business activities have increased dramatically. The average increase in the prices of products and services needed to run a business was 37.4%, and according to entrepreneurs, the prices of raw materials (48%) and fuel (43%) increased the most (NFG, 2022). The increase in current operations costs was the reason for the change in the method of carrying out corporate purchases. Entrepreneurs indicated that they looked for promotions and price deals more often (35%), purchased cheaper substitutes (31%), or limited purchases (30%).

A positive change that has taken place in recent years has been the dissemination and reduction of the cost of using the Internet and computer hardware. According to the annual report 'Information Society in Poland', up to 98.2% of Polish small companies and 99.7% of medium companies had broadband Internet access in 2021. At the same time, up to 28.4% of small and 66.4% of medium enterprises indicated that in 2020 there was an increase in the level of use of information and communication technologies. To a large extent, this change was forced by the pandemic, the need to work remotely, and the lack of direct contact with contractors (Statistics Poland, 2022).

The trend observed in Poland is confirmed throughout the world. The results of the Techaisle worldwide survey of more than 3,600 SMEs show that in 2020 51% of SMEs increased their digital transformation investments and 22% reported such plans. SMEs with organisation-wide digital transformation experience 2.1 bigger cost reduction, have 1.9 better levels of customer intimacy, and 1.4 higher levels of productivity than the rest of the firms (Agrawal, 2020).

An additional element causing changes in the way shopping is done are new habits: younger employees (and also owners) more and more often notice how many things can be done via the Internet. Habits transferred from the B2C market and consumerization of B2B behaviour are also important here. A study by Salesforce Research on a group of almost 7,000 business customers showed that for 81% of them the customer experience (user experience related to the purchase process), especially the adaptation to buyer preferences in terms of communication, is as important as the products and services offered by the vendor. Respondents believed that the quality of services should be comparable to that they know from B2C platforms (Santander, 2021).

3. Electronic purchasing in domestic SMEs

3.1. IT tools in purchase

The greatest advantages of using electronic tools in supply market activities are access to comprehensive data resources not restricted by spatial and temporal barriers, saving time, low cost of data acquisition and convenience. There are two main types of electronic tools used to buy on the B2B market: the B2B online store and the B2B e-Marketplace (platform) (Prałat, 2017).

The B2B e-commerce website presents the offers of one supplier and is an online store acting only on the B2B market. It offers the product solely to registered customers. Not only a configuration of a product can be personalised, the amount of the discount or the deferment of the payment date can also depend on the previous cooperation quality or individual arrangements. There are various methods of product search: the standard way (by their names), by bar codes, manufacturer names, or their attributes (for example, by numerous technical parameters that characterised the product). B2B orders are usually repeatable, so a function of creating a new order on the basis of the previous ones is common. The choice of the product that best fits the buyer's needs is possible due to a comparison tool that considers numerous criteria (Prałat, 2018).

The B2B e-commerce website is usually integrated with company computer system (an Enterprise Resource Planning System, a Customer Relationship Management System, a warehouse or an accounting system). The full automation of the orders placement speeds up their realisation, reduces the possibility of mistake, and eliminates the need of a direct communication with suppliers.

The B2B e-marketplace presents the offers of numerous suppliers and is created to automate the purchase and sale process. This type of solution is usually created by an external operator, who makes it available to verified suppliers presenting their offers and buyers looking for

suppliers of goods or services. It is possible to find the required products, complete the transaction and settle it. Buyers search for products by browsing catalogues (they may be linked with the suppliers' sales platforms) or issue requests addressed to suppliers (for information, for a proposal, for a price). The B2B e-marketplace also provides advanced search and communication tools (Radzikowska, 2014).

An additional element available on the platform are electronic auctions conducted in real time, which causes stronger competition among bidders and, as a consequence, allows for significant savings (price reduction is on average 15%) (Wyld, 2011). Another advantage is the increased credibility and transparency of the auction results. Purchase auctions can be used in various situations: from one-off purchases of products, through the selection of suppliers of goods of a specific type (framework contracts) and ending with the finding suppliers of various types of services (cleaning, maintenance) (Prałat, 2017).

Communication is simplified and accelerated both between all employees involved in purchasing processes and between companies that are parties to the transaction. An important issue is also the ability to optimise procurement processes and supervision over the budget of each cost centre. In turn, the main benefit offered by platforms to suppliers is that it is easier to reach customers with their offer and thus increase the number of concluded transactions. Purchasing platforms are sometimes very extensive and have many different functionalities; however, their modular structure causes the customer to pay only for those elements that he actually uses.

The use of IT tools in the company that support the purchase process gives the company the opportunity to achieve many benefits. They are related to the areas discussed below (Ścisło, 2015; Deloitte & Aleo, 2017; Prałat, 2017; Sánchez-Rodríguez et al., 2020):

a) Reduction of purchase prices. Purchasing platforms allow the use of quantitative leverage: suppliers can offer products with a lower unit margin thanks to the aggregation and unification of orders on procurement platforms.
b) Savings resulting from expanding the supplier market. Purchasing platforms aggregate information about offers, but also constitute a database of potential suppliers, also geographically distant. They also enforce the standardisation of products and services and facilitate their comparison. These conditions are conducive to free competition, which, in turn, translates into more favourable (compared to traditional markets) offers to customers. An additional benefit is also that it reduces the time to search for suppliers, analyse offers, and negotiate transaction terms.
c) Process and organisational benefits. B2B e-commerce websites provide buyers with tools to support the purchase planning process, supplier credibility analysis, billing, and document circulation. For large enterprises, they also facilitate the consolidation of orders from different departments.

d) Management benefits. Through specialised purchasing platforms, buyers have easier access to historical data, which is conducive to their analysis and making decisions on this basis, reducing the company's supply costs (e.g., negotiating more favourable terms with the supplier based on information on the total transaction volume from the last few years).
e) Business performance. Performance gains are related to increased productivity, return on assets, and return on investment. e-procurement is regarded as a capability that can lead to a sustained competitive advantage.

3.2. The level of use of information technology in purchases in domestic SMEs

The introduction of IT solutions is proof of the innovativeness of the organisation, i.e., the ability of both owners and employees to search for, implement, and disseminate innovations. It is often considered a measure of the level of modernity and company progress (Zakrzewska-Bielawska, 2011). Various types of innovation are being implemented in small and medium-sized domestic enterprises. When it comes to innovative methods of data processing or communication, in 2018-2020 11.2% of companies in the industrial sector and 15.6% of those providing services used them. It should be noted that compared to the previous research period (2017-2019), the results of industrial companies doubled and, in the case of the enterprises providing services, increased at least three times (PARP, 2022). In 2021, almost 60% of medium-sized enterprises used ERP systems, i.e. software that enables the management of enterprise resources through the exchange of information between various departments of the company. This result means an increase of almost 6% compared to 2019. Among small enterprises, systems of this type were used by 24.4%, and the increase was slightly greater than 3% (Statistics Poland, 2022).

According to the Deloitte & Aleo report (Deloitte & Aleo, 2017), small and medium enterprises use B2B e-commerce tools not only to buy, but also to support purchasing planning, supplier credibility analysis, and negotiation. Executing these tasks in a short time is particularly important for SMEs, where, as mentioned in Section 2, purchasing is often handled by managers who also have many other responsibilities.

A study conducted in the first quarter of 2022 by Marketplanet shows that small companies (up to 50 employees) are very active in using B2B e-commerce tools. The percentage of companies that indicated the use of a purchasing platform (marketplace), B2B online stores provided by suppliers, and their own catalogues corresponding to the warehouse's material indexes was almost the same. It amounted to about 25% in case of a purchasing platforms and to about 20% for their own catalogues. The highest result (30%) concerned the use of B2B online stores and is also related to the widespread use of e-catalogues to reduce potential errors in purchase specifications and to cut customer service costs (Marketplanet, 2022).

The results obtained also show that the Internet is the basic tool for searching for sources of supply and suppliers. Regardless of the size of the company, Google is the most popular search engine, and price comparison websites are also highly rated.

Respondents were also asked about the elements that discourage them from buying on the electronic market. However, up to 27% of them pointed to the 'lack of precise description of the products', however, there were many more opinions pointing to the low quality of the data contained in the e-catalogues and the difficulty of searching for them. The respondents also mentioned the long time needed to search for an item of purchase (23%), low efficiency in searching for products in catalogues (20%) and low quality of product descriptions (10%) (Marketplanet, 2022).

4. Research methodology and results

4.1. Research methodology

To evaluate the use of electronic tools in the purchase process, a study was conducted among small and medium companies in the Lower Silesia Region. This research was part of a more extensive research carried out by the author related to purchases in small and medium sized Polish enterprises (Prałat, 2020). The research tool was the questionnaire form, and the CAWI survey technique was used. Only the part of the questionnaire whose results are used in this paper will be discussed. The main objectives were the following.

- to determine whether SME companies use the Internet in the purchasing process,
- to determine the level of usage of electronic tools at individual stages of the purchasing process,
- to determine the advantages of electronic tools in the purchasing process,
- examine possible differences in actions between small and medium enterprises.

The mentioned part of a questionnaire consisted of four questions, most of them closed-ended, with nominal or ordinal scale. Moreover, the respondent's particulars part included questions concerning the enterprise size (the only division criterion was number of employees: small enterprises employed 10 to 49 persons and medium-sized ones employed 50 to 249 persons), industry, business line, etc. After introducing the necessary changes resulting from a pilot survey, the main survey was conducted. 126 questionnaires really concerned small and medium companies and were correctly completed (Prałat, 2020).

4.2. Discussion and results

In 90 small and 36 medium-sized enterprises participated in the research. They operate mainly in the trading, service, and manufacturing industries. Small enterprises operated first of all in local and regional markets and medium ones in regional and national markets. Almost three-fourths of medium-sized enterprises (72.3%) and more than half of small enterprises (52.3%) operated on the market for more than five years (Prałat, 2020).

An average score was calculated that shows the frequency of using the Internet for each individual action related to buying (0 points were assigned to the answer 'never' and 4 points were assigned to the answer 'very often'). Depending on the sizes of the companies examined, there are differences between levels of use of the Internet in purchasing. The results shown in Figure 1 indicate that small companies use the Internet in 11 of 12 analysed actions. The largest difference appeared in the case of 'call for tenders' and was equal to 0.92 points. An advantage for medium-sized enterprises was also great in the case of setting contract terms (0.79) and searching for the product and establishing contacts with the supplier (in both cases, the difference was equal to 0.75 points).

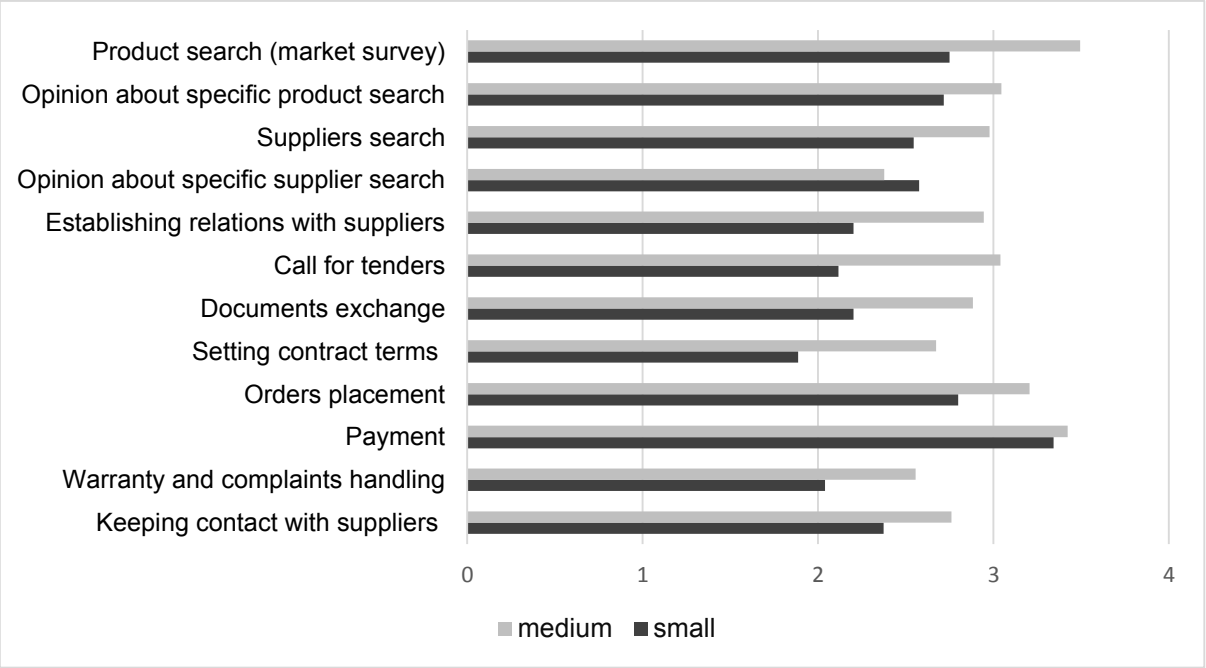

Figure 1. Use of the Internet at individual stages of the purchasing process: differences between small and medium-sized enterprises.

Source: Prałat, 2020.

In the case of online shopping, B2B online stores are used the most, where 47.4% of medium-sized businesses and 21.1% of small businesses make their purchases (Figure 2). B2B e-marketplaces are used much less frequently, only by 26.3% of medium-sized and 10.5% of small enterprises. The use of these platforms is often payable, so it may be the reason, moreover companies can be afraid of their insufficient skills or have no awareness of the benefits that can be reached by use of such a solution.

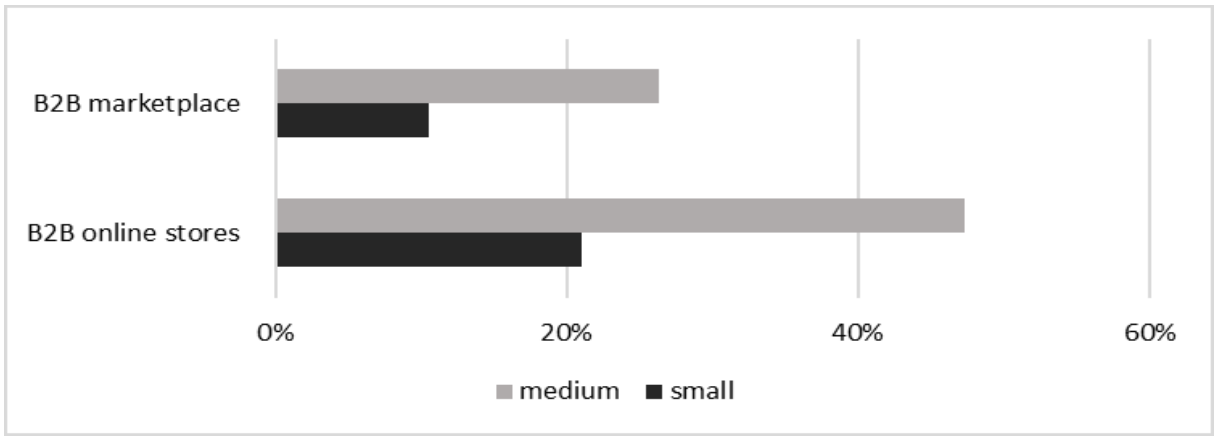

Figure 2. Use of electronic tools in purchasing: differences between small and medium enterprises.

Source: own.

Respondents were asked to indicate the greatest benefits of using electronic tools in the purchase process. They could choose up to three of the seven proposed answers. Medium-sized companies indicated 'convenience' (72%), 'possibility of reaching out to many suppliers' (67%) and 'lower prices' (61%).In the case of small companies, the three main advantages were the same. The benefit of 'quick and easy communication with suppliers' was also highly rated by respondents regardless of the size of the company. The results are shown in Figure 3. The only benefit rated higher by the respondents from small companies was 'unlimited access to information', which can mean that obtaining information is easier in medium companies.

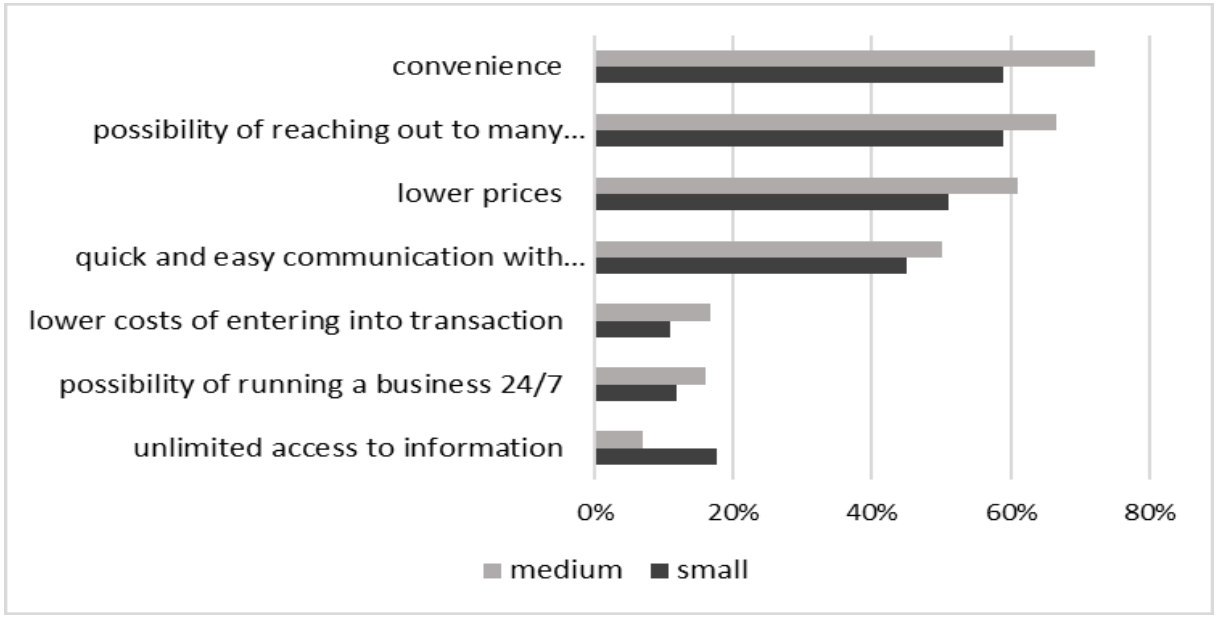

Figure 3. Perception of the benefits of electronic tools in the purchasing process – differences between small and medium-sized enterprises.

Source: own.

5. Conclusions

The main objective of the paper is to determine the way SMEs use the Internet and electronic tools in purchasing, and how the problems with the durability of supply chains influence the way of application of new solutions. The author's own research and a review of the latest literature allowed the search for answers to the research questions posed at the beginning of the article.

The Covid-19 pandemic and the war in Ukraine made it necessary to analyse existing sources of supply and identify new ones. Inflation, on the other hand, influenced the search for savings. Therefore, often even those enterprises in which supply chains are still functioning correctly, analyse them in terms of profitability and consider new opportunities, also in terms of supplying enterprises.

The long-term effect may be not only deglobalization, but even regionalisation of supply chains and a change in the way of thinking about suppliers. Weak links in supply chains should be identified in advance, key suppliers should be qualified in detail, and relations with them properly managed (strengthening cooperation).

In small and medium-sized enterprises, after a long period of cooperation with regular suppliers, often without regular market analysis, managers decided to perform a market analysis and verify the competitiveness of the received offers. The results of the author's research show that the Internet is now a common source of information for Polish enterprises from the SME sector, which is used both to search for information about products and opinions about companies that offer them. The Internet then facilitates obtaining information from potential suppliers (for example, RFI, RFP, RFQ or even simple e-mail exchange).

Polish enterprises from the SME sector, despite the fact that they are considered more traditional compared to larger organisations, are also more and more willing to use electronic purchases, appreciating the convenience, possibility of reaching out to many suppliers and lower prices. The issue of facilitating communication with suppliers is also highly appreciated. According to forecasts (EFL, 2021), over the next five years there will be an increase of at least 1/3 in the number of enterprises from the SME sector that will make purchases in this way.

The biggest enthusiasts are primarily younger managers, but older buyers are also convincing them. This is related to the already mentioned consumerization of purchases on the B2B market. It should be emphasised that in addition to B2B online stores, small and medium-sized entrepreneurs are increasingly willing to shop on B2B trading platforms, including the Allegro Biznes platform launched in 2020, where they can find more than 200 million offers from various industries.

The paper focusses on the analysis of the Internet and the use of electronic tools in the purchase of Polish SMEs. It is a preliminary study with some limitations. The first limitation results from the fact that the surveys were conducted at the beginning of the pandemic.

It is worth repeating them and comparing the obtained results. The study was also limited by the sample, which covered only a single country. Therefore, extending them to other countries should also be considered.

References

1. Agrawal, A. (2020). *Digital transformation on the radar of SMBs*. Retrieved from: https://techaisle.com/blog/412-digital-transformation-on-the-radar-of-smbs, 11.10.2022.
2. Bartczak, K. (2016). *Bariery rozwojowe handlu elektronicznego*. Wrocław: Exante.
3. Deloitte & Aleo (2017). *Raport. Digitalizacja rynku B2B. Cyfrowe platformy zakupowe*. Retrieved from: https://aleo.com/_fileserver/item/14139/Raport_Aleo-Deloitte_2017_online-1.pdf, 22.09.2022.
4. EFL (2021). *Raport. Cyfrowa (r)ewolucja na rynku leasingu. Pod lupą.* Retrieved from: https://efl.pl/wp-content/uploads/2021/06/efl_cyfrowa_rewolucja.pdf, 11.10.2022.
5. eGospodarka (2022). *Przerwane łańcuchy dostaw problemem blisko połowy firm.* Retrieved from: https://www.egospodarka.pl/177816,Przerwane-lancuchy-dostaw-problemem-blisko-polowy-firm,1,39,1.html, 11.10.2022.
6. Gabryszak, R. (2008). Zastosowanie zdolności menedżerskich w systemie funkcjonowania przedsiębiorstwa. In: S. Piocha, R. Gabryszak (Eds.), *Ekonomia menedżerska dla MSP*. Warszawa: Difin.
7. Janczewski, J. (2016). Logistyka w mikro i małym przedsiębiorstwie. *Zarządzanie Innowacyjne w Gospodarce i Biznesie. Vol. 1, No. 22,* pp. 113-126.
8. Jukowski, K. (2021). *5 (zakupowych) grzechów głównych MŚP*. Retrieved from: https://pl.linkedin.com/pulse/5-zakupowych-grzech%C3%B3w-g%C5%82%C3%B3wnych-m%C5%9Bp-krzysztof-jukowski, 10.10.2022.
9. Kowalska, K. (2005). *Logistyka zaopatrzenia*. Katowice: Akademia Ekonomiczna.
10. Lysons, K., Farrington, B. (2020). *Procurement and Supply Chain Management*. Canada: Pearson Education Limited.
11. Marketplanet (2022). *Raport. Rynek e-commerce B2B w Polsce*. Retrieved from: https://s3-eu-west-1.amazonaws.com/landingi-editor-uploads/gNLLpYVq%2FeCommerce_B2B_w_ Polsce_raport_Marketplanet.pdf, 20.09.2022.
12. Mushanyuri, B.E. (2014). An Investigation into the Purchasing Practices by Small to Medium Enterprises (SMES) in the Leather, Clothing and Textile Manufacturing in Zimbabwe – Case of Harare SMES. *The International Journal of Business & Management, Vol. 2, Iss. 12,* pp. 278-282.
13. NFG (2022). *Raport. Zakupy firmowe*. Retrieved from: https://nfg.pl/blog?page=11, 18.09.2022.

14. Nitychoruk-Brzeska, K. (2018). *Here are the 5 reasons why e-procurement makes sense for SMEs*. Retrieved from: https://www.nextbuy24.com/en/2018/03/07/e-procurement-in-sme/, 22.09.2022.
15. Paik, S.K., Prabir, B., Skjøtt-Larsen, T., Adams, J. (2009). Purchasing Development in Small and Medium-Sized Enterprises (SMEs). *Supply Chain Forum: An International Journal, Vol. 10, Iss. 1*, pp. 92-107.
16. PARP (2020). 2020 *Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce.* Warszawa.
17. PARP (2022). 2022 *Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce*. Warszawa.
18. Prałat, E. (2017). Możliwości elektronicznych zakupów na polskim rynku B2B. *Nierówności Społeczne a Wzrost Gospodarczy, Vol. 52, No. 4*, pp. 500-509.
19. Prałat, E. (2018). Elektroniczne platformy handlowe na polskim rynku B2B. *Ekonomiczne Problemy Usług, Vol. 131, No. 2,* pp. 187-195.
20. Prałat, E. (2020). *Internet in Purchase Processes of Polish SMEs.* Proceedings of the 35th International Business Information Management Association Conference (IBIMA). K.S. Soliman (Ed.), pp. 6229-6242.
21. Quintens, L., Matthyssens, P., Faes, W. (2005). Purchasing Internationalization on Both Sides of the Atlantic. *Journal of Purchasing and Supply Management*, *Vol. 11, No. 2,* pp. 57-71.
22. Radzikowska, A. (2014). *Specjalistyczne platformy handlowe*. Retrieved from: https://spolecznosc.ing.pl/-/Blog/Specjalistyczne-platformy-handlowe-B2B/ba-p/90, 22.09.2022.
23. Ramsay, J. (2001). Purchasing's Strategic Irrelevance. *European Journal of Purchasing & Supply Management*, *Vol. 7, No. 4,* pp. 257-263.
24. Sánchez-Rodríguez, C., Martínez-Lorente, A.R., Hemsworth, D. (2020). E-procurement in small and medium sized enterprises; facilitators, obstacles and effect on performance. *Benchmarking: An International Journal, Vol. 27, No. 2,* pp. 839-866.
25. Santander (2021). *E-commerce B2B – biznes w sieci*. Retrieved from: https://eizba.pl/wp-content/uploads/2021/10/eCommerce-B2B-Raport.pdf, 10.10.2022.
26. Sila, I., Dobni, D. (2012), Patterns of B2B e-commerce usage in SMEs. *Industrial Management & Data Systems, Vol. 112, No. 8,* pp. 1255-1271.
27. Smolarek, M. (2015). Wybrane aspekty rozwoju małych i średnich przedsiębiorstw. *Zeszyty Naukowe Wyższej Szkoły Humanitas. Zarządzanie.* Retrieved from: https://www.humanitas.edu.pl/resources/upload/dokumenty/Wydawnictwo/Zarzadzanie_zeszyt/Zarzadzanie%20zeszyt%203_2015%20podzielony/smolarek.pdf, 21.10.2022.
28. Statistics Poland (2018). *Uwarunkowania rozwoju przedsiębiorczości w sektorze MŚP*. Warszawa.
29. Statistics Poland (2022). Społeczeństwo informacyjne w Polsce w 2021 r., Warszawa.

30. Ścisło, A. (2015). Platformy zakupowe business-to-business jako innowacja procesu zakupowego małych i średnich przedsiębiorstw. *Nowoczesne Systemy Zarządzania, Vol. 10, Iss. 1,* pp. 249-260.
31. Wagner, B.A., Fillis, I., Johansson, U. (2003). E- business and e- supply strategy in small and medium sized businesses (SMEs). *Supply Chain Management*, *Vol. 8, No. 4,* pp. 343-354.
32. Wyld, D.C. (2011). Current Research on Reverse Auctions: Part II - Implementation Issues Associated with Putting Competitive Bidding to Work. *International Journal of Managing Value and Supply Chains (IJMVSC), Vol. 2, No. 4,* pp. 101-115.
33. Zakrzewska-Bielawska, A. (2011). Relacje między strategią a strukturą organizacyjną w przedsiębiorstwach sektora wysokich technologii. *Zeszyty Naukowe, No. 1095*. Łódź: Wydawnictwo Politechniki Łódzkiej.

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TOWARDS CHANGE – FROM CLASSICAL TO CONTEMPORARY APPROACHES AND CLASSIFICATION OF INNOVATION

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Purpose: The aim of this paper is to capture the changes taking place in terms of capturing innovations, as well as the types of innovations emerging from them, characteristic of two research streams: classical and contemporary.
Design/methodology/approach: The methodology applied in the article refers to the methodological canon of management sciences, including, among others, conceptual-theoretical research methodology. On their basis, a critical analysis of foreign and Polish literature on the subject in the field of management science, partly marketing and economics, was carried out. At the same time, a descriptive method and a comparative method were used to interpret and analyze the collected material.
Findings: Significant changes taking place in the definition and classification of innovations by selected representatives of the studied currents were recognized. Significant factors causing these changes were identified, as well as the new values that appear in them. On this basis, it was shown that the understanding of innovation is significantly expanded over the years, because of which it should be considered incomplete. This justifies the continuing need to analyze emerging approaches and types of innovation.
Research limitations/implications: The analysis of the subject matter in the proposed methodological approach makes it possible to systematize the knowledge of innovation in terms of defining the category "innovation" and its typology. Thus, it increases the recognition of the changes that accompany them. The important role of the factor of time, environment, information technology, values, and new needs of the recipients of innovations in the studied process is recognized.
Originality/value: Deepening and updating the knowledge of defining categories of innovation and their classification. Evaluation of progressive changes in the scope of the concepts studied.

Keywords: innovation, change, development, classifications of innovation.

Category of the paper: A literature review.

1. Introduction

Issues related to the development and creation of innovations have for years been an important topic covered in both domestic and foreign scientific journalism, in which various aspects of innovation are discussed. One of them is undoubtedly the evolution of changes that are taking place in the process of interpreting and understanding the category of innovation. This evolution, as indicated by the considerations of many authors (among others: Talukder, 2014; Borowiecki, Dziura, 2016; Dieter, Schmitt, 2018; Ober, 2022) is an expression of a broader process of change associated with the transition from an industrial economy to a knowledge-based economy. Within them, two defining trends can be distinguished: classical and contemporary (Arnason, 2015; Chen, 2023). Hence, capturing the changes taking place in terms of framing innovation, as well as the emerging types of innovation characteristic of the two research currents was made the main objective of the study.

The rationale for considering the question of interpretation and typology of innovations stems primarily from two facts. First, innovations occupy an important place in the economy, contributing to the growth of competitiveness, which is undoubtedly their asset and the cause of development (Zastempowski, 2014; Borowiecki, Dziura, 2016). The second premise of a scientific nature stems from the fact that several studies on innovation can be found in the literature, but the aspect linking the modern with the classical definition of innovation requires continuous learning and consolidation of the knowledge derived from it. The significant dissimilarity of the classical and modern notion of innovation is pointed out, among others, by Żabiński (2013), Tidd and Bassant (2005), O'Sulivan and Dooley (2009), Prahalad and Krishnan (2012) and Dieter and Schmitt (2018). Confirmation of the above problem is the dissimilarity of definitional approaches in the literature. The issue addressed is reflected in the title of the study.

2. Theoretical Background

Based on a review of the scientific literature, important concepts for the research area were analyzed. Their problem scope includes various approaches and classifications of innovation as important for the development of science and business practices.

2.1. The Classical Current and its Defining Approaches

Referring to the classical trend, it is worth starting with an analysis of the colloquial understanding of innovation. The literature states that the term means something new and different from existing solutions, which is generally associated with a needed change for the

better. The concept of innovation was first introduced into the literature of economic science in 1911 by J. Schumpeter, seeing it as a source of economic development.

This author made important contributions to the development of innovation theory in the 20th century. In his reflections, he focused on explaining and emphasizing the functional role of innovation (including entrepreneurship). Relating innovation to five areas, as shown in Table1.

Table 1.
Capturing innovation according to J. Schumpeter

Innovation area	Importance innovation
New product	Innovation means introducing a new product that consumers have not yet encountered or giving new features to a product.
New production method	Innovation means the introduction of a new method of production, not yet tried in a particular industry.
New market	Innovation is the opening of a new market, i.e., one in which a particular type of domestic industry has not previously operated, regardless of whether the market existed before or not.
New source of raw materials	Innovation is the acquisition of a new source of raw materials or semi-finished products regardless of whether that source already existed or had yet to be created.
New structure of the organization	Innovation refers to the introduction of a new structure for the organization of some industry, such as the creation of a monopoly or the breaking of a monopoly.

Source: Schumpeter, 1960, p. 104.

The approaches to innovation presented above, due to the very broad spectrum of analysis, have been significantly modified over the years. As a result, the object scope of the classical concept of innovation has expanded, mainly due to the intensive development of services (1980s and 1990s), but also the development of marketing, and yet another (new) approach to management, including organization (Dieter, Schmitt, 2018).

Significant achievements in the above regard should be attributed to the modern pioneer of the study of innovation and entrepreneurial processes, P.F. Drucker. This author defines innovation in demand terms "as a change in the value and satisfaction of consumer needs, through the use of certain resources" (Drucker, 1992, p. 42). They are also a change in the process by which people work and produce something. Successful entrepreneurs (regardless of their individual situation) seek to create value, that is, to make a specific contribution. However, they are not satisfied with mere modifications, so they try to create thereby new and different values, new and different ways of satisfying needs, transform a material into a resource or combine existing resources into a new, more efficient configuration of them. In the accepted logic, innovation is more of an economic or social concept than a technical one. Hence P. Drucker (1992) introduced into professional terminology the concept of so-called systemic innovation, which consists of a deliberate and organized search for change and a systematic analysis of the opportunities for social or economic innovation that such change could enable.

R. Rothwell (1990) on the other hand, analyzes innovation by defining five generations of the innovation model, distinguishing between the technology-pushed model, the market-pulled model, the combined model, the integrated, parallel model and the integrated, network model. The approach used reflects the evolution of changes in defining the concept under analysis, also pointed out by D. O`Sulivan and L. Dooley (2009) showing that these changes, were in market economies after World War II in successive periods "pushed" by technology, "pulled" by the market, shaped by both of these stimulators combined, dynamized over time in the process of progressive globalization, and crossed the boundaries of innovator companies to ensure innovation success. Instead, over time, they have come to rely on knowledge retrieved and adapted to the distributed economic and social networks in which modern innovative companies increasingly operate (Putri, Rumamby, Mercia, 2018).

A large contribution to the development of the studied concept was made by the representative of management and competition sciences M.E. Porter (2001, p. 23) who in his definition of innovation emphasizes its competitive nature, defining it as: "the economically successful exploitation of new ideas". In this approach, in addition to fundamentally new products and processes that are new to industry or commerce, innovation also includes simple modifications that are new to individual companies.

In turn, according to R.U. Ayres (1987, p. 350) pointing to the economic aspect of the issue at hand, innovation should be understood as: "creativity, involving the production of new products, new technological processes, as well as the organization of a new enterprise. Coinciding with this view is the position of H.G. Barnett (1985), who in defining innovation emphasizes originality, a significant difference from existing solutions, while emphasizing the importance of innovation in the changes taking place in the economy.

In the area of Polish literature on the subject, changes in the perception of innovation and innovative activities of enterprises were introduced only by the systemic transformation. As a result of its processes in the economy, the economic aspect of innovation came to the fore (as in the case of foreign researchers), and the technical aspect receded into the background.

Among the Polish representatives of the above trend, it is worth mentioning, among others: S. Marciniak, I. Hejduk, W. Grudzewski, A. Pomykalski and S. Gomułka, although it should be emphasized that this group is formed by a much broader group of researchers who have contributed to the development of classical approaches to innovation. The cited authors, like foreign representatives of the analyzed trend, make various attempts to interpret the concept of innovation, as shown in Figure 1.

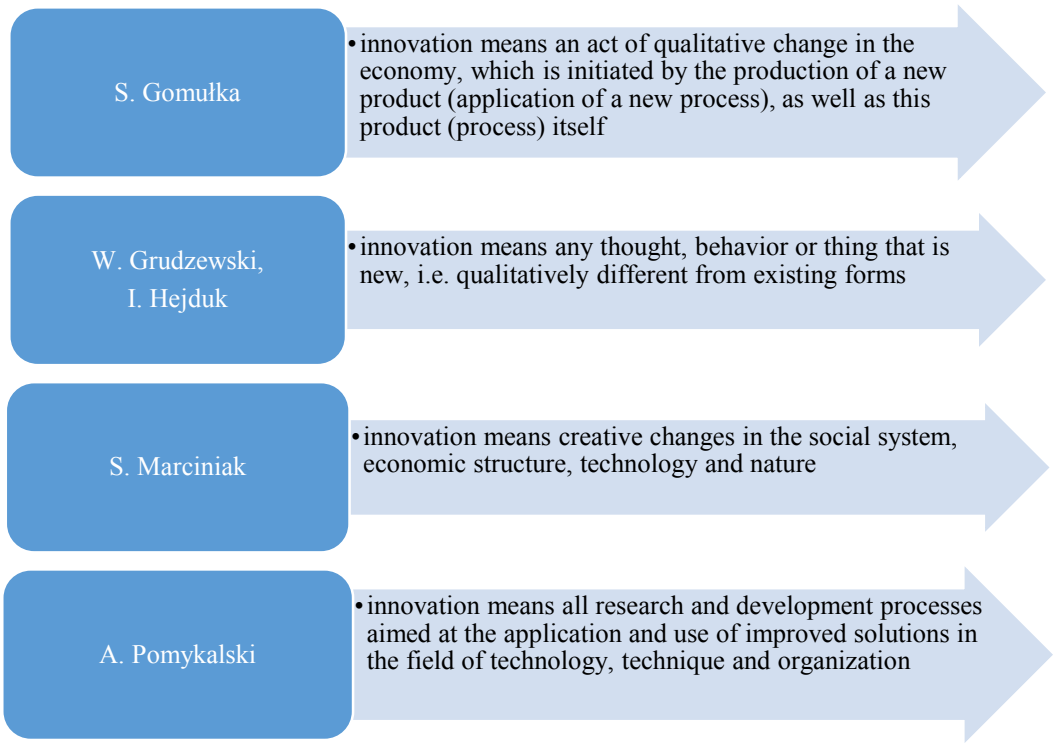

Figure 1. The concept of innovation according to selected Polish representatives of the literature on the subject.

Source: elaboration based on Gomułka (1998, pp. 17-20); Grudzewski, Hejduk (2000, pp. 138-140); Marciniak (2000, pp. 11-18); Pomykalski (2001, p. 17).

In addition to the above-mentioned authors, an original approach to the definition of innovation is expressed by the excellent Polish historian Professor Gerard Labuda (2008, p. 561), according to whom the history of civilization is the history of innovation. According to him, every innovation arises and develops in three stages. First, an idea or project, i.e., invention, is born in the head of the creator, then from the realized idea a work or deed is created, i.e., innovation in the strict sense. Finally, when the work finds recognition among the public, it is disseminated, imitated, reproduced, and applied in social practice. On this basis, we note that Prof. Labuda's reflections connect the history of civilization with the theory of innovation, which was presented much earlier by J. Schumpeter (1960, p. 64.), already mentioned in the introduction. This author was the first to recognize the need to analyze innovation through the prism of the above-mentioned stages of action, which are: invention - innovation - imitation.

It is worth noting that the definition of G. Labuda has several important advantages. First, it treats thinking about innovation in a broad context, showing that innovation is a feature of social reality in all its dimensions (i.e., technical, organizational, cultural, and political). Second, it reveals the complex, systemic nature of the innovation process, each stage of which requires separate analysis. With this view, many modern researchers of the concept of innovation agree.

The above definition strand focuses primarily on issues related to the development of production resources. To transform innovations into products and market activities is to start something completely new, to undertake a complex activity with a high degree of risk and uncertainty. Innovation in business includes products and services and activities to bring them to buyers and convince them of their usefulness.

2.2. Contemporary Current – Key Approaches to Innovation and their Basis for Classification

The modern understanding of innovation, in addition to the general statement that it is the result of something new, points to the important aspect of obtaining the benefits it provides to both companies, consumers and the economy (Szatkowski, 2016).

A significant contribution to the current of contemporary views on innovation, is made by C.K. Prahalad and M. Krishnan (2012), among others, who define it as: "shaping consumers" expectations, but also continuously responding to their changing demands, behaviors and experiences (even a single one and often with his participation, according to the N = 1 rule). According to the cited authors, one must innovate by reaching for the best talent and resources available anywhere in the world (according to the R = G principle), that is, the resources of the many to meet the needs of the individual. The glue of these two pillars of innovation is flexible and resilient business processes (based on data analysis), and the foundations of the so-called "new edifice of innovation" (in the new era of innovation) are the technical architecture of the company (information technology) and the social architecture of the company (appropriate qualifications, attitudes and orientations of managers, organizational structure, ways of measuring performance, training, qualifications and value of the organization). From the definition presented, it follows that the development of innovation depends on the formation of consumer expectations, as well as the continuous response to changing consumer demands, behaviors and experiences, and the processes that accompany them. Innovation understood in this way can be analyzed through the complexity of the changes generated by it, as shown in Figure 2.

The types of innovations outlined above depend on changes in the business environment, which are triggered by the needs and behavior of modern consumers. Therefore, their implementation should be the result of a study of the environment in which certain market players operate. The division of these innovations therefore requires the identification of factors that shape the environment of companies from the point of view of the needs of their target markets. The problem of the needs and expectations of consumers as recipients of innovations is strongly emphasized sometimes in the marketing literature.

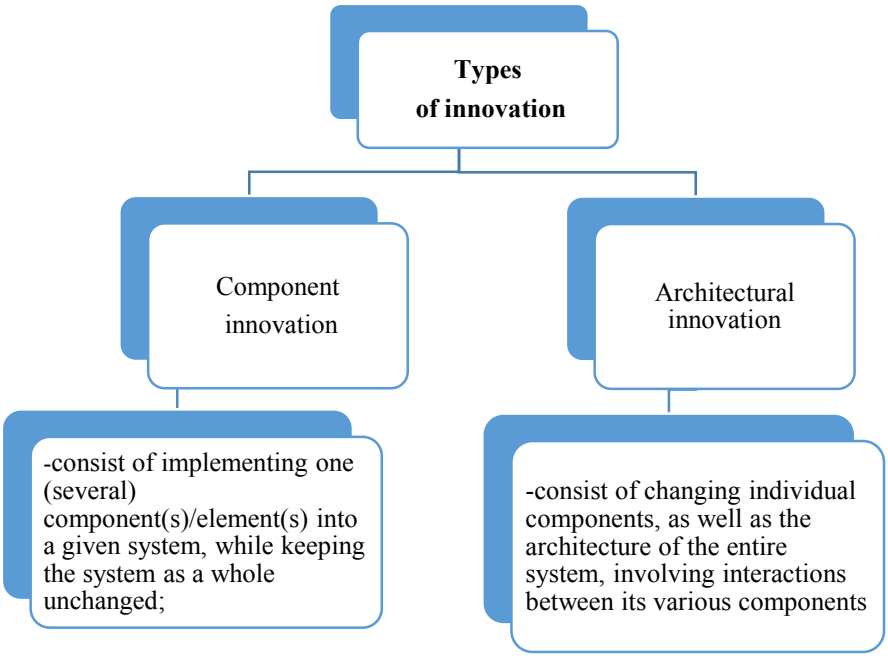

Figure 2. Types of innovations based on the criterion of comprehensiveness of changes generated by innovation.

Source: elaboration based on Child, Faulkner and Tallman (2005, pp. 186-189).

A prominent representative of the above approach to innovation is Ph. Kotler (2004), who points out the vital importance of the subjective aspect and the resource trend related to the market. On this basis, together with F. Trias de Bes (2004) he states that innovation is created by the market. This is because within its mechanisms, both actual and potential consumer needs are met. In addition, the market creates new consumer expectations and needs. These expectations are a resource that can turn into an innovation idea, and its successful implementation can determine the success of a company. This approach describes the concept of vertical and lateral marketing.

According to the first concept mentioned, that of vertical marketing, the search for innovation within the market in which the company operates requires the exclusion of solutions that go beyond the company's market. Therefore, the selection of opportunities is done by restriction. The resulting innovations do not create new product categories or new technologies, as they always occur within the category in which the product idea originated. According to lateral marketing, on the other hand, innovations generated within it fall outside a specific product category or market, leading to the creation of a new product category or market. As a result, the chosen product transforms sufficiently to be able to meet new needs or the needs of new customers.

A continuation of the above considerations is Ph. Kotler's concept 3.0, developed jointly with H. Kartajayna and I. Setiawan (2010) in which the authors also emphasize the importance of the subjective aspect and the resource trend related to the market.

W. Chan Kim and R. Mauborgne (2005) on the other hand, try at an integral view, introducing the concept of value innovation, which is the basis for building strategies that allow modern companies to achieve above-average profits. This concept is in part a complement to earlier approaches, but it does so in a way that differs significantly from other approaches to innovation found in the literature.

In recent years, it can be noted that the creation of innovations that generate value for companies depends largely on knowledge (intellectual capital), which should be skillfully used (Borowiecki, Dziura, 2016; Skrzypek, 2020; Usman, Fadhilah, 2020). The acquired knowledge of the market, is based on the resources of modern technologies, being an important source of creation and creation of innovations in various sectors of the economy. This aspect is also pointed out by Polish representatives of the contemporary trend, such as G. Gierszewska (2017), J. Baruk (2020) and W. Dyduch (2021).

In addition to market knowledge, the time factor, the level of development of the economy, and the progress brought about largely by modern technologies are important in new approaches to innovation. The aforementioned factors determine the development of innovation highlighted by another group of representatives of the modern trend, who emphasize the aspect of novelty in their definitional approaches (Anderson Potocnik, Zhou, 2016; Styś, Dejnaka, 2018; Ober, 2022). On this basis, we can classify two types of innovations that form:

a) imitative innovations (so-called secondary innovations), meaning adaptation to other markets and in other companies, the essence of which is captured by the slogan: "new for the company", "new for the market" (e.g., next-generation smart clothing for the medical services market).
b) creative innovations (so-called primary innovations) - denoting the first worldwide commercialization of an innovation /inventor. Their essence is captured by the slogan: "new to the world" (e.g., the emergence of the Amazon shopping portal).

In a similar vein, innovations are analyzed by J. Tidd, J. Bessant and K. Pavit (2005), who reduce the problem of the degree of novelty to technology and the idea of the product, and distinguish three types of innovations, shown in Figure 3.

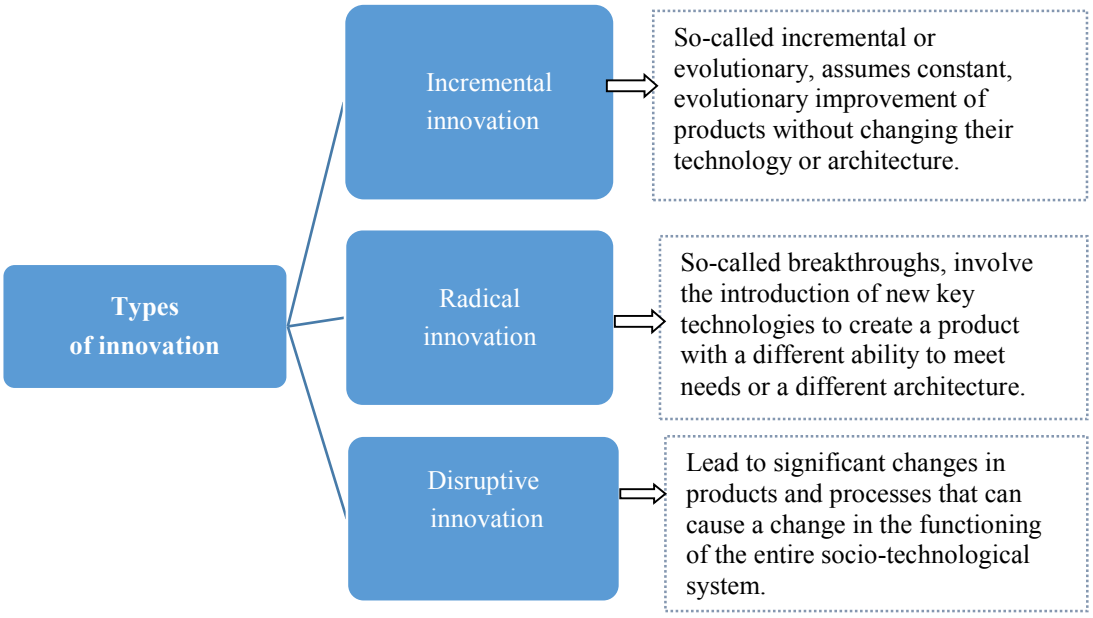

Figure 3. Division of innovations according to the degree of novelty of technology and product idea.
Source: elaboration based on Tidd, Bessant, Pavit (2005); Christensen et al. (2010).

Changes in the environment and new market challenges emerging in the last decade of the modern trend prompted a new version of the definition of innovation, published in the Oslo Manual (Oslo Manual, 2018) by the Organization for Economic Cooperation and Development OECD in 2018[1]. According to its description, the previous complexity of the definition of innovation, has been significantly reduced. As a result of the changes, the 4 main types of innovation (product, process, organizational and marketing), classified by the Oslo Manual in 2005, have been reduced to only two types of innovation: product innovation and business process innovation (Oslo Manual, 2018, p. 3.25). The elaborated definition also reduced the ambiguity of the requirement for a "significant" change by comparing both new and improved innovations with a company's existing products or business processes (Oslo Manual, 2018, p. 3.36). Their essence is explained in Table 2.

[1] The Oslo methodology is the basis for innovation statistics surveys conducted under the auspices of the European Commission as part of the large-scale Community Innovation Survey (CIS) program, which is currently the main source of information on innovation activity in European countries (the data generated by the Community Innovation Survey program is one of the sources feeding the European Innovation Scoreboard, or EIS).

Table 2.
The essence of the meaning of innovation according to the Oslo Manual 2018

Types of innovation	Definition and essence of innovation
Innovation Product	- "a new or improved product or service that differs significantly from the company's existing products or services and that has been introduced to the market"; - must provide a significant improvement in one or more characteristics or performance specifications; - considers the addition of new features or improvements to existing functions or user usability; - its functional characteristics include quality, technical specifications, reliability, durability, economy in use, affordability, convenience, usability, and user-friendliness; - does not necessarily involve improving all functions and performance specifications.
Innovation in the business process	- "a new or improved business process for one or more business functions that differs significantly from the company's existing business processes and that has been put into use by the company; - relates to six different management functions of the enterprise: two of them relate to the core business (manufacturing and delivering products for sale) the others relate to supporting activities (marketing, information and communication systems, administration and management, product development and business processes); - may arise from objectives related to implementing business strategies, reducing costs, improving product quality, or working conditions, or meeting regulatory requirements.

Source: elaboration based on Oslo Manual (2018, paragraphs 3.25; 3.36).

The types of innovations introduced by Oslo Manual 2018, despite the limitations imposed by their definitions, are distinguished by a much broader approach in which the use values of the product generated for customers, rather than its "technical" parameters as before, play a key role. This important aspect of analysis is also confirmed in the literature (Mahajan, 2020).

As a result of the changes introduced by the Oslo Manual 2018, the functional features of products and services are undoubtedly gaining in importance, enabling increased affordability, financial convenience and reduced manufacturing costs that translate into the final competitiveness of the enterprise, which is also confirmed in the subsequent period caused by the Covid-19 pandemic. Its effects verified the activities of modern enterprises, making innovation necessary to survive this difficult time. This is because it quickly became apparent that the existing environmental conditions not only give rise to threats for companies, but also opportunities to function in the conditions of the pandemic.

The above issue is addressed, among others, by K. Heinonen and T. Strandvik (2020), who show in their considerations that opportunities arising during the pandemic period can be a catalyst for innovation. This has led to an increase in creativity and the development of new types of survival-oriented innovations. They are now supported by digitization, automation, remote work, and new business models to overcome the problems of smooth operations by taking advantage of the unlimited.

The results of the research presented by W. Mierzejewska and P. Dziurski (2021) further show that innovations introduced during the pandemic period most often took the form of process and "open" innovations relying on the cooperation of entities in the R&D area and knowledge sharing. However, it should be added that the development of "open" innovations in Poland was already visible before the pandemic. An analysis of its status on, for example,

SMEs (Small and Medium Enterprises) was carried out and described, among others, by R. Borowiecki, T. Kusio and B. Siuta-Tokarska (2018)[2].

At the same time, it should be noted that the difficult time of the pandemic became a catalyst for technological change triggering the development of innovations, which were accelerated by the digitization of services and processes, online communication, and remote forms of service. In particular, the period saw the quick development of innovations related to ecology and health. Which indicates that in the existing environment, companies are trying to be more flexible, that is, prepared for change, quickly adapting, and adjusting to new conditions. This is in line with the common statement that necessity is the mother of invention. Observed innovations during this period are primarily aimed at providing its recipients with security, comfort, time savings, while supporting the development of business and partner relationships.

Guided by the conviction that it is the factor of time and the environment, combined with the parallel development of potential and access to modern information technologies, that condition the development of modern approaches and typologies of innovation, it should be stated, following J. Tidd (2021, p.6) that there is no single ideal recipe for the development of a particular type of innovation. Indeed, what is needed in difficult times for all is the search for different combinations or configurations of solutions that best fit the nature of the problem and the given environment.

3. Conclusions

The considerations presented in the paper indicate the evolutionary nature of the development of both classical and modern approaches to the categories of innovation and related typologies. This evolution, in turn, reflects the significant changes that have occurred in the interpretation of categories and types of innovation. From the definitions and typologies of innovation presented, it is clear that their subject matter is so broad as to give them a complex and difficult to evaluate character.

The definitions and classifications of innovations that emerge over time are created in relation to the changing environment, including the processes of socio-economic development and the new values emerging in them, as well as new information technologies. Hence, it is extremely important to follow both the scientific achievements developed by prominent theorists (classics) of the analyzed field of management, as well as current developments in the current post-state reality.

[2] The basic premise of these innovation is that the added value for the customer is co-created by the customer together with the company. The customer becomes at the same time a co-producer of the final product, whereby the co-creation of value is not only reduced to the customization of the product at the final stage of the process of its delivery to the customer but begins already at the stage of product design.

The analysis carried out allows us to formulate the following conclusions:

- in the case of classical approaches, the so-called "closed" innovation dominates, which means that it arises only inside a specific company - so inventions, products, technologies are developed by a specific group of people in a company or research and development institution, and the knowledge about them does not go beyond a particular company;
- "closed" innovations are characteristic of large companies with a strong competitive advantage and a strong market position, as well as companies operating in niche industries that use rarely available and severely limited resources;
- in the case of the modern trend, innovations occur both inside and outside the company, often creating " open" innovations - with this approach, both technologies, processes and products created in this way are better tailored to the needs of customers, evolve more easily and quickly in response to the dynamics of change in the world. Thus, they are much more profitable for companies that are willing to share their knowledge with the environment, leading to more innovative products than is possible under "closed" processes;
- phenomena associated with the development of new types of innovations indicate that companies are significantly active in the direction of increasing their adaptability to new environmental conditions - this approach is due to the development of desirable innovations and the changes taking place in their structure, which provide a solution to overcoming the crisis caused by the pandemic;
- among the "open" innovations, a model of marketing-driven and user (consumer) driven innovation is emerging, based on a proper understanding of the user's needs and consistent involvement of the user in innovation activities.

A comprehensive approach to the analysis of the essence of innovation and its conceptual scope, made it possible to see the changes that have occurred over time within the interpretation and understanding of innovation and their impact on the development of the classifications encountered in the literature. The identified changes are a derivative of certain conditions related primarily to the time factor, IT advances, access to knowledge, evolving concepts of value, an environment that is difficult to predict, and the increasingly exorbitant needs and expectations of innovation recipients.

The considerations presented in the article should be regarded as a voice in the discussion of the problem of changes occurring within the interpretation and typology of innovations observed over time.

References

1. Anderson, N., Potocnik, K., Zhou, J. (2014). Innovation and Creativity in organizations: A State-of-the-Science Review, Prospective, Commentary and Guiding 370 Framework. *Journal of Management, Vol. 40, Iss. 5*, pp.1297-1333, doi.:10.1177/0149206314527128.
2. Arnason, J.P. (2015). Theorizing capitalism: Classical foundations and contemporary innovations. *European Journal of Social Theory, Vol. 18, Iss. 4*, pp. 351-367, doi.: 10.1177/1368431015589153.
3. Ayres, R.U. (1987). Technological Protection and Piracy. *Economic Impact*, *No. 1.*
4. Barnet, H.G. (1953). *Innovation the Basic of Cultural Change*. New York: McGraw-Hill Book Company.
5. Baruk, J. (2020). Zarządzanie innowacjami ukierunkowane na współtworzenie wartości w ramach partnerskich relacji [Innovation management focused on value co-creation in partnerships]. *Marketing i Rynek* [*Marketing and Markets*]*, Vol. 27, Iss. 5*, pp. 3-14.
6. Borowiecki, R., Dziura, M. (2016). Nowa gospodarka-aspekty wiedzy i innowacji [New economy-aspects of knowledge and innovation]. *Przegląd Organizacji [Organization Overview*], *Vol. 5, Iss. 916*, pp. 9-16.
7. Borowiecki, R., Kusio, T., Siuta-Tokarska, B. (2018). Innowacje otwarte w MSP [Open innovation MSC]. *Studia i Prace WNEIZ US [Studies and Papers of WNEIZ US], 52(2),* pp. 71-86.
8. Chen, J. (2023). *East Meets West: Dialogue Between Classical and New Innovation Theories*. Holistic Innovation. Singapore: Springer, pp. 45-81, DOI: 10.1007/978-981-19-8625-3_2.
9. Child, J., Faulkner, D., Tallman S. (2005). *Cooperative Strategy. Managing Alliances, Network, and Joint Ventures*. New York: Oxford University Press.
10. Christensen, C.M., Scott, D., Anthony, E., Roth, A. (2010). *Innowacje - następny krok* [*Innovation - the next step*]. Warsaw: Studio Emka Publishing House.
11. Dieter, W., Schmitt, W. (2018). A Literature Review on Innovation Proces. East African Scholares. *Journal of Economics, Business and Management, Vol. 1, Iss. 3*, pp. 64-71, doi.: 10.36349/easjebm.2018.v01i03.003.
12. Dyduch, W. (2021). Tworzenie i przechwytywanie wartości w przedsiębiorstwach w Polsce: ocena podejmowanych działań. Identyfikacja kluczowych zmiennych oraz ich wpływ na efektywność [Creating and capturing value in companies in Poland: an assessment of actions taken. Identification of key variables and their impact on efficiency]. *Przegląd Organizacji* [*Organization Overview*], *Vol. 6, Iss. 977*, pp. 7-16.
13. Gierszewska, G. (2017). *Wspomaganie zarządzania wiedzą we współczesnych organizacjach* [*Supporting knowledge management in modern organizations*]. In: A. Gąsiorkiewicz, K. Sitarski, O. Sobolewska, M. Wiśniewski (eds.), *Gospodarka*

cyfrowa 2016. Zarządzanie, innowacje, społeczeństwo i technologie [*Digital Economy 2016 Governance, Innovation, Society and Technology*] (pp. 19-37). Warsaw: Wydawnictwo Politechniki Warszawskiej [Warsaw University of Technology Publishing House].

14. Gomułka, S. (1998). *Teoria innowacji i wzrostu gospodarczego* [*Theory of innovation and economic growth*]. Warsaw: CASE Publishing House.
15. Grudzewski, W., Hejduk, I. (2000). *Przedsiębiorstwo przyszłości* [*Enterprise of the future*]. Warszawa: Difin.
16. Heinonen, K., Strandvik, T. (2020). Reframing Service Innovation: COVID-19 as a Catalyst for Imposed Service Innovation. *Journal of Service Management*, *Vol. 32, Iss. 1,* pp. 101-112, doi.:10.1108/JOSM-05-2020-0161.
17. Kim, Ch.W., Mauborgne, R. (2005). *Strategia błękitnego oceanu. Jak stworzyć wolną przestrzeń rynkową i sprawić, by konkurencja stała się nieistotna* [*Blue Ocean Strategy. How to create free market space and make competition irrelevant*]. Warszawa: MT Biznes.
18. Kotler, Ph., Kartajaya, H., Setiawan, I. (2010). *Marketing 3.0. Dobry produkt? Zadowolony klient? Spełniony człowiek*? [*Marketing 3.0: Good product? Satisfied Customer? A fulfilled person?*]. Warsaw: MT Business Publishing House.
19. Kotler, Ph., Trias de Bes, F. (2004). *Marketing lateralny* [*Lateral marketing*]. Warszawa: PWE.
20. Labuda, G. (2008). *Rozważania nad teorią i historią kultury i cywilizacji* [*Reflections on the theory and history of culture and civilization*]. Poznan: Wydawnictwo Poznańskie.
21. Lisiecka, K. (2011). Józef A. Schumpeter – piewca innowacji i „twórczej destrukcji" [Joseph A. Schumpeter - the singer of innovation and "creative destruction]. *Forum, No. 32,* pp. 19-26.
22. Mahajan, G. (2020). What Is Customer Value and How Can You Create It? *Journal of Creating Value*, *Vol. 6, Iss.1,* pp. 119-121, doi.:10.1177/2394964320903557.
23. Marciniak, S. (2000). *Innowacje i rozwój gospodarczy* [*Innovation and economic development*]. Warsaw: Kolegium Nauk Społecznych i Administracji Politechniki Warszawskiej [College of Social Sciences and Administration of Warsaw University of Technology].
24. McGraw, T.K. (2007). *Prophet of Innovation: Joseph Schumpeter and Creative Destruction.* Cambridge: Harvard College Press.
25. Mierzejewska, W., Dziurski, P. (2021). *Wpływ pandemii na strategie innowacji realizowane przez przedsiębiorstwa w Polsce* [*Impact of the pandemic on innovation strategies implemented by companies in Poland*]. In: J. Wielgórska-Leszczyńska, M. Matusewicz (eds.), *Nauki ekonomiczne przed, w czasie i po pandemii* [*Economic science before, during and after a pandemic*] (pp. 281-299). Warsaw: Oficyna Wydawnicza SGH w Warszawie [Publishing House SGH in Warsaw].

26. O'Sullivan, D., Dooley, L. (2009). *Applying Innovation*. Boston, Massachusetts: Sage Publications Ltd.
27. Ober, J. (2022). *Adaptacja innowacji w świetle zachowań organizacyjnych. Wybrane aspekty* [*Adapting innovation considering organizational behavior. Selected aspects*]. Gliwice: Wydawnictwo Politechniki Śląskiej [Silesian University of Technology Publishing House].
28. Pomykalski, A. (2001). *Zarządzanie innowacjami* [*Innovation management*]. Warszawa-Łódź: PWN.
29. Porter, M.E. (2001). *Porter o konkurencji* [*Porter on competition*]. Warszawa: PWE.
30. Prahalad, C.H., Krishnan, M.S. (2012). *Nowa era innowacji* [*A new era of innovation*]. Warszawa: PWN.
31. Rothwell, R. (1992). Successful Industrial Innovation: Critical Success Factors for the 1990. *R&D Management, Vol. 22, Iss. 3*, pp. 221-240, doi.:10.1111/j.1467-9310.1992.tb00812.x.
32. Schumpeter, J. (1960). *Teoria rozwoju gospodarczego* [*Theory of economic developmen*]. Warszawa: PWN.
33. Skrzypek, A. (2020). Uwarunkowania funkcjonowania i doskonalenia organizacji zorientowanej na jakość w nowej gospodarce [Determinants of functioning and improvement of quality-oriented organization in the new economy]. *Problemy Jakości* [*Quality Problems*], *No. 4,* pp. 2-8.
34. Śledziewska, K., Włoch, R. (2020). *Gospodarka cyfrowa jak nowe technologie zmieniają świat* [*The digital economy how new technologies are changing the world*]. Warsaw: Wydawnictwo Uniwersytetu Warszawskiego [University of Warsaw Publishing House].
35. Styś, A., Dejnaka, A. (2018). *Innowacje w biznesie* [*Innovation in business*]. Warszawa: Difin.
36. Szatkowski, K. (2016). *Zarządzanie innowacjami i transferem technologii* [*Innovation and technology transfer management*]. Warszawa: PWN.
37. Talukder, M. (2014). *Managing Innovation Adoption. From Innovation to Implementation*. London: Routledge.
38. Tidd, J. (2021). A Review and Critical Assessment of the ISO 56002 Innovation Management Systems Standard: Evidence and Limitations. *International Journal of Innovation Management. Vol. 25, Iss. 1,* 2150049, doi.:10.1142/S1363919621500493.
39. Tidd, J., Bessant, J., Pavitt, K. (2005). *Managing Innovation: Integrating Technological, Market and Organizational Change*. Hoboken, New Jersey: John Wiley & Sons.
40. Usman, M., Fadhilah, F. (2020). Knowledge Management Practice for Competitive Advantage Through Innovation. *International Journal of Business and Management Invention, Vol. 9, Iss. 7*, pp. 01-05.
41. Żabiński, L. (2013). Innowacyjne produkty systemowe i ich konsumpcja. Uwarunkowania, mechanizmy rozwoju [Innovative system products and their consumption. Determinants,

mechanisms of development]. *Konsumpcja i Rozwój* [Consumption and Development], *No. 1(4),* pp. 3-20.

42. Zastempowski, M. (2014). Innowacyjność i jej wpływ na konkurencyjność tajemniczych mistrzów polskiej gospodarki [Innovation and its impact on the competitiveness of the secret masters of the Polish economy]. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie [Scientific Journals of the Małopolska Wyższa Szkoła Ekonomiczna in Tarnów], No. 1(24),* pp. 233-240.

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EARLY WARNING SYSTEMS AGAINST BANKRUPTCY RISK AND NLP: CAN CHATGPT PREDICT CORPORATE DISTRESS?

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Purpose: The main purpose of this paper is to evaluate the effectiveness and usability of one of the more groundbreaking and more widely commented NLP-technique-employing inventions, i.e., the ChatGPT application acting as a digital advisor in the field of counterparty financial standing and bankruptcy risk assessment.
Design/methodology/approach: The algorithmic potential presented by the ChatGPT tool can be a valuable solution in supporting the manager's work. In this study, the current potential of this solution in supporting financial analysis, and in particular, bankruptcy risk assessment, was checked. The study was carried out using the following methods: analysis and synthesis (1.), critical analysis of the literature (2.), and an experiment involving the use of a natural language processing application (3.).
Findings: In the course of the research, it was found that the ChatGPT tool, according to the current state of knowledge, has extensive usability and is able to conduct interactions that in many cases are similar to communication with a human being. The tested language model shows a much higher level of training on general data than in solving narrow problems in specific fields. Nevertheless, its development potential should be assessed highly and probably its adaptation to solve highly specialized tasks in management will not be a long-term process, which makes it a candidate for the role of a digital managerial advisor in the future.
Research limitations/implications: The first stage of the research covered only solving problems with the use of the simplest algorithms, such as discriminant analysis (MDA) and the study of entities whose financial statements are widely available on the web, which was a relatively low level of complexity for the language model.
Practical implications: The research results are a signal that digitization and the digital revolution are not just theoretical slogans, but real functioning technologies that can change the nature of the manager's work (and the entire management system) in the near future. The development potential of NLP technology in management, which was confirmed in this work, suggests that an appropriate strategy for implementing these technologies is needed today.
Originality/value: In this study, one of the first attempts was made to assess the potential and adaptability of natural language processing systems to support a manager in assessing the financial condition and risk of bankruptcy of entities.

Keywords: early warning systems against bankruptcy, insolvency, artificial intelligence, natural language processing, chatGPT.

Category of the paper: Research paper, Literature review.

1. Introduction

Artificial intelligence technology is being implemented in an increasing range of areas of daily human life. Spanning from transportation flow support (Paprocki, 2017), through strategies of marketing message individualization, to cell phones, the more or less complex algorithms consistently attempt to predict user behavior and environment changes, simultaneously improving themselves. Artificial intelligence solutions are also increasingly widely applied in management – by relieving cadres of simple, repetitive tasks, they allow for, inter alia, process automation (Sliż, 2019) or detection of fraud and abuse, based on vast data sets (Aslam et al., 2022). It should be emphasized the efficiency thereof is often many times higher than that of the same activity carried out by a human, while the entire work is often free of defects and errors that are inherent in human work. An increasing amount of discussion nowadays is devoted to the involvement of artificial intelligence in more creative management tasks, such as consulting or support during managerial decision-making at not only operational but also tactical and strategic levels. One important aspect to stress entails the fact that the mere implementation of artificial intelligence in an enterprise does not necessarily bring spectacular business results if it is not preceded by development of a well-thought-out plan and a strategy for the implementation thereof (Sira, 2022). The development of an implementation plan is essential to identifying the areas most susceptible to AI support in a particular enterprise. In management, one of the areas utilizing numerical algorithms and artificial intelligence, characterized by a long tradition of AI application, is the so-called early warning against corporate bankruptcy (Siciński, 2021). Using historical data derived from financial statements, these measures enable enterprise classification and thus identification of entities at risk of bankruptcy, several years in advance. This allows appropriate anticipatory reaction on the part of a manager, such as e.g., a change in the trade credit policy towards such an entity or discontinuation of business cooperation. Early warning algorithms can be built using both simple mathematical methods as well as complex, sophisticated artificial intelligence and machine learning methods (Shetty, 2022). Since early warning models offer significant support in risk management (e.g., in the formation of counterparty credit policies) (Antonowicz, 2007), managerial cadres have for years shown interest in the implementation of such models in daily management. The main barrier to the implementation and everyday use thereof, however, still lies in the fact that even the simplest EWS (Early warning systems) require certain analytical and financial skills on the part of the users, as well as prior acquisition of quality financial data. Even more advanced early warning systems using e.g., machine learning or artificial intelligence are extremely difficult to utilize in practical management, as they often take the form of a so-called black box, i.e., they do not offer any separate, user-visible functions with parameters. This analytical form renders these systems extremely unintuitive for managers lacking data-science expertise. The issue of how to make classification and prediction methods

more accessible and understandable to mass users in management practice is not covered broadly in the literature. The research deficit particularly concerns the realm of bankruptcy early warning systems. This particular issue represents a research gap identified by the Author, which needs to be filled. In the Author's view, one prospective approach to systems of early warning against bankruptcy, which can contribute to the wider and more effective use thereof in management, entails natural language processing (NLP) technology. Such an approach can be referred to as a so-called hybrid technique, which involves the use of artificial intelligence support in handling other data-science techniques that are beyond the reach of managers lacking adequate knowledge. Similar attempts to support the users are already underway, e.g., using external software (a robot) by means of voice commands, artificial intelligence can generate complex computational functions in an MS Excel spreadsheet, with the ability to export those functions into the spreadsheet.

The purpose of this paper is to evaluate the effectiveness and usability of one of the more groundbreaking and more widely commented NLP-technique-employing inventions, i.e., the ChatGPT application acting as a digital advisor in the field of counterparty financial standing and bankruptcy risk assessment. This assessment was carried out using so-called systems of early warning against the risk of bankruptcy. The study was aimed at verifying whether the ChatGPT algorithm has knowledge of the essence and mathematical specification of as well as the rules of application and inference from the most popular bankruptcy risk assessing models.

The research process planned is of a long-term nature and will be materialized with a series of publications, whereas the research results presented in this article are preliminary and concern the results of the ChatGPT algorithm’s interaction with the least complex early warning technique (often of first choice) - namely, multiple discriminant analysis (MDA). The research questions posed were as follows:

RQ1. Do natural language processing algorithms exhibit utility in the application of other data-science-based solutions in the sphere of finance and early warning against insolvency?

RQ2. Does the current effectiveness of advanced NLP methods indicate that in the future, specialized chat-bots will be able to comprehensively assess the financial condition of a counterparty and recommend appropriate management actions, reducing thereby the need for external expertise and work-intensive analyses?

The following were employed as the research methods: analysis and synthesis (1.), critical analysis of the literature (2.), and an experiment involving the use of a natural language processing application (3.). The research hypothesis posed states: Intelligent natural language processing algorithms can provide support to managers as digital advisors in assessing the external standing of a company (e.g., a contractor), using systems of early warning against bankruptcy.

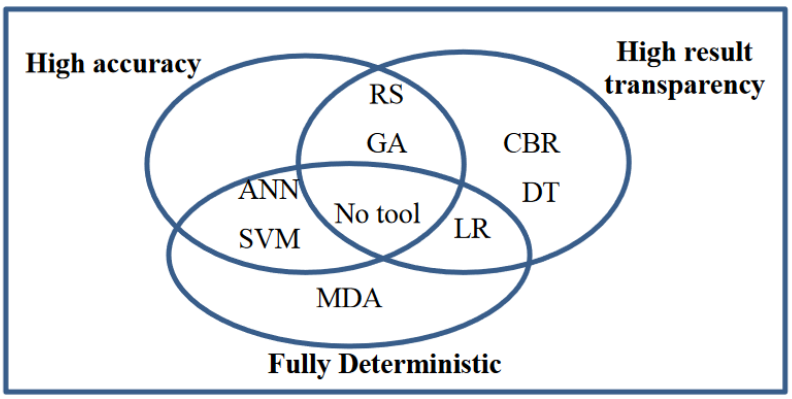
2. Early warning systems against bankruptcy – literature review

Early warning systems (EWS) are designed to determine the risk of a company's bankruptcy with sufficient time in advance (minimum one year). Such a model can take the form of a linear equation (sometimes a complex algorithm), the purpose of which is to dichotomously classify a company using a point predictive score based on selected data contained in the financial reports issued by the company. It is believed that one of the first historical events that led economists to consider the possibility of predicting financial risk was the Great Depression of the 1930s (Kowalak, 2017). Over the following decades, the development of such models accelerated, mainly as a result of two factors: the improvement of data analysis methods (1.) and the increasingly broader and effective corporate financial reporting obligation (2.) (Siciński, 2021). A distinction can be made between three main quantitative methodological currents, in which models of early warning against bankruptcy are developed (Pociecha et al., 2014):

- discriminant analysis,
- econometric methods,
- artificial intelligence methods (including neural networks).

In practice, other approaches, embedded in experimental and higher mathematics, such as entropy theory and fuzzy logic, can also be distinguished. Moreover, machine learning methods, such as random forest and Extreme Gradient Boosting (XGBoost) algorithms, are gaining popularity as well. The latter (XGBoost), which has been under test in bankruptcy risk prediction environment for a relatively short time, yet achieves very high predictive performance, seems to be a particularly promising one (Zięba et al., 2016). Regardless of the wide range of methods, the Z-Score early warning system developed by Edward Altman (Altman, 1968) is considered in the financial world as a pioneering, most popular model.

The multiplicity of bankruptcy risk assessment methods and techniques should be deemed positive, in the context of this trend's development and further advancement. Nevertheless, typically, the predictive accuracy of these methods increases with the sophistication of the algorithm, and this in turn leads to increased difficulty of use for recipients, who accordingly require correspondingly higher knowledge of financial analysis and data science. It can thus be argued that the above-mentioned methods of early warning model construction are characterized by three fundamental user attributes, which, as a rule, exert adversarial effects on one another. This means that, in principle, the high deterministic nature of functions entails lower predictive accuracy and lower transparency of results, and vice versa - neural networks are characterized by lower determinism and low transparency yet high efficiency of bankruptcy risk prediction (Alaka et al., 2018). This relationship is shown in Figure 1.



Note. MDA - Multiple Discriminant Analysis, LR - Logistic regression, ANN - Neural Network, SVM - Support vector machines, RS - Rough Sets, CBR - Case Based Reasoning, DT - Decision Tree, GA - Genetic Algorithm.

Figure 1. Performance of tools in relation to result-related criteria.

Source: Alaka, H.A., Oyedele, L.O., Owolabi, H.A., Kumar, V., Ajayi, S.O., Akinade, O.O., Bilal, M. (2018). Systematic review of bankruptcy prediction models: Towards a framework for Tool Selection. Expert Systems with Applications, 94, 164-184. https://doi.org/10.1016/j.eswa.2017.10.040.

The very application of fully deterministic methods, which are considered the least complicated (e.g., MDA - multivariate discriminant analysis or LR - logit regression), requires basic knowledge of the accounting, financial and data-analysis principles. This is because assessment of bankruptcy risk by means of such models involves acquisition of data, calculation of relevant metrics and subsequent determination of the function's scoring, along with its interpretation. Moreover, discriminatory functions are, in principle, characterized by a very high sensitivity to changes in input parameters, and even seemingly insignificant errors in the calculation of metrics can contribute to radical changes in the result of the final classification. Even experienced analysts not infrequently can belittle a fact of an erroneous approach to the proper averaging of certain financial categories (a requirement for some financial analysis indicators) (Antonowicz, 2011), which can distort the results of insolvency risk assessment.

Summing up, systems of early warning against bankruptcy are characterized by a long history of use, while the model itself can be built to varying methodological standards. These methods differ in effectiveness as well as the scale of difficulty in application and interpretation by the user (e.g., a manager).

3. Natural language processing (NLP) in ChatGPT algorithm

Natural language processing (NLP) is categorized as one of the so-called cognitive technologies and is often customarily classed within the boarder category of artificial intelligence (Osika, 2021). NLP can be defined as a set of various computational techniques that are oriented toward analysis of text and human-like understanding thereof (Liddy, 2001). This means that natural language processing models human characteristics by giving computers

the ability to respond to various commands delivered through spoken and written language (IBM, 2023). The technology owes its capabilities to sophisticated computational techniques, which employ mathematical models, statistics, machine learning and so-called deep learning. NLP has a wide range of practical applications, the most widespread forms of which include (Khurana et al., 2022):

- text translation,
- text categorization,
- support of anti-spam systems,
- establishment of interactions in the form of dialogues (e.g., through so-called chat-bots),
- sentiment analysis.

This technology, as evident by the above examples of application, touches almost every person, oftentimes in ways they are unaware of. We come into contact with NLP even through sending and receiving e-mail, for instance, where a relevant system ensures reduction of unwanted advertising message (SPAM) influx. Likewise, interaction with most online stores or any form of off-premises product acquisition is no different - online sales often involve human interaction with bots guiding customers through the sales or complaint process. Nevertheless, the greatest state-of-art NLP technology invention is, first and foremost, the GPT-3 language model (Maciąg, 2022) and the hugely gaining media popularity language processing system called ChatGPT. The effectiveness of comprehension and interaction, as well as the overall representation of human nature in these models, are sufficiently high for the models to be attributed with very significant impact on social life and the world around us (Tamkin et al., 2021). The effectiveness of such a language model can be assessed using the so-called Turing test (Turing, 1950). The technique involves judges (real users) engaging in a conversation with an unseen interlocutor. If, during a 5-minute conversation, even a share of those engaged in the dialogue (minimum 30% of the judges) are unable to distinguish whether they have interacted with a bot or a real person, such an algorithm should be considered as meeting the requirements of the Turing test (Gov.pl, 2023). Research into ChatGPT is still ongoing, but unofficial reports indicate that it is likely capable of passing the Turing test procedure (Mpost, 2023). The outstandingly high efficiency in user interaction demonstrated by ChatGPT in various applications is also contributive to the discussion on the potential role of this tool in financial management. Cognition of the model's potential in solving not only predictable and linear problems (these issues are already pursued freely in business practice) but complex matters requiring creativity and abstract thinking specifically, is of particular importance.

4. Experiment methods and assumptions

The study employed three research methods: analysis and synthesis, critical analysis of the literature, and an experiment with the use of an algorithm processing natural language (ChatGPT). The assumptions underlying the ChatGPT experiment carried out took the form of a four-phase scenario. Three discrimination functions of early warning against insolvency (one of foreign and two of Polish origin) were selected for this purpose:

1) E.I Altman's discriminant function (Z-Score) model:

$$Z = 1{,}2X_1 + 1{,}4X_2 + 3{,}3X_3 + 0{,}6X_4 + 0{,}999X_5 \quad (1)$$

where:
X1 – net working capital/total assets,
X2 – retained earnings/total assets,
X3 – ebit/total assets,
X4 – enterprise value/book value of debt,
X5 – sales/total assets.

2) Prusak's P1 discriminant function model:

$$Z_{P1} = 6{,}5245X_1 + 0{,}1480X_2 + 0{,}4061X_3 + 2{,}1754X_4 - 1{,}5685 \quad (2)$$

where:
X1 – ebit/total assets,
X2 – operating costs/short-term debt,
X3 – current assets/short-term debt,
X4 – ebit/sales.

3) INEPAN's[1] Z7 discriminant function model (developed by a scientific team led by Elżbieta Mączyńska):

$$Z_{7INE} = 9{,}498X_1 + 3{,}566X_2 + 2{,}903X_3 + 0{,}452X_4 - 1{,}498 \quad (3)$$

where:
X1 – ebit/assets,
X2 – total equity/total assets,
X3 – earn after tax + depreciation)/total debt,
X4 – current assets/short-term debt.

[1] INEPAN: The Institute of Economics of the Polish Academy of Sciences [Instytut Nauk Ekonomicznych Polskiej Akademii Nauk] is a public Polish research center for economic and business studies, with rights to bestow doctoral and habilitation degrees as well as initiate professorship procedures.

The inclusion of models estimated by the discriminant analysis method (MDA) in the experiment was motivated by the fact that the technique has been most widely used (the so-called 'first choice' method). The article additionally presents the first stage of the Author's current research in this domain, hence the selection of this method as the first to interact with the ChatGPT algorithm can be considered legitimate. The functions selected for the study are considered to be among the most reliable and accurate in the practice of financial risk prediction (Antonowicz, 2007) and are frequently featured in various analyses within this research stream (Kitowski, 2021). The assumptions underlying individual phases of the experiment, including the related goal of knowledge exploration and objective to assess the language model's potential with respect to the issue under study are summarized in Table 1.

Table 1.
ChatGPT language model experiment assumptions - four phases of the interaction scenario

Phase	Model's interaction issues	Phase Objective
1.	General knowledge of early warning systems against bankruptcy	Checking whether the language model has knowledge of the basic assumptions underlying systems of early warning against bankruptcy.
2.	Area knowledge of specific bankruptcy models	Checking whether the model is equipped with knowledge on mathematical specification of selected discriminant functions.
3.	Calculation of discriminant function score	Assessment of the language model's analytical and mathematical skills and its ability to search for accurate financial enterprise data.
4.	Formulation of conclusions regarding the risk of insolvency	Checking whether the model can formulate correct conclusions based on the results of each discriminant function.

Source: Own elaboration.

Proper execution of all four interaction scenario phases will indicate the full capability of the ChatGPT language model in handling the most popular methods of discriminant analysis in early warning against bankruptcy. Correct implementation of only the first two phases will indicate the algorithm's theoretical knowledge of bankruptcy early warning systems, with absence of utility potential as managerial support in the sphere of finance. Moreover, a situation where theoretical and general knowledge of early warning systems is low (Phases 1 and 2) is also possible, and yet the ChatGPT algorithm is still capable of making correct calculations and accurate inferences from the mathematical function. Such a result shall be referred to as an unconscious skill, i.e., correct use of the early warning system, without a proper theoretical layer. In the third and fourth phases, fifteen randomly selected companies, whose shares are publicly traded and included in the main indices of selected world stock exchanges, were incorporated into the study. The collective encompassed: ten companies listed on the Warsaw Stock Exchange (WSE), ten listed on the German stock exchange (DAX), and ten on the US stock exchange (Dow Jones). The primary language of communication with the ChatGPT algorithm was Polish. The proposed size of the collective should be considered sufficient, since the architecture of language models (as well as that of other artificial intelligence solutions) exhibits a dichotomous approach. If the algorithm shows ability to solve a certain problem on object i_1, it is generally also able to solve the same problem on object i_2.

5. Results

The results of the user interaction with the ChatGPT model are presented in accordance with the experimental plan outlined earlier (Table 1). Phase one and phase two ended with a positive or negative result. A positive result in the theoretical stages (phases one and two) occurred when the following conditions were jointly met:

- the messages generated by the language model combined logic with proper argumentation,
- the response generated by the chatbot allowed sufficient implementation of the preformulated phase objective (Table 1),
- the ChatGpt responses provided were of characteristics similar to natural human communication.

With respect to the third and fourth phases (calculation stages), the totals of entities classified correctly after entering the command "Calculate the index ....(Altman, P1 Prusak, Z7 INE PAN) for company X in 2021" into the chatbot are tabulated in the corresponding Table 2 cells. More so, in case of an incorrect answer to this phrase, a second attempt was undertaken using a modified command "Determine the 2021 bankruptcy risk for entity X by means of model X." Ultimately, after executing the commands for the three discriminant functions and all the companies listed in the indices selected, the language model was assigned a final overall score on its ability to use each function for bankruptcy risk estimation. Definitive positive assessment resulted when the language model was able to execute a minimum of one theoretical phase correctly and obtain a minimum of 50% of accurate classifications and conclusions based on the computational phases carried out for the exchange entities selected. The results of each phase are summarized in Table 2.

Table 2.
Results of four-phase interaction with natural language processing model (ChatGPT)

Model / **Experiment phase (stage)**	**Z-Score discriminant function (E.I Altman)**	**P1 Prusak discriminant function**	**Z7 INE PAN discriminant function**
Results from the phase 1	Positive		
Results from the phase 2	Positive	Negative	Negative
Results from the phase 3	Number of correct calculations of the scoring function:		
WSE	7/10 (70%)	0/10 (0%)	0/10 (0%)
DAX	10/10 (100%)	0/10 (0%)	0/10 (0%)
DOW JONES	10/10 (100%)	0/10 (0%)	0/10 (0%)
Results from the phase 4	The number of correctly formulated conclusions from the result of the scoring function:		
WSE	7/10 (70%)	0/10 (0%)	0/10 (0%)
DAX	10/10 (100%)	0/10 (0%)	0/10 (0%)
DOW JONES	10/10 (100%)	0/10 (0%)	0/10 (0%)
Overall score of ChatGPT in each discriminant function	Positive	Negative	Negative

Source: Own elaboration.

The first phase tested the ChatGPT model's general knowledge of bankruptcy early warning systems. The linguistic algorithm responded correctly to the inputted command *Do you know what a system of early warning against bankruptcy is?* In the feedback message, the model formulated a logical and concise answer, stating it is a system aimed at early detection of financial risks before a company's situation becomes too serious for implementation of corrective measures. The quality of this message should be considered sufficient and satisfactory; thus, the first phase can be assessed as successful. The only drawback entails the fact that the language model failed to pinpoint the most important attribute of EWS solutions, namely that bankruptcy risk assessment results from the processing of indicators calculated from financial data. Phase two went far less successfully. A command was introduced into the tool: *Specify the formula of the discriminant function '...'* (the names of the functions checked for were entered in the designated ellipsis, respectively: E.I Altman / Z7 INE PAN / P1 Prusak). The model was able to correctly describe and show the specification of E.I Altman's (1968) discriminant function but had very limited knowledge of the leading bankruptcy models designed for Polish economic conditions. With respect to the Altman Z-score, the ChatGPT algorithm formulated the model specification, number of variables, names of the variables, and the values and signs of the structural discriminant function's parameters correctly. It also accurately indicated the so-called cut-off points and the theoretical rule for inferring the result. When dealing with INEPAN's Z7 and Prusak's P1 models, the language model confirmed that it was familiar with these solutions, yet it formulated the functions incorrectly, misstated the number and names of the discriminating variables, and improperly composed the numerical assessments of the structural parameters. Occasionally, it also confused these solutions with completely different financial analysis tools.

In the calculation phases (stage 3 and 4), the language model operated very well with the E.I Altman's discriminant function. It correctly calculated the score for all selected DAX and DOW Jones index listed entities, as well as carried out 70% of positive calculations for WSE-listed companies. It is noteworthy that correct calculations were also followed by well-formed conclusions regarding the risk of bankruptcy. This means that the ability to correctly calculate a given function was always accompanied by the ability to correctly interpret the result. Referring to the leading discriminant functions developed in Poland (Prusak's P1 function and INEPAN's Z7), practical knowledge application (calculation phases) was fully correlated with the lack of theoretical knowledge on the two (phase 2). The linguistic algorithm failed to respond adequately to the commands regarding determination of the discriminant function value for a given company, although it correctly drafted and presented selected financial data for potential calculations, explaining that its knowledge in this area was running out. The algorithm, however, suggested risk assessment for the company in question using another bankruptcy model it was familiar with. This phenomenon highlights a degree of information noise which probably occurred during the ChatGpt algorithm training – in the large datasets processed, the model had most likely come across theoretical information on the models

(Z7 INE PAN, P1 Prusak) but blended it with information on other, unspecified discriminant functions from unverified sources. This presumably indicates an under-training of the algorithm with data from outside the United States and/or information recorded in a language other than English, as well as its tendency to cross-reference disparate information. The current revision of the ChatGPT model, according to the developers' assertions, is based on a training dataset dated at the end of 2021. This means that interactions regarding tasks, events and facts occurring after that time are significantly limited. The two models (Z7 INE PAN, P1 Prusak) are among the most widely used ones in Poland and have been the subject of several hundred publications in both Polish and English (with numerous citations), but they were developed several years ago, which is a serious indication of the language model's non-time-related deficiencies. This implies that there is a large number of potential input (training) data, both spatially and temporally, which the algorithm probably did not process properly in the learning process. Referring still to E.I Altman's discriminant function, the algorithm furthermore rightly signaled its limitations, stressing: *the Altman index comes with certain limitations and does not necessarily accurately reflect the financial situation of a company* [translated from the original in Polish by author].

6. Discussion

The results of the study carried out suggest a noticeable under-training of the algorithm when it comes to the realm of non-U.S. data, particularly if the interaction with the language model involves complex, specific issues and requires prior acquisition of secondary financial data. Nevertheless, the algorithm shows impressive training at the level of general issues, fulfilling, so to speak, the role of a 'communicating encyclopedia.' Referring to its management support suitability, specifically as a digital managerial advisor in the assessment of corporate financial health or bankruptcy risk, the algorithm is characterized (according to the current state of knowledge) by a clearly inferior potential to infer and formulate abstract judgments with additional input data requiring further processing (e.g., corporate financial reports). In other words, the model is almost flawless in its analytical operations, when it receives an entire set of input data in a command from the user, as opposed to when it is constrained to acquire this data on its own. This should not be considered a categorical disadvantage, as the process was to some extent intended by the developers of the tool - the model is meant to gain a broad multi-domain communication capability of building on huge datasets (WEF, 2023) rather than specialize in a narrow problem area. The current potential of the ChatGPT language model (and other language models currently being developed by competitors), however, indicates that its adaptation to more specialized and industry-specific problems should not be particularly challenging. What is more, steps are already being taken in the business world to implement

natural language processing systems into management support, which is in line with the projections of the Author of this article. One example is the project developed by a well-known venture capitalist Peter Thiel, aimed at development of a managerial chat-bot supporting financial directors and managers in day-to-day accounting and finance decision making (Bloomberg, 2023). According to the Author of this paper, the key to developing such a solution (or to specialized/industry-wide adaptation of such models as ChatGPT) is to provide enough high-quality data, which will serve as a training set, and integrate the tool with a structured digital database of financial reports (e.g., Bisnode). The combination of these two factors, should enable construction of a chatbot characterized by intuitiveness and freedom of communication similar to the ChatGPT model, but enriched with highly specialized knowledge of finance, financial statements, and bankruptcy risk analysis. Such a combination would be the likely seed for establishment of a fully functional digital financial management advisor for executives.

7. Summary

The digital revolution, inextricably accompanied by the expansion of artificial intelligence, has been stirring up many extreme emotions in society, ranging from the hope that machines will completely free the human species from tedious, repetitive tasks, to more radical expectations that all of humanity will soon be able to stop working and robots will be taxed, which will lead to technological unemployment (Moser, 2021). This will give every human being the right to a permanent income in the form of a so-called technological dividend, payable regardless of status, and financed by taxing robot labor. These predictions coincide with the fears expressed in the past, more specifically, in the lead-up to the Great Industrial Revolution. Indeed, at that time, fears were expressed that machines and the associated mass production would deprive the society of jobs. Nowadays, opinions can be found that intelligent solutions, including artificial intelligence, will wipe out many of today's well-known and practiced professions. In such borderline considerations, the truth usually lies in the middle. One highly probable scenario is that within 10-20 years, every human engaged in professional work will become, to a greater or lesser extent, a so-called ‘robot shepherd’ (Forsal, 2023). This should be interpreted to coincide with the actual effects of the 18th century industrial era - most workers did not lose their jobs altogether, but simply became machine operators. A similar scenario is materializing today in many areas of the economy - in an ever-increasing number of professions, workers who were once fully dependent on analog work tools must coordinate and supervise the operation of intelligent systems, often merely fulfilling the role of an automated process operator. Referring to the ChatGPT model’s potential in supporting human labor, especially in the process of financial management, however, it often exhibits characteristics

coinciding with the ‘Renaissance mind’. The tool, in its current version, efficiently handles interactions across nearly any subject sphere - from social sciences to higher mathematics (provided it receives adequate information input and assumptions from the user). It should be borne in mind, though, that this is still a solution trained on general knowledge, as well as on Internet resources, the quality of which is not fully controlled, as evidenced by the results of the experiment and the errors identified at the level of even the second phase of interaction. Any mathematical model training its algorithm with dirty data, for instance, will, to some extent, carry these distortions over onto the final prediction results, leading to the so-called ‘GIGO’ (Garbage in, garbage out) effect (Najman, Migdał-Najman, 2018). The study conducted seems to confirm that the current version of and the degree to which the language model implemented in the ChatGpt tool has been trained does show impressive features at a general level, but specialized issues requiring it to launch an exploration of Internet resources (e.g., independent acquisition and selection of relevant financial annual report data) often fall beyond its capabilities. This is true even for publicly traded entities, whose financial reports are widely available in various formats in the Web resources, and should again be attributed to the nature of the invention, as it was trained with a dataset predisposing it to resolving general knowledge problems rather than to the narrow realm of financial engineering and bankruptcy risk. Nevertheless, it ought to be emphasized that, based on the results of individual experiment phases, the model probably holds unlimited development potential and its adaptation to the issues of bankruptcy risk assessment and the broadly understood business standing assessment, should the need arise, would be a matter of months rather than years. Even now, financial institutions are successfully employing simple, autonomous installment loan granting systems, while the increasingly widespread marketing of BNPL (Buy now, pay later) solutions is fully based on artificial intelligence. More earnest and creative attempts to adapt chatbots to managerial support are likewise taking place, as evidenced, inter alia, by projects under development by well-known VC investors. The research questions formulated should thus be answered as follows:

RQ1: Natural language processing algorithms (including ChatGPT), even at this stage, demonstrate utility in the implementation and application of such other data-science-based methods as e.g., bankruptcy risk assessment models.

RQ2: The current efficiency in text processing by NLP-type systems, combined with the intuitiveness thereof for the user suggests that in the near future, many tasks involving the broadly defined assessment of corporate financial health (including counterparty bankruptcy risk) may be automated by intelligent Chatbots. This trend's existence is evidenced not only by the skills demonstrated by the ChatGPT model in the experiment, but also by the extensive commercial attempts to create ‘management advisor chatbots’, identified in the course of literature research.

Referring to the research hypothesis posed, it should be affirmed that intelligent natural language processing algorithms are capable of contributing managerial support in the assessment of a company's standing (e.g., using systems of early warning against bankruptcy). It should be caveated, however, that the capability is strongly conditioned by access to an appropriate dataset on which the algorithm will be 'trained' and highly dependent on proper integration of the tool with a database of high-quality financial data. The trend to refine these tools in this area of expertise is positively developmental, which means that soon many managerial activities will be able to receive autonomous support. In the foreseeable future, will an opportunity arise for an appropriately trained bot or virtual assistant processing natural language to respond adequately to the question *Check whether company X is a reliable contractor and whether I should agree to credit a sale to this entity, and if so, under what conditions?* The current state of knowledge and the results of the research conducted suggest that the answer is "yes". Certainly, the direction for further research lies in the realm of how ChatBot-type solutions will cope with more advanced financial threat prediction tools (e.g., when operating with black box tools, i.e., without a visualized function).

The main limitations in the study carried out stem from the fact that the experiment was based on existing and ready-made discriminant functions, which not infrequently show differential predictive performance, depending on the entity sector and country of origin. This means that the language model was confronted with a relatively undemanding task - namely, the need to use a ready-made, universal function to assess bankruptcy risk. The direction of further research, and at the same time a serious challenge (which currently likely lies beyond the potential of the Chatgpt model), would be to use an optimally selected classification function (e.g., matched to the sector or life cycle stage of the entity under investigation), or have the NLP model design its own function or neural network in real time at the user's command, each time it is queried about a company's bankruptcy risk/financial health. This would certainly require a redefinition of the entire solution's architecture, although in this case, the algorithm would not need to be trained on a broad, general data set (which customarily is very time-consuming), but only on information of a narrower and specialized nature (financial risk and financial analysis). This kind of NLP model capability (to create custom AI solutions in real time) would then bear traits of next economic revolution predicted by futurologists (after the coming digital and artificial intelligence revolution), namely the era defined by the moment when Artificial Intelligence begins to produce its own AI (robots produce their own robots). Indeed, a similarity can be discerned - a natural language processing algorithm, as a robot, designs an autonomous neural network (another robot), tailored and trained to the nature of the inputted command, to maximize the prediction results (e.g., a particular entity's financial problem/risk of bankruptcy).

References

1. Alaka, H.A., Oyedele, L.O., Owolabi, H.A., Kumar, V., Ajayi, S.O., Akinade, O.O., Bilal, M. (2018). Systematic review of bankruptcy prediction models: Towards a framework for Tool Selection. *Expert Systems with Applications, 94*, pp. 164-184. https://doi.org/10.1016/j.eswa.2017.10.040
2. Altman, E.I. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *Journal of Finance, 23(4),* pp. 589-609. https://doi.org/10.1111/j.1540-6261.1968.tb00843.x.
3. Antonowicz, P. (2007). *Metody oceny i prognoza kondycji ekonomiczno-finansowej przedsiębiorstw.* Gdańsk: Wydawnictwo ODiDK.
4. Antonowicz, P. (2011). Długość cyklu inkasa należności i rotacji zapasów w przedsiębiorstwach na trzy lata przed sądowym ogłoszeniem upadłości. *Problemy Zarządzania, no. 1(31),* pp. 53-71
5. Aslam, F., Hunjra, A.I., Ftiti, Z., Louhichi, W., Shams, T. (2022). Insurance fraud detection: Evidence from Artificial Intelligence and machine learning. *Research in International Business and Finance, 62,* 101744. https://doi.org/10.1016/j.ribaf.2022.101744
6. Bloomberg (2023). *CFOs Will Get Their Own AI Chatbot as Part of Brex Project.* Retrieved from: https://www.bloomberg.com/news/articles/2023-03-07/brex-to-offer-chatgpt-style-openai-chatbot-for-cfos-finance-professionals#xj4y7vzkg?leadSource=uverify%20wall, 09.03.2023.
7. Forsal (2019). *Pasterz robotów i manager śmierci cyfrowej. W ciągu 10 lat powstaną zupełnie nowe zawody*. Retrieved from: https://forsal.pl/artykuly/1410248,praca-przyszlosci-w-ciagu-10-lat-powstana-zupelnie-nowe-zawody.html, 07.03.2023
8. GOV.PL (2020). *Test Turinga i sztuczna inteligencja*. Retrieved from: https://www.gov.pl/web/ncbr/sztuczna-inteligencja--czy-pamietamy-o-tescie-turinga, 27.02.2023.
9. IBM (2023). *Natural language processing.* Retrieved from: https://www.ibm.com/topics/natural-language-processing, 27.02.2023.
10. Khurana, D., Koli, A., Khatter, K., Singh, S. (2022). Natural language processing: state of the art, current trends and challenges. *Multimedia Tools and Applications, 82(3),* 3713-3744. https://doi.org/10.1007/s11042-022-13428-4.
11. Kitowski, J. (2021). Modele dyskryminacyjne jako instrument oceny zagrożenia upadłością przedsiębiorstw. *Nierówności Społeczne a Wzrost Gospodarczy, 68(4),* 145-160. https://doi.org/10.15584/nsawg.2021.4.8.
12. Kowalak, R. (2017). Rola systemów wczesnego ostrzegania w procesie podejmowania decyzji o restrukturyzacji przedsiębiorstwa. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, no. 470,* p. 159.

13. Liddy, E.D. (2001). *Natural Language Processing*. Encyclopedia of Library and Information Science, 2nd Ed. NY. Marcel Decker, Inc. p. 2.
14. Maciąg, R. (2022). Zaawansowane procedury NLP jako przesłanka rekonstrukcji idei wiedzy. *Zarządzanie w Kulturze, 23(1),* pp. 37-53.
15. Migdał-Najman, K., Najman, K. (2018). Dirty data – profiling, cleansing and prevention. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 508,* 146-156. https://doi.org/10.15611/pn.2018.508.15.
16. Moser, E. (2021). Against robot taxes: scrutinizing the moral reasons for the preservation of work. *AI And Ethics, 1(4),* 491-499. https://doi.org/10.1007/s43681-021-00062-3.
17. MPost (2023). *Chaptgpt passes the turing test*. Retrieved from: https://mpost.io/chatgpt-passes-the-turing-test/, 27.02.2023.
18. Osika, G. (2021). Dilemmas of social life algorithmization - technological proof of equity. *Scientific Papers of Silesian University of Technology Organization and Management Series, 151.* https://doi.org/10.29119/1641-3466.2021.151.36.
19. Paprocki, W. (2017). Perspektywy zastosowania sztucznej inteligencji w systemach obsługi mobilności - przykład organizacji pasażerskich przewozów lotniczych. *Research Journal of the University of Gdańsk. Transport Economics and Logistics, vol. 74,* pp. 341-355.
20. Pociecha, J., Pawełek, B., Baryła, M., Augustyn, S. (2014). *Statystyczne metody prognozowania bankructwa w zmieniającej się koniunkturze gospodarczej*. Kraków: Fundacja Uniwersytetu Ekonomicznego w Krakowie, p. 8.
21. Shetty, S., Musa, M., Brédart, X. (2022). Bankruptcy Prediction Using Machine Learning Techniques. *Journal of Risk and Financial Management, 15(1),* 35. https://doi.org/10.3390/jrfm15010035.
22. Siciński, J. (2021). *System wczesnego ostrzegania przedsiębiorstw przed ryzykiem upadłości na przykładzie branży transportowej*. Sopot: Centrum Myśli Strategicznych, pp. 8-10.
23. Sira, M. (2022). Artificial Intelligence and its application in Business Management. *Scientific Papers of Silesian University of Technology. Organization and Management Series, 165,* 307-346. https://doi.org/10.29119/1641-3466.2022.165.23.
24. Sliż, P. (2019). Robotization of business processes and the future of the labor market in Poland–preliminary research. *Organizacja i Kierowanie, 185(2),* p. 67-79.
25. Tamkin, A., Brundage, M., Clark, J., Ganguli, D. (2021). *Understanding the Capabilities, Limitations, and Societal Impact of Large Language Models,* ArXiv:2102.02503. Retrieved from: https://arxiv.org/abs/2102.02503v1, 27.02.2023.
26. Turing, A.M. (1950). Computing Machinery and Intelligence. *Mind, 236(14),* 433-460.

27. WEF (2023). *How does chagpt differ from intelligence.* Retrieved from: https://www.weforum.org/agenda/2023/02/how-does-chatgpt-differ-fromhuman-intelligence?utm_source=facebook&utm_medium=social_scheduler&utm_term=Artificial+Intelligence&utm_content=28%2F02%2F2023+20%3A40, 7.03.2023.
28. Zięba, M., Tomczak, S.K., Tomczak, J.M. (2016). Ensemble boosted trees with synthetic features generation in application to bankruptcy prediction. *Expert Systems With Applications, 58,* 93-101. https://doi.org/10.1016/j.eswa.2016.04.001.

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REVERSE LOGISTICS OF E-COMMERCE AS A CHALLENGE FOR THE CEP INDUSTRY

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Purpose: The aim of this article is presenting the CEP market from the perspective of the development of reverse logistics in e-commerce, which has recently played an important role both from the perspective of the customer and the companies.
Design/methodology/approach: The article is based on the analysis of literature, results of secondary research and own research conducted in 2017, 2019 and 2021 among online shops and in 2021 among CEP companies. A survey of Polish e-commerce and courier companies using the CAWI technique was conducted to gather information on the behaviours, expectations and attitudes of e-customers towards making purchases and returning goods in order to identify challenges for the CEP market.
Findings: As can be seen from the data analysis, the growth of the CEP industry during the Covid-19 pandemic is undeniable and is the result of the development of e-commerce and returns services. The average annual growth of courier services by 2025 in the Asia-Pacific area will be 10.8%, in America Sem. - 5.2%, in Europe - 5.1%, and in Poland - between 7-8%. The industry therefore has to deal with an increasing number of orders resulting from online shopping, new customer expectations related to security, or the reduction of direct contact.
Research limitations/implications: The return policy in e-commerce is still a growing topic, which is the biggest challenge for both online stores and courier companies. The conducted research is a starting point for further analyzes regarding: e-customers' expectations regarding the level of service in the area of returns, cooperation between entities from the CEP industry and online stores, or the automation and support of reverse logistics processes in the CEP industry.
Practical implications: The presented research results can serve as a source of knowledge for e-commerce entities as a foundation for building a competitive advantage on the market. For courier companies, they are the starting point for designing processes dedicated to handling return logistics for e-commerce.

Originality/value: The covid-19 pandemic contributed to the acceleration of the development of the e-commerce market around the world faster than specialists had predicted. This situation forced the KEP industry to redefine the processes so as to adapt them to the new reality and respond to the growing requirements of the client. However, as the volume of online purchases increased, so did the volume of returns, which has always been a challenge for e-commerce. The conducted research showed through which activities the KEP industry redefined its role in the electronic trade.

Keywords: CEP market, e-commerce, reverse logistics, Pandemic Covid-19.

Category of the paper: Research paper.

1. Introduction

The CEP industry has become one of the most important segments of the logistics sector. Its development, but also the redefinition of its activities, is undoubtedly influenced by e-commerce, reverse logistics, and the Covid-19 pandemic. The industry faces increasing expectations that it has to address. In addition to operational flexibility, more advanced e-customer service processes and innovative solutions in the field of devices/applications that facilitate order delivery or return, as well as maintaining sanitary safety in customer service are expected. Handling the increasing number of orders resulting from online purchases is undoubtedly a challenge for the CEP industry, but the key challenge is the handling of returns, i.e. reverse logistics, which has recently become increasingly important also for logistics operators.

Reverse logistics applies to all operations related to the reuse of products and materials. This is a type of supply chain management that moves goods from customers back to the sellers or manufacturers. Usually logistics deals with the events that bring the product to the customer. In reverse logistics, the asset moves back one or more steps in the supply chain.

Reverse logistics start at the end consumer, moving backward through the supply chain to the distributor or from the distributor to the manufacturer. Reverse logistics can also include processes where the end consumer is responsible for the final disposal of the product, including recycling, refurbishing or resale. The goal of reverse logistics is to recover value and ensure repeat customers. Less than 10% of in-store purchases are returned, compared with up to 40% of products ordered online (Courtney, 2019). Operative companies use reverse logistics to build customer loyalty and repeat business, and to minimize return losses.

Currently, according to the report *Reverse Logistics Market by Return type and End User: Global Opportunity Analysis and Industry Forecast, 2018-2025*, the global reverse logistics supply chain is valued at $ 415.20 billion and is projected to reach over $ 600.00 billion by 2025. Worldwide, returns are worth almost a trillion dollars annually and have become increasingly common with the growth of ecommerce. These predictions regarding the

development of the Reverse Logistics area are not surprising when you look at the parcel delivery market. Statista, a company that provides market and consumer data, provides data and forecasts for global package volume. In 2019, this number amounted to approximately 103 billion parcels and it is expected that by 2026 this volume will more than double - to 262 billion parcels sent (Placek, 2022). In Poland, the market of courier, express and parcels is also developing rapidly. In 2018, it was worth PLN 6.95 billion, which means an increase of 60% compared to 2014. Forecasts say that in 2023 the operators of this market will handle almost 850 million parcels, and the market value will reach nearly PLN 12 billion (The CEP market in Poland in the face of trends and new challenges).

As online sales boom, there's an inevitable side effect: More merchandise is getting returned, boosting costs and complexity for retailers. Not being able to see an item in person accounts for part of the difference, but consumers also shop differently online than in store. They may order multiple sizes or colors to try on at home, and then ship or take back what they don't want, with shipping paid for by the retailer, both ways in some cases.

Average return rates vary by category, but clothing and shoes bought online typically have the highest rates with 30 to 40 percent returned. In the next several years, as e-commerce grows globally, the amount of returns is going to be over a trillion dollars a year (Courtney, 2019).

Another factor adding to rising returns is more relaxed return policies. As retailers fight for market share in an increasingly competitive industry, return policies are allowing longer windows to bring back items. Also, retailers are often accepting online returns in stores, even if the items were never sold at the store. It is also worth returning to the aspect of customer experience with a brand that applies the reverse logistics strategy in its approach. Appropriate care of the customer who purchased the products is reflected in brand loyalty and is conducive to generating positive opinions. In the era of the virtual world and the ease with which users share their observations online, this is an element that must be taken into account in the strategy of operations.

To fully present the idea of this article and the carried out research, first of all, it is necessary to refer to the theoretical and terminological aspects of the CEP, e-commerce and reverse logistics market. However, the greatest attention has been given to explaining and presenting the terminology of reverse logistics, due to the fact that currently this terminology is used for various forms of returns, not only for waste.

2. CEP market, e-commerce - evolution and terminology

The history of mail order trade has a long pedigree, as the first large-scale sales attempts in this system were recorded as early as 1881. It was then that Alfred Hammacher issued and distributed to his customers a catalog with construction equipment and electronic tools. While this solution seemed very convenient over the decades, the disadvantages of catalog selling began to be noticed over the years. The catalogs were published seasonally and presented a limited assortment, and you had to wait up to several months for the next offer. The possibility of selling via the Internet meant that the offer of stores could be constantly updated, which was enthusiastically received by consumers, because they could make a purchase when the need arose.

The full potential of the Internet in commerce began to be used in 1994. During this time, the number of Internet users in the world grew by 2-3% per month. It was then that the first typical online stores were created, where an order could be placed via a special form or by adding a product to a virtual basket. Consumers immediately began to appreciate the fact that they decide when, where, for what amount and what they buy. The possibility of comparing prices and properties of various products in the network turned out to be important, thanks to which it was possible to quickly select the most advantageous offer (Skurpel, 2019).

Electronic commerce (e-commerce) is most often presented in two terms: narrower - in which it means the way of selling and buying products / services using electronic means via the Internet - and wider - in which it means concluding various commercial transactions via teleinformatic networks, without the need for direct contact between the parties, at the same time including making payments.

When defining the CEP market, a conventional definition of the CEP industry should be mentioned, describing it as courier, express, parcel services (CEP). It results from the fact that it is difficult to separate express services from parcel or courier services, as there are only few differences between them. For example, what can be considered as a difference is:

- in the case of courier services, the most important role is played by the courier responsible for delivering the parcel to the recipient,
- when it comes to express services, they are aimed at fast and reliable delivery of parcels, but are not accompanied by personal courier care,
- as for parcel services, they focus on domestic, often regular shipments of light weight and specific sizes.

The global dynamics of the CEP market is determined by the development of the e-commerce industry, reverse logistics, government regulations of individual countries, or restrictions related to the Covid-19 pandemic.

Polish law does not clearly define the courier service, which is the pillar of the CEP industry services (courier, express, parcel). On the one hand, the courier service is classified as a postal service, on the other - a transport service, and this approach may justify the lack of one specific definition. Courier companies in Poland began to appear in the 1980s, and therefore it is a relatively young industry. The opportunity for these entities was the liberalization of international transport regulations. Currently, the courier services market in Poland has a structure similar to their counterparts in the European Union. It covers all groups of service providers, i.e. integrators, entities offering express transport services throughout the country, local companies, enterprises operating in market niches, and intermediaries. Courier services are characterized by high diversity, which is influenced by: the subject of the services provided, the time of delivery, the type of transport, the geographical area of the operator's activities, as well as the type of the sender and recipient.

The CEP market continues to record a high pace growth around the world. Especially perceive can be impressive growth in developing countries itself, driven by the increasing popularity of the trade the increasing penetration of the Internet and smartphones, a growing middle-class population and theirs wealth and improved living standards. New technologies are transforming the entire supply chain and redefine the CEP industry. Technology becomes a key factor enabling the increase efficiency and meeting consumer expectations.

In 2018, the global CEP market amounted to EUR 306.2 billion (this is 8.6% more than the year before). At that time, there were 55.6 billion shipments in circulation (increase by 9.7%). Growth dynamics in the following years it won't be as fast anymore, but it has to stay on high level. In 2019, the CEP market in terms of value grew by 7.9%, reaching EUR 330.3 billion and in terms of numbers by 9.1% to 60.7 billion parcels (Statista, 2019). And in 2020 in terms of value, the market will reach EUR 356 billion, and in terms of numbers 63.6 billion shipments. Assuming a similar growth rate in the following years, the value of the world market in three years will amount to EUR 415 billion with 73.5 billion shipments.

The global CEP market grew by 13% in 2020. Both the domestic and international parcels market grew dynamically - by 13.2% and 12.5%, respectively. On the one hand, the pandemic in 2020 resulted in the collapse of the B2B parcel market, on the other hand, it caused the volume of B2C parcels to increase, thanks to which the record growth of this market was achieved. This is undoubtedly the effect of the development of e-commerce. Due to the Covid-19 pandemic, in 2020 and 2021 there was a dynamic accumulation of new online shopping users. According to the e-Marketer, the global e-commerce market grew by over 27% in 2020. The largest is the Asian market with 45% world market share. In the following years, this one the first will develop the fastest. In terms of the largest share in the world market KEP has DHL (38%), closely followed by FedEx (24%) and UPS (22%), TNT (5%) (Statista, 2018). According to the research carried out by TI - Transport Intelligence and Upply (https://trans.info/pl..., 27.10.2022) the growth rate of the courier and express parcels market will slow down after 2021. The average annual market will increase its value by 7.5% in 2020-

2025. According to the calculations of the authors of the report, this will mean that the value of the global express and courier parcels market in 2025 will be over 62% higher than in 2019.

Analyzing the development of courier services in individual regions, the Asia-Pacific area will maintain the highest growth rate in 2020-2025 with an average annual growth of 10.8%. This growth will be mainly due to the dynamic development of the market in China and other Far East economies.

North America and Europe will see much more modest growth in the courier industry - in the order of 5.2% and 5.1%, respectively, on an annual average.

In Europe, the B2B segment accounts for EUR 35 billion (52%), B2C - EUR 22 billion (32%) and C2X - EUR 11 billion (16%). B2B (business to business) includes outbound shipments and received by institutional clients, and in B2C (business to customer) is addressed to customers individual. C2X applies to postage shipments and received by individual customers, returns from consumers to online retailers and part shipments from micro-retail trade.

The European CEP market in 2018 was worth 67.8 billion euro (an increase of 5.1%), reaching approx. 10 billion parcels (increase by 5.9%) (Wik-Consult, 2019). It constitutes 22.1% in terms of value and 18% by number of the global market. The largest share in the European market, CEPs have domestic shipments. Foreign shipments amount to 25% respectively in value and 8% in number, the most of which The European CEP market is quite concentrated. Germany, Great Britain, France, Spain, Italy, The Netherlands, Belgium and Poland account for 76% of Europe GDP and 80% of total revenues from CEP. Most shipments for one person is in Germany, UK, France, Austria and countries Benelux. The German market is the largest market CEP - 3.52 billion parcels generated turnover worth EUR 20.4 billion (CEP Research, 2019). It has the largest potential, but characterized by strong competition and large barriers to entry. A bit smaller, but very much the British and French markets are large. In 2019, the European CEP market in terms of value grew by 4.9%, reaching EUR 71.1 billion and numerically by 5.8% to 10.6 billion parcels. In 2020 in terms of value, the market will reach EUR 74.5 billion, and in terms of numbers 11.2 billion parcels. Assuming a similar growth rate in the following years, the value of the European market too in three years it will amount to EUR 81.8 billion with 12.5 billion parcels.

The Polish CEP market in 2018 was worth PLN 6.95 billion, which was an increase of 60% compared to 2014 (12.5% average annual growth). The greatest increase valuable (14.8%) was recorded in 2018. However, the growth rate of the market in terms of numbers in 2018, compared to 2017, it reached 15.6%, which means the number was still growing faster shipments than the market value. Differences they will be at the pace of development in terms of value and volume to decrease in the following years.

Figure 1. Development of the CEP industry in Poland in comparison with Europe and the world in 2020. Source: own study.

According to the Last Mile Experts (https://trans.info/pl.., 27.10.2022) report, the Polish CEP market in 2020 reached a value of approx. PLN 10.7 billion and thus increased by over one fifth (by 22%) compared to 2019. 814 million parcels were sent. That was an increase by 34.8% compared to 2019. From 2015, the volume of parcels on the market increased by 163%. from the level of 309 million parcels. The Polish market is dominated by B2C shipments, which in 2020 accounted for 76.6% of the total volume of shipments. Those sent by enterprises to other companies represented 18.7% of the market, and those sent by private individuals - 4.7% (the dynamic development of the market was visible especially in the OOH - out-of-home segment). According to forecasts, in 2023 the CEP market in Poland will reach the value of PLN 16.2 billion, which will mean an increase by as much as 51.4% over three years. The volume of parcels on the market will reach 1.31 billion items in 2023. This is an increase of over 61% compared to the level from 2020 (especially dynamic in the B2C segment). In the years 2020-2023 (by an annual average of 19.7%). In this sector the volume will increase by a total of 72%.

3. Place of reverse logistics in traditional supply chains

Taking into account the specifics of the handling of returns in e-commerce, reverse logistics can be defined as the management of product flows (with accompanying information), returned from the consumption points to a retailer, distributor, manufacturer in order to recover the value

of goods as a result of repair and reassembly. sale, also to carry out their disposal or return for recycling (then these returns are referred to as EOL - end –of- life product return), finally to repair defective goods under the applicable warranty.

The reasons for such returns may be different and result, for example, from: failure to meet the customer's expectations (size, quality, color, etc.), product defect, wrong product not in accordance with the specificity of the order (mistake in packaging, incomplete order). This definition refers to the specificity of e-commerce returns in terms of the type and purpose of returns.

Reverse logistics can be defined as the process of managing products in the supply chain, recovered from individual exchange partners or their end users (Table 2). These are also any after-sales activities related to a product or service, aimed at optimizing or increasing the efficiency of all after-sales activities, contributing to savings in financial and natural resources (Reverse Logistics Association, 2012).

Table 1.
Reverse logistics areas of product management and reverse logistics market by return type

The area of sales process and products use	Area of after-use	Reverse logistics market by return type
- Returns of stocks and products surplus from advertising companies, - Product under warranty returns - Returns of complaint products due to defects and faults, - Returns of brand new products unwanted by customers	- Return of worn out products, - Return of obsolete products, - Return of physically and economically worn out products	- Recalls - Commercial Returns - Repairable Returns - End-of-use Returns - End-of-life Returns

Source: Wodnicka M., D. Skurpel, Reverse Logistics in Polish Commercial Companies from Economic and Management Perspective, European Research Studies Journal, Vol. XXIV, Iss. 4, 2021, pp. 821, 825.

Along with the growth of the e-commerce market and its importance for the customer, there has been a clear increase in interest in another dimension of the reverse logistics concept, which concerns the flow of returns of both full-value and defective products. At this point, the question arises whether the division into return logistics and reverse logistics is justified in the light of changes taking place in the economy, namely the development of the e-commerce market, or the enterprises in the area of customer service. Both reverse logistics and return logistics are related to the essence of the supply chain and flows occurring in it, and also relates to the management of goods / products returned. Currently, the scope of reverse logistics is not limited to waste only.

It covers material flows related to the recall of full value products from the customer as well as those that require repair or complaint, and therefore cannot be defined as waste. The status of the product after return depends on the condition of that product and the decision of the company to which such return is directed. Given the above, it becomes justified to use the term "reverse logistics" in a broader sense, referring it to both reverse logistics and return logistics.

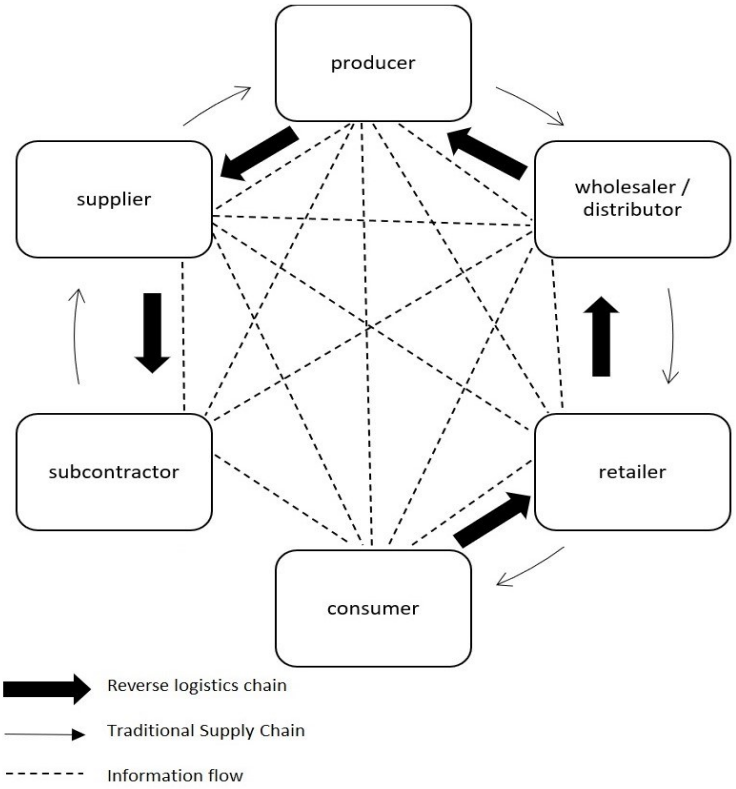

Figure 2. Reverse logistics in the supply chain.

Source: own study based on Lummus R.P., Krumwiede D.W., Vokurka R.J. (2001), The Relationships of Logistics to Supply Chain Management: Developing a Common Industry Definition, "Industrial Management and Data Systems", No. 108/8, p. 426.

The concept was further refined in subsequent Stock publications (1998) in Another Council of Logistics Management book titled Development and Implementation of Reverse Logistics Programs, and Rogers and Tibben-Lembke (1999) in a book published by the Reverse Going Backwards Logistics Association: Reverse Logistics Trends and Practices.

The product data collected when engaging with customers after delivery is an advantage of well-executed reverse logistics. Data provides insight into an organization's supply chain and an opportunity to improve products and/or the customer experience.

Optimized reverse logistics also leads to better supply chain visibility, which leads to benefits like:

- Cost reduction.
- Greater customer satisfaction.
- Better customer retention.
- Faster and better service.
- Loss reduction.
- Improved brand sentiment.
- Waste reduction and greater sustainability.

Successful implementation of RL networks requires many decisions relating to different hierarchical levels: strategic, tactical, and operational. However, the design of the RL network can be considered crucial in the decision making process. In practice, numerous RL networks can be observed that depend on the nature of the returned product (EoU: end-of-use products, EoL: end-of-life, etc.), the recovery process (remanufacturing, reuse, recycling), or the forward channel structure (centralized, decentralized). This way, the design of the RL network becomes a strategic issue in the context of SCM, and it is actually difficult to find a supply chain where RL is not present at least to some degree.

Nevertheless, the design of an RL network is based on three basic activities:

1. Collection of EoU products: according to (Dale et al., 1998) collection of EoU products can be considered the starting point of the system, and three different collection options can be observed depending on whether the collection is made directly by the manufacturer or remanufacturer, through a network of distributors and retailers, or through third-party logistics providers.
2. Inspection and Classification: one of the main characteristics of the product recovery management is the uncertainty associated to the recovered products, in terms of quantity (how many products will be returned), quality (about the condition of the returned products), and time (when the EoU product will be returned). These activities (inspection and classification) will determine the condition of the returned products, so an analysis of the locations and capacities of sorting centres is required.
3. Recovery Process: can be considered as the key element of an RL network due to, in this phase, the economic value of the returned product being recovered through one of the following options:
    - Reuse: implies very basic activities to recondition the product (cleaning, minor repairs) that do not modify their structure or their nature (Carrasco-Gallego et al., 2012).
    - Remanufacturing: requires additional activities (disassembly, inspection, repair, and assembly) to recover the value of the returned products and give them similar qualities and technical characteristics to the original products: laptops, printers, mobile phones, etc.
    - Recycling: only the economic value of the raw materials is recovered, so the returned product loses its identity: packaging material, glass, paper, plastic, etc. New opportunities for research in this stream can be considered, particularly those related to empirical application that could be of immediate help to practitioners (Aras, Boyaci, Verter, 2010).

A challenge of reverse logistics is that the flow must be bi-directional. Managers need to set up the right infrastructure for it to be effective. That often requires software that can automate and track every step of reverse logistics. Additionally, once that infrastructure is in

place, management needs to continually monitor and evaluate the organization's reverse logistics processes to ensure efficiency.

Companies must track inbound and outbound logistics to get the full picture. Inbound logistics manages the receipt of raw materials or goods from the supplier to the manufacturer. Outbound logistics is the processes that deliver the finished goods to the end user. Both inbound and outbound logistics are measured from the manufacturer's perspective, while reverse logistics can be part of any point in the supply chain.

4. Reverse logistics in e-commerce as the biggest challenge for the CEP market

According to a Happy Returns survey, nearly three-quarters of Americans say returns are their least favorite part of shopping online, so an easy return system is crucial for retaining shoppers.

In 2019, the return delivery costs amounted to 363 billion U.S. dollars in North America alone and global return costs of over one trillion U.S. dollars. The reverse logistics process may also include management and sale of surplus or returned equipment and machines from the hardware leasing business.

For example, when a defective item is returned by a customer, the manufacturing firm organizes return shipping, testing, dismantling, repairing, recycling or disposing of the defective product. In 2015, over 65 million U.S. dollars worth of defective sales products were returned to stores worldwide, while clothing and accessories accounted for the largest share of returned items in 2016. In the United States, some 5.8 million packages were returned in the first week of January, 2017. One of the most important return policy characteristic of online purchases is when return shipping is free or when the customer is able to get a full refund rather than a partial refund or in-store credit.

Consumers or end-users return a product for a variety of reasons, such as product defect, incorrect product delivery, end-of-life returns, and end-of-life returns. Reverse logistics deals with the logistics of these products. Reverse logistics therefore relates to all activities related to the transport of goods from the place of consumption to the place of origin (includes producers or distributors). The main goal of reverse logistics is to get as much value as possible from the returned product. The market is expected to grow with a CAGR of 4.48%. The market will grow to expected revenues of approximately $ 657.66 million by 2027 (InkWood). The base year included in the study is 2018 and the estimated period is 2019-2027. The growth of this market is driven by the following factors:

- Growth in the e-Commerce industry.
- Strict government regulations regarding the quality of products in the automotive industry.
- Need for reverse logistics in the pharmaceutical market.

The most important driving force is the development of the e-Commerce industry. The progress and wide use of technology make the e-commerce sector efficient and attainable. In 2018, Reverse Logistics by e-Commerce had the largest share in the revenues of 23.56% of the market according to the End User segment. The global e-Commerce logistics market is growing. However, the recall is more prominent in the e-commerce end-user segment. Withdrawals from the market are mainly due to a product that is not in line with customer satisfaction, a damaged product, offers to replace old products with new ones, etc. Reverse logistics is very important in this segment. The cost of returns is between 5% and 6% of the total revenue. Moreover, many e-commerce companies have a high percentage of returned goods. For example, the rate of return for Amazon is between 8% and 16%. This is a key challenge for the development of the global e-Commerce logistics market. It is also expected to be the fastest growing segment (InkWood).

The largest and fastest market for reverse logistics belongs to the Asia-Pacific region. The boom in e-Commerce and the creation of joint ventures by leading car transportation logistics companies are expected to drive the Asia-Pacific market. India is the fastest growing market in the Asia-Pacific region. India has over 400 million databases of internet users. E-commerce is seeing unprecedented growth in India.

The global reverse logistics market is market segmented by payback type and end user. The market by type of return is further broken down into recall, trade returns, repairable returns, end-of-life returns, and end-of-life returns. The end-user market is further broken down into e-commerce, automotive, pharmaceuticals, consumer electronics and more.

It is no longer a secret that returns in online retailing can make the difference between success and failure for e-commerce companies. To emphasize the importance of returns and reverse logistics in online retailing, and how customer behavior has changed in regards to returns. Even before the COVID 19 pandemic, the likelihood of a return after an online purchase was already 3 times higher than for offline purchases. Despite this, 66% of consumers have since preferred returns in brick-and-mortar retail regardless of purchase method. However, that has changed dramatically. E-commerce has grown at an unimaginable speed. As a result, both fulfillment toward customers and reverse logistics have become critical factors in customer satisfaction. For this reason, 40% of online retailers changed their return policies during the first phase of the COVID pandemic. Another 27% considered adjusting their returns strategy already back in May 2020 (https://blog.getbyrd.com/en/reverse-logistics).

Online retailers' membership schemes are also likely to have contributed to the rise in returns. By paying a monthly subscription for free delivery and returns, the marginal cost of purchasing/returning goods online is reduced and the perceived 'risk' of buying a product that

is not suitable is removed. 17% of EU28 (Eurostat) respondents announced that they would not buy online due to concerns about returning goods, according to a Eurostat survey.

Given the above-mentioned statistics, it is safe to say that reverse logistics and returns became an important part of doing business online. Howbeit, as online shoppers' behavior adapts to utilize returns as part of their shopping journey, costs for reverse logistics quickly skyrocket. To keep costs under control, e-commerce shops can explore ways to reduce the number of preventable returns.

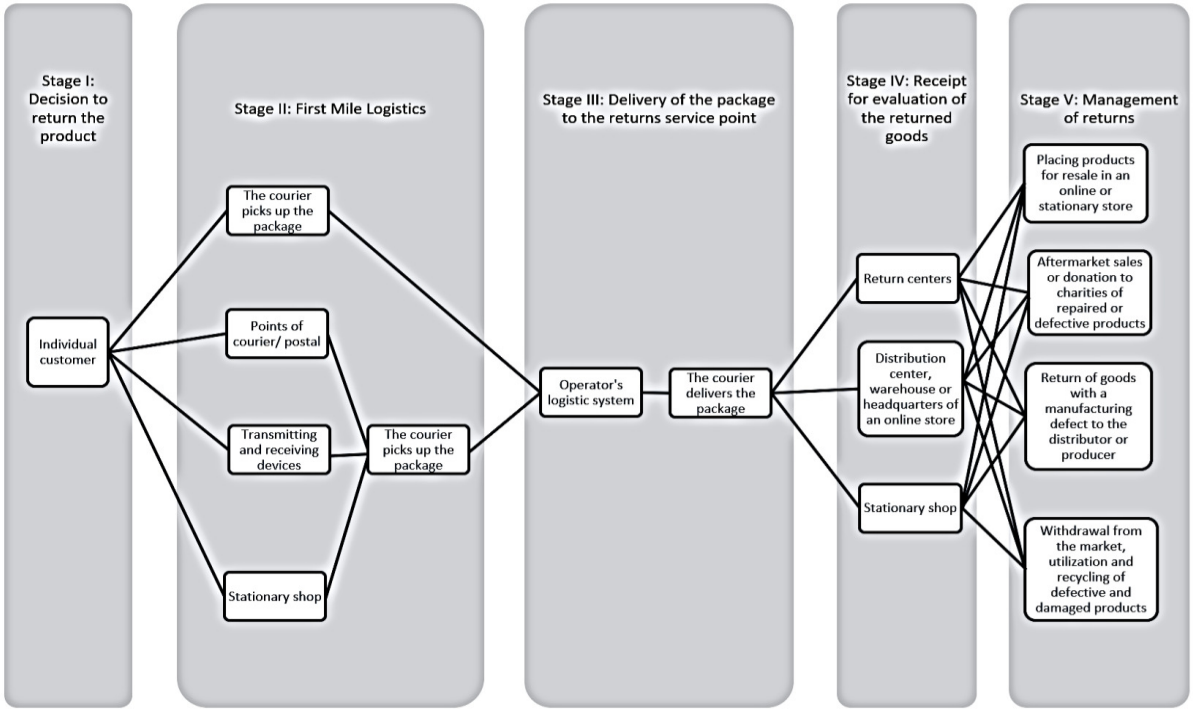

Figure 3. Product flows in the B2C e-commerce reverse logistics process.

Source: Monika Wodnicka, Dagmara Skurpel, Reverse Logistics in Polish Commercial Companies from Economic and Management Perspective, European Research Studies Journal, Vol. XXIV, Iss. 4, 2021, p. 825.

There are several basic stages in the B2C e-commerce reverse logistics process. The process is complex and includes a number of activities related to the collection of products from consumers, organization of transport, handling of warehouse processes, including quality control of returned goods and their re-sale or recycling, as well as the preparation of documents and information flow.

The product flow in the B2C e-commerce reverse logistics process consists of the following stages:

Stage 1: Decision to return the product.

Stage 2: First Mile Logistics.

Stage 3: Delivery of parcels to returns service points.

Stage 4: Receipt and assessment of returned goods.

Stage 5: Handling of returns.

The return logistics process is started when the consumer decides to withdraw from the contract and return the goods purchased in the online store. Pursuant to the Act on consumer rights of 30 May 2014, the buyer has the right to withdraw from a distance or off-premises contract and return the goods within 14 days from the moment the consumer receives the goods, and not from the date the contract is concluded, without the need to giving the reason. Some online stores offer longer terms, e.g. 30 days to cancel your purchase. During this time, the consumer must inform the seller about the withdrawal from the contract. He then has a few days to ship the products. Depending on the shop's policy, the customer may first, according to the information on the shop's website, send the returned goods at his own expense without contacting the seller. The consumer chooses any of the parcel delivery services available on the market, guided by the criterion, e.g. the lowest price or the convenience of sending the parcel. In the systems of the CEP and postal companies, this form of return is treated as posting the shipment by a person physical and not as a return.

Second, the consumer can send back the goods using the printed return label attached to the package. In order to create return labels, the online store must activate a service dedicated to handling return shipments at the CEP or postal operator. In Poland, as research has shown, this option is not very popular so far. E-shops fear that such simplification of return procedures will make it easier for consumers to decide whether to send back the goods.

In the third option, the consumer reports to the online store that he or she wishes to resign from the purchase (e.g. via e-mail, a form on the website or by calling the hotline). The e-shop indicates the address to which the product will be sent, as well as the documents and data that the customer should provide in electronic form and attach to the shipment. The seller can authorize a return order before sending the package and decide whether to cover the cost of the shipment whether he will cede it to the consumer. The Act of May 30, 2014 on consumer rights requires the seller to return to the customer only the costs of purchasing the product and delivery (in the amount of the cheapest delivery service offered by him). He is not obliged to cover the costs of the return shipment.

The second step in the process involves "first mile" logistics, the main challenge of which is to collect individual products from individual customers. There are several solutions available on the Polish market, offered by CEP and postal operators, which can be used to collect parcels from customers. The main difference between them is the degree of consumer's involvement in the service of the "first mile" and the subjective sense of comfort.

In the first variant, the courier collects the parcel in the door-to-door system at the location indicated by the consumer, e.g. at home. In the second option, the customer engages in the process of creating value by delivering the parcel to a selected place: a branch of the CEP company or a post office, partner points for collecting and sending parcels (including service companies, gas stations and stores open late) or self-service devices for collecting and sending parcels. As a rule, couriers collect postage.

Return parcels on the occasion of delivering parcels to a given point/device, which reduces the costs of transport and handling the "first mile". Some bricks and clicks retailers also offer customers the option of returning products purchased from an online store directly to a physical outlet. The seller can then check the condition of the goods and decide on its further path. A product can be put on sale in a store or sent up the supply chain.

At the third stage, the parcels go through the logistics system of the CEP operator or the postal operator handling the parcels. Most often it is organized in the hub and spoke system with a central sorting facility for a given region of the world or country and regional or local terminals. Local branches have two functions: they collect parcels sent by couriers from a given region, from where they are delivered to the system of national sorting plants, and separate parcels incoming from central sorting plants to couriers. Returns are delivered by couriers to the places indicated by the online store (e.g. to the address provided on the website or on the return label). The place of return may be different from the place sending the parcel.

The quick and efficient handling of returned goods is as challenging as 'first mile' logistics. Due to the scale of operation, small and micro online stores can handle returns on their own in the warehouse that prepares shipping. Large online stores usually outsource these activities to a logistics operator that handles shipments or specializes in handling returns, the so-called return centers. Employees in each of these places check the quantity and quality of the returned goods and the condition of the packaging. Then they decide whether the returned product is defective or damaged or is suitable for resale.

The further route of returns and the logistic handling of flows depend on the assessment of the condition of the returned goods, their type and place of storage. Efficient, undamaged products in original packaging can be immediately resold in an online store, stationary store or outlet (e.g. products returned after the season or after the collection has been withdrawn from regular sale). An important action is also to restore the value of the returned goods by, for example, repair or replacement of the damaged packaging. Defective or damaged products are usually repaired, discounted and sold on secondary markets (e.g. Allegro, e-Bay) or in special outlets or donates to charities. Goods with manufacturing defects may be advertised and sent back by the e-retailer to the distributor or manufacturer. Defective and unrepairable or expired goods are recycled or utilized.

5. Return logistics in Polish e-commerce- Research results

5.1. Data sources, instruments, tools and methods of research data analysis

In the academic field, most research conducted to date has been focused on tactical and operational aspects rather than on strategic issues (Carrasco-Gallego et al., 2010). As has been

previously reported, there are numerous reasons for implementing or operating an RL system. The most important of these are the following (Rubio et al., 2008):

- Economic: direct reasons (decreasing the use of raw materials, reduction of disposal costs, creation of added value for end-of-use products) and indirect reasons (demonstration of environmentally responsible behaviour, improved customer relations).
- Legal: in many countries (within the European Union, for example) companies are held accountable for the recovery or correct disposal of waste generated by products they produce or distribute.
- Social: the increased social awareness of the need to protect the environment has led to increasing demands for environmentally responsible behaviour by companies, particularly in terms of carbon emissions and waste generation.

The further part of the article, based on own research, presents the process of reverse logistics in e-commerce in the B2C segment. The study used secondary data, but most of all information collected during own research conducted in 2017, 2019 and 2021 on a group of 121, 139 and 141 e-commerce companies, respectively, and among e-customers, on a sample of 1,709 respondents who have ever made purchases online. Both surveys were carried out using CAWI (Computer-Assisted Web Interview) surveys on the internet panel.

Survey invitations for online stores were sent by e-mail. Due to the possibility of sending a certain number of messages by e-mail, a quota selection was decided according to the provincial criterion, and the sample size was set at 25% of the population.

In addition to the size of the sample, the key aspect determining its quality is representativeness, therefore the structure of the e-customer research sample was adjusted using an analytical weight to match the structure of Polish society in terms of key features related to the subject of the study. When constructing the weight, socio-demographic variables such as gender, age and place of residence were taken into account.

In 2021, qualitative research was also carried out using the in-depth interview tool. The survey was conducted among the managers of enterprises operating on the CEP market. The aim of the study was to determine what new solutions and innovations are introduced by enterprises related to adapting to the new conditions caused by the Covid-19 pandemic.

5.2. The CEP industry in the handling of e-commerce returns

PostNord's survey of European consumers indicates that German shoppers were the most likely to have returned a package in 2018, with 53%: of respondents having returned items. This could partly be down to payment methods – in Germany, for example, it is usual to pay for ecommerce purchases by credit card, and consumers are charged at a later point for their online orders, whereas, in the UK, consumers are generally charged at the point of purchase. It's also worth considering that the increasing ease of purchasing goods online using website cookies at checkout etc. could ultimately result in a rise in impulse or 'panic' purchases.

An estimated 315 million parcels were returned in Germany in 2020. This is an increase of 4.6 percent. compared to the number of parcels returned in 2019, which is attributed to the impact of the COVID-19 pandemic on purchasing behavior.

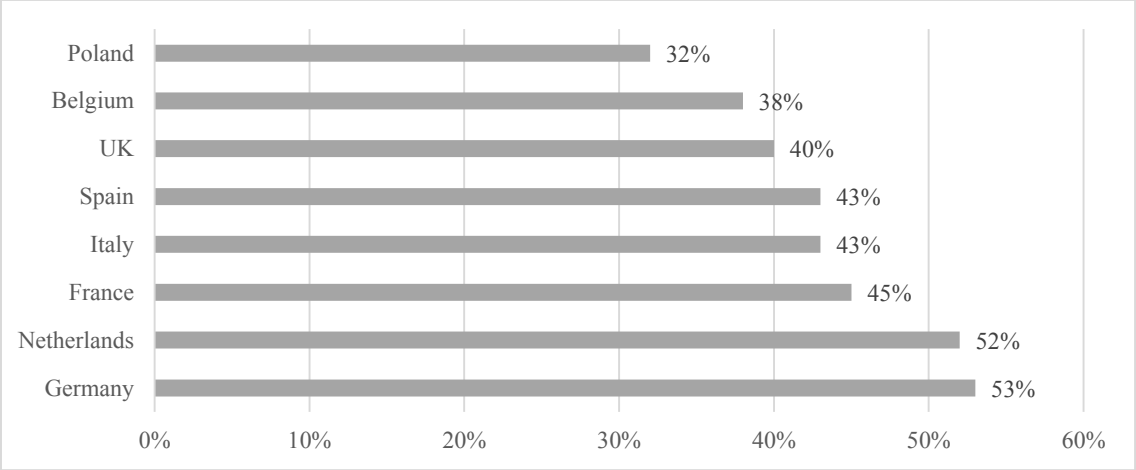

Figure 4. Share of population returning online purchases in 2018.

Source: Eurostat.

Europe's retailers are now having to adapt their logistics operations to deal with ecommerce returns as consumers are faced with more ways to return goods bought online across the continent.

Some multinational ecommerce operators are now developing dedicated centres across Central Eastern Europe (CEE) to process returns. Amazon's returns warehouses in Dobrovíz, Czech Republic and Sereď, Slovakia cater for returns across CEE markets, similar to the Dunfermline returns centre for Amazon's UK returns.

However, most online retailers continue to carry out returns operations from their existing distribution centres. Poland remains a key distribution hotspot among ecommerce operators in Europe due to cheaper labour costs, proximity to the rest of Europe, access to power and ability to develop new stock. Zalando's distribution centres are strategically located across Poland to cater for distribution and returns within the Baltic and Scandinavian markets. For smaller online retailers, we are seeing a rising number of parcel drop off lockers emerge from companies such as Polish company, InPost. These companies partner with online retailers and parcel delivery companies to provide a convenient drop off point in urban areas, including shopping centres and transport hubs.

Own research shows that the level of returns recorded by Polish enterprises is stable. 7 out of 10 respondents declare that returns constitute up to 10% of all completed orders. Only every fifth respondent indicates that the level of returns oscillates around 11-10 percent (Figure 3).

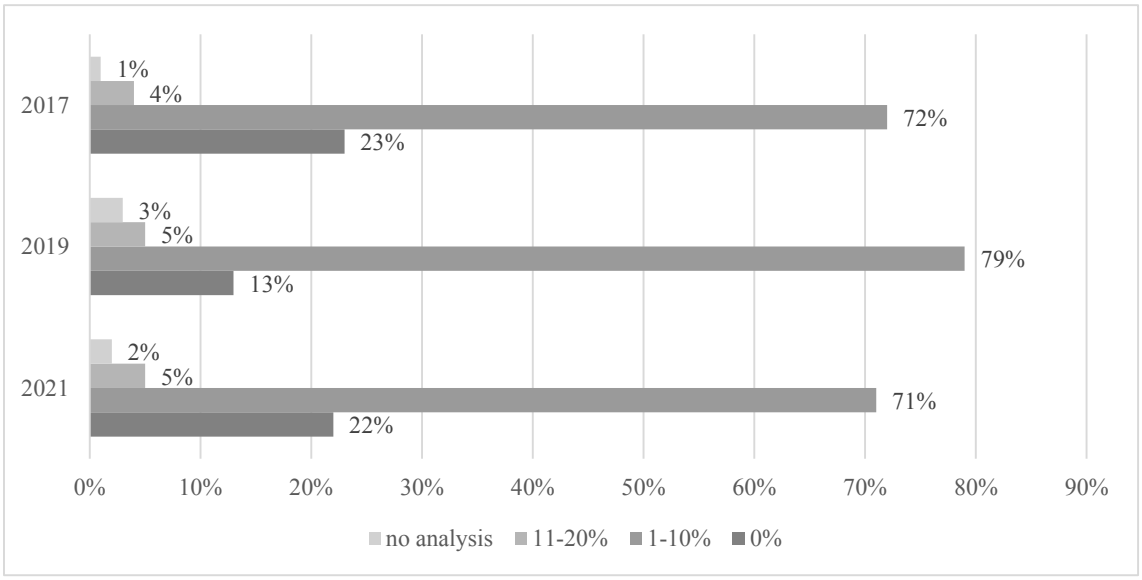

Figure 5. Percentage of returns on all orders in Poland.

Source: own research.

Based on our own research, there are three main and basically the only reasons why customers decide to return the goods: damage to the goods in transport (42% in 2021), sending the wrong goods (44% in 2021) and breakdown (failure) of goods during use (14% in 2021). There are several basic stages in the B2C e-commerce reverse logistics process. Depending on the type of company - operating only on the Internet (pure player) or having a network of traditional outlets (brick and click) in addition to an e-shop - different channels and return options are available. According to the 3C rule (convenience, choice, channel), defining the needs of customers in online commerce, the key factors in ensuring an appropriate return policy are: convenience in returning goods, flexibility of the system and the choice of several options for returning goods. Equally important for e-customers are free returns. Some companies have made free returns an element of their business strategy and an asset that distinguishes them on the market (Wodnicka, Skurpel, 2021).

As the research carried out shows, more than half of those asked, 52% to be exact, returned the goods to an online store at least once. The most common reason for sending the order back is the aforementioned possibility of exercising the right of return without giving a reason. This proves that e-shop customers are not only aware of their rights, but also become a source of value that they use.

Another reason for the return of purchases is the seller's mistake, as a result of which the buyer received products other than what he ordered. 43% of respondents received damaged goods, and 39% complained about a product that broke during the warranty period. Among the other motives, the most frequently mentioned were the wrong size of the clothes, product non-compliance with the description, unsatisfactory quality and the wrong choice of goods.

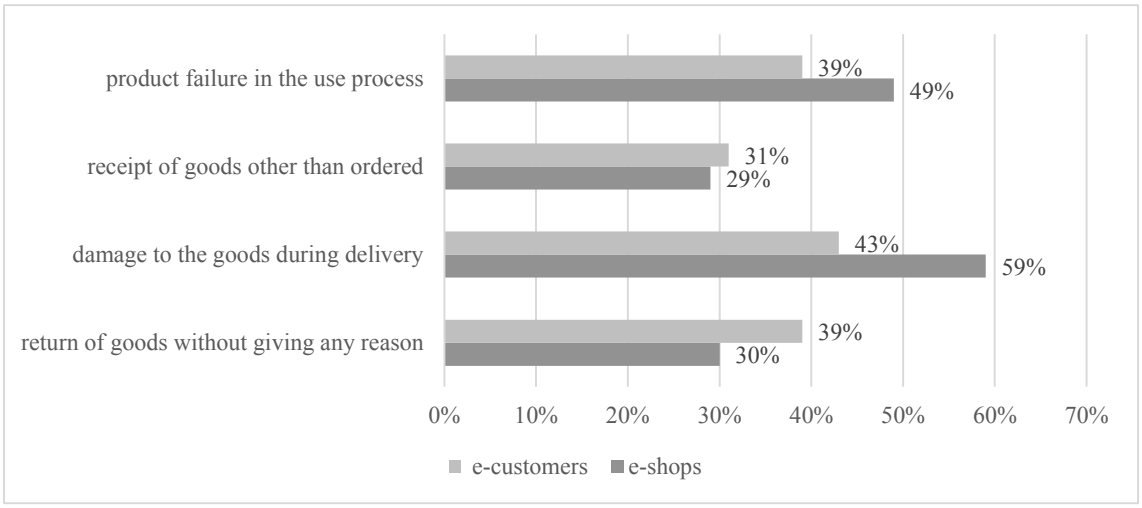

Figure 6. Reasons for returns from the point of view of online stores and their customers.
Source: own research.

According to e-stores, complaints resulting from a product failure during the warranty period account for 30% of returns, 59% of damage in transport, and 29% of all returns were the result of an error by a store employee. Almost half of the returns were determined by the customer's decision to return it without giving a reason.

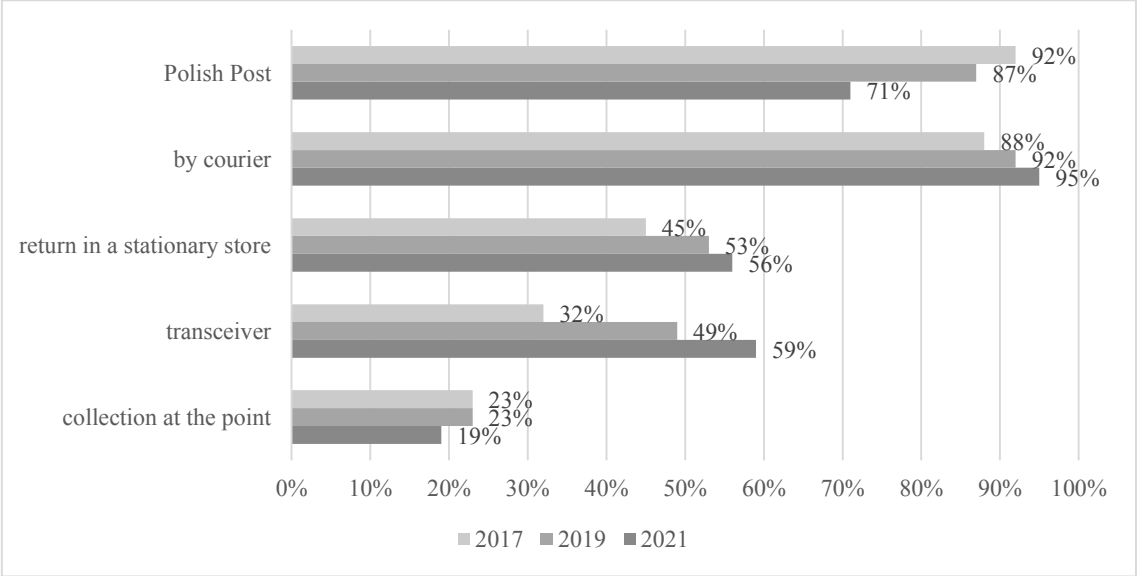

Figure 7. Channels through which the customer can return the product.
Source: own research.

Polish online stores most often offer customers the possibility to choose from several return channels (Figure 5). In recent years, Polish postal services have been losing popularity in favor of courier companies, sending and receiving devices (in Poland, so-called parcel lockers) and the possibility of returning goods in a stationary store. An issue still neglected by entrepreneurs is the costs associated with returns. In 2019, only 21% of the surveyed entities declared that they cover the cost of shipping the returned goods, in 2021 it was 23%. This means that in

7 out of 10 stores, the customer bears the cost of returning the products to the online store. Every 10th return must take place through the same channel as the delivery. The decision to replace the goods or return the money is made in 61% of cases within 48 hours, only every fifth e-shop needs 5 working days for it.

Among the customers who advertised the goods, 9% reported that they encountered problems in the complaint process related to the e-shop's refusal to accept the goods, the lack of any response from the store's staff or the need to repeatedly ask for a refund.

The complaint process in electronic stores is assessed positively, but the cost of returning the goods and the repair time are still questionable aspects. Online stores should bear in mind in this respect that customer service from the store and the costs borne by the customer are an attribute of value. Therefore, it is important not to charge the costs of customer returns, especially when the return is the result of incorrect shipment of the goods.

Complaints also inform the supplier that there are errors in the delivery of the order. Therefore, they cannot be taken personally, but conclusions must be drawn from delivery or product irregularities

According to the LME report on OOH deliveries, the number of PUDO points in Poland increased by 70% at the turn of 2020 and 2021 compared to mid-2019 and currently there are over 30,000. such locations (the much more populous Great Britain and Italy have 38,000 and 36,000 such points, respectively). For comparison, the increase in OOH supplies in Europe in this period was 40%.

Table 2.
Actions Taken by companies operating on the CEP market in pandemic COVID-19

Actions	**Description**
Ozonation of packages	Shipments are ozonated in the carrier's warehouses and then safely delivered to the addressee.
Possibility of cashless payment and resignation from cash on delivery payments	This solution in the courier industry has long been a matter of time. However, the pandemic effectively accelerated their implementation, which significantly improved the delivery process.
Delivery to a parcel machine - Paczkomat, Locker, SwipBox machine.	The development of a network of parcel machines in a situation of distance restrictions, parcel lockers turned out to be the most promising form of picking up and sending the parcel. The clear leader of this form of delivery in Poland is InPost.
Introduction of the parcel collection service without the need for a signature	When placing an order, it is enough to select the option with a request to leave the package at the door or in another place that is safe for the shipment. A solution in which the recipient does not have to sign the confirmation of receipt has become popular. Instead, all he has to do is give the courier the PIN code he receives via SMS or email before delivering the package.
Development of a network of coolomats	The increase in the popularity of online grocery shopping has driven the emergence of parcel machines with a cooling function to safely store heat-sensitive products, and above all, food.
Contactless returns	Quick returns service, which allows you to return at parcel machines to selected partner e-shops without registration.

Surce: own research.

The respondents pointed out one more important aspect which is directly related to the development of reverse logistics. It is primarily about the creation and development of shipping and collection points or tools for self-management of delivery or returns.

In the process of reverse logistics in B2C e-commerce it is important to identify the reason for the return at the earliest possible stage and to make the return route of the products dependent on it. Thanks to this, it is possible to shorten the process implementation time and reduce logistic costs (including inventory and transport costs). Visibility of the shipment thanks to the visibility of the shipment is essential for the efficient management of the process real-time information flow between e-retailers and logistics companies and consumers. It is possible thanks to unfolding applications and information technologies by logistics operators and CEP, and system integration IT business partners. Also equally important are: flexibility of the system, for the sake of to the high uncertainty as to the time, quantity and quality of returned goods, and the time of the process. This is crucial for retailers operating in industries with a high return rate (e.g. clothing or footwear), products with a short life cycle, seasonal, with a short shelf life and high value goods.

6. Conclusions – summary

To sum up, with the advent of e-commerce and the change in the commercial policy of enterprises, reverse logistics refers to the return of a given good / product to the place of origin, as well as its management through, firstly, re-entering the market of a product that has a different price due to for a lower quality or after minor treatment, restoration to the as-delivered condition with a specified quality (e.g. replacement of the packaging); second, as part of recycling, recovering some parts of the product that can be repaired and used in the production of new products, or using recovered materials to produce other goods, and ultimately disposal.

As the data analysis shows:

1. The development of the CEP industry during the Covid-19 pandemic is undeniable and is the result of the development of e-commerce services and returns.
2. Average annual growth in courier services through 2025 in Asia Pacific will be 10.8%, in North America. - 5.2%, in Europe - 5.1%, and in Poland between 7-8%. (the courier market in Poland is one of the fastest growing segments of the logistics sector in Europe).
3. The CEP industry has to deal with the handling of the increasing number of orders resulting from online purchases, new customer expectations related to security, or the limitation of direct contact.

4. The form and quality of delivery in online commerce constitute a very important element of the "customer experience". This means that consumers perceive the online purchase execution and the courier service as a whole.
5. The return market is also a challenge. The results regarding returns of goods are questionable, although the vast majority of e-shops state that the share of returns in the total number of orders does not exceed 10%. Among the people who returned, nearly 30% received the goods that did not comply with the order, and another 43% returned the parcel because it was damaged in transport. These results clearly show the importance of delivery logistics and are the basis for a thesis that the quality of delivery affects the value for the customer. For over 80% of customers, contact with e-shop employees in the process of returning the goods was not a problem, as well as the effectiveness of product repair, which probably translated into the assessment of the service in the eyes of the customer. Communication with customers is a strong point of online stores.
6. The CEP industry, in order to meet the requirements of the market changed by the pandemic, will have to adapt new solutions in operational processes and definitely focus on the development of technology.

References

1. Aras, N., Boyaci, T., Verter, V. (2010). Designing the reverse logistics network. In: M.E. Ferguson, G.C. Souza (eds.), *Closed-loop supply chains: new developments to improve the sustainability of business practices* (pp. 67-97). CRC-Press, Taylor & Francis.
2. Carrasco-Gallego, R., Ponce-Cueto, E., Dekker, R. (2012). Closed-loop supply chains of reusable articles: a typology grounded on case studies. *International Journal of Production Research, 50*, pp. 5582-5596.
3. CEP Research (2019). *German CEP market growth slows but record peak looms*, https://www.cep-research.com/news/german-cep-market-growthslows-but-record-peak-looms, 20.10.2022.
4. Corominas, A., Mateo, M., Ribas, I., Rubio, S. (2015). Methodological elements of supply chain design. *International Journal of Production Research, Vol. 53, Iss. 16*, pp. 5017-5030.
5. Courtney, R. (2019). *That sweater you don't like is a trillion-dollar problem for retailers. These companies want to fix it.* CNBS.
6. Dale, S.R., Tibben-Lembke, R.S. (1998). *Going Backwards: Reverse Logistics Trends and Practices.* Reno, NV: Reverse Logistics Executive Council.
7. E-commerce in Europe 2020, postnord, https://www.postnord.se/siteassets/pdf/rapporter/e-commerce-in-europe-2020.pdf, 27.10.2022.

8. Eurostat.
9. Global parcel shipping volume between 2013 and 2027 (2022).
10. Global Reverse Logistics Market Forecast 2019-2027. InkWood research. www.inkwoodresearch.com, 25.10.2022.
11. https://blog.getbyrd.com/en/reverse-logistics, 17.09.2022.
12. https://happyreturns.com/resource, 27.10.2022.
13. https://trans.info/pl/globalny-rynek-przesylek-kurierskich-bedzie-rosl-rocznie-o-7-proc-do-2025-241727, 25.10.2022.
14. https://trans.info/pl/rynek-kurierski-w-polsce-rosnie-dwucyfrowo-wzrost-jeszcze-przyspieszy-227511, 15.09.2022.
15. Huk, K., Robaszkiewicz-Ostręga, J. (2018). Logistyka zwrotów na przykładzie hurtowni farmaceutycznej Neuca-Logistyka sp. z.o.o. *Prace naukowe Uniwersytetu Ekonomicznego we Wrocławiu, nr 505*, p. 304.
16. Khurana, A. (2019). *Defining the Different Types of E-Commerce Businesses,* https://www.thebalancesmb.com/ecommerce-businesses-understanding-types-1141595, 23.10.2022.
17. Kozerska, M. (2014). Obsługa logistyczna obszaru e-commerce. *Zeszyty Naukowe Politechniki Śląskiej, seria: Organizacja i Zarządzanie, z. 68,* p. 52.
18. Lysenko-Ryba, K. (2015). Logistyka zwrotna jako źródło korzyści konkurencyjnych. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, nr 249*, p. 194.
19. OECD. Guide to Measuring the Information Society. The role of the e-procurement in the purchasing process (2011). RePEc OECD, p. 72.
20. Reverse Logistics Association (2012). http://www.reverselogosticstrends.com/reverse-logistics.php, 16.09.2022.
21. Reverse Logistics Market by Return type and End User: Global Opportunity Analysis and Industry Forecast, 2018-2025 (2019).
22. Rubio, S., Chamorro, A., Miranda, F.J. (2008). Characteristics of the research on reverse logistics (1995-2005). *International Journal of Production Research, 46*, pp. 1099-1120.
23. Rubio, S., Jiménez-Parra, B. (2014). Reverse Logistics: Overview and Challenges for Supply Chain Management. *International Journal of Engineering Business Management*, p. 1.
24. Sadowski, A. (2006). Reverse logistics w terminologii logistycznej. *Logistyka, nr 4*, p. 38.
25. Skurpel, D. (2019). *Obsługa logistyczna w handlu elektronicznym*. Wydawnictwo Uniwersytetu Łódzkiego, pp. 45-46.
26. Skurpel, D. (2019). *Obsługa logistyczna w handlu elektronicznym*. Wydawnictwo Uniwersytetu Łódzkiego, pp. 83-84.
27. Statista (2018). *Couriers and local delivery service providers' global market share in 2018*, https://www.statista.com/statistics/236309/market-shareof-global-express-industry, 27.10.2022.

28. Statista (2019). *Courier, express and parcel (CEP) market size worldwide between 2009 and 2019,* https://www.statista.com/statistics/723986/cepmarket-total-revenue-worldwide, 27.10.2022.
29. Stock, J.R. (1988). *Development and Implementation of Reverse Logistics Programs*. Oak Brook, IL: Council of Logistics Management.
30. Stock, J.R. (1992). *Reverse Logistics*. Oak Brook, IL: Council of Logistics Management.
31. *The CEP market in Poland In the face of trends and new challenges*, https://www.gs1pl.org/kontakt/publikacje-i-wytyczne/branze/transport-spedycja-logistyka-tsl/426-rynek-kep-w-polsce-w-obliczu-trendow-i-nowych-wyzwan/file, 25.10.2022.
32. Wik-Consult (2019). *Development of Cross-border E-commerce through Parcel Delivery*, https://www.wik.org/fileadmin/Studien/2019/ ET0219218ENN_ParcelsStudy_Final.pdf. 28.10.2022.
33. Wodnicka, M., Skurpel, D. (2021). Growth Global Market of E-Commerce Cross Border: The Case of Poland. *European Research Studies Journal, Vol. XXIV, Iss. 1*, p. 1122.
34. Wodnicka, M., Skurpel, D. (2021). Reverse Logistics in Polish Commercial Companies from Economic and Management Perspective. *European Research Studies Journal, Vol. XXIV, Iss. 4*, pp. 821, 825.

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ASSESSMENT OF THE FINANCIAL SITUATION OF RURAL MUNICIPALITIES IN POLAND DEPENDING ON THE ACTIVITY OF THEIR INHABITANTS IN THE DEVELOPMENT OF NON-AGRICULTURAL BUSINESS ACTIVITY

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Purpose: The purpose of the article is to identify and assess the financial situation of rural communes in Poland depending on the activity of their inhabitants in undertaking and developing non-agricultural economic activity.
Design/methodology/approach: The financial situation of rural communes in Poland was identified and assessed depending on the activity of their inhabitants in undertaking and developing non-agricultural economic activity. The empirical material of the article applies to both the whole country and all rural communes in Poland. Numerical data come from the Local Data Bank of the Central Statistical Office in Warsaw and concerns 2019-2021. The empirical material collected and ordered was developed in a descriptive, tabular, and graphic form, using the comparative analysis method. Furthermore, a point assessment of all diagnostic characteristics was performed that illustrates the financial situation of rural communes in Poland against the background of the entire country for the years 2019-2021.
Findings: The analysis of statistical data has confirmed the research hypothesis, which assumes that the financial situation of rural communes in Poland is related to the activity of their inhabitants in undertaking and developing non-agricultural business activity, with it clearly the best in units with high activity of residents in this area.
Originality/value: The originality of the work is the original approach to the analysis of the research issues undertaken. For the use of the research, the article combined and uses an original indicator of residents' activity in the development of non-agricultural economic activity in a given local government unit (commune) against the background of the country and other local government units (communes). In addition, the financial situation of the examined local government units was also assessed in the context of the country. The work is addressed primarily to local government officials responsible for public local government finances, as well as for conditions and possibilities and directions of local socioeconomic development of rural communes in Poland.

Keywords: financial situation, rural communes in Poland, economic activity of residents, non-agricultural economic activity

Category of the paper: research paper.

1. Introduction

The issues of entrepreneurship, the entrepreneur, and their institutional expression, i.e. an enterprise, occupie a serious place both in the theory of economics and in economic practise. The experience of highly developed countries indicates that they are the main media of progress, initiative, creative approach and innovation, thus constituting a dynamizing force of the process of growth and economic development, as well as an important source the prosperity of every economy, including rural (Schumpeter, 1960; Drucker, 1992; Kamerschen, McKenzie, Nardinelli, 1992; Gruszecki, 1994; Sawicka, 2000; Strużycki, 2008; Kulawiak, 2022).

The development of non-agricultural economic activity in rural areas is one of the priorities of the European Union's economic policy, including Poland. This is due to the fact that it positively changes rural areas, improving the quality and living conditions of the population, and maintaining their economic, social and environmental, and even cultural life, which is extremely important from the point of view of the multifunctional concept and sustainable development. The conditions for the development of non-agricultural economic activity in rural areas result from its considerable importance in the economy and in society. It brings financial benefits not only to people directly involved in it, but also to the commune itself in the form of revenues from fees and taxes, which are part of the commune's budget revenues. Causes that the municipality becomes more self -sufficient in terms of access to various products and services, promotes the attraction of investors from the outside and the creation of new business entities, causes the need for new and development of existing institutions or organisations, improves the image of the commune outside, and prevents the depletion of areas rural. However, the pace of development of non-agricultural economic activity in rural areas in Poland is still considered insufficient, but this applies not to the total number of business entities as their low ability to compete and finance development, and uneven territorial arrangement and insufficient creation of new jobs. Therefore, there is still a huge need for this activity in rural areas, which is also noticed by representatives of local governments and included in the strategic development plans of individual communes (Hybel, 2000; Kłodziński, Rosner, 2000; Zając, 2014; Kulawiak, 2022).

The development of non-agricultural economic activity in rural areas is conditioned by exogenous and endogenous factors, but it remains under the strong influence of regional and even local conditions. This process is usually carried out in the local environment (in a particular commune), which is why it depends largely on the endogenous features of this environment, which can either facilitate or hinder it. As a result, non-agricultural economic activity develops well in rural areas around larger urban centres and located along the main communication routes, where there is a significant degree of concentration of population, significant size labor market, appropriate infrastructure, greater wealth of the population, high

demand, high own income of communes, convenient own income Location relative to the market. Non-agricultural economic activity is also developing well where there are traditions of doing business, where there are better educated, enterprising and leaders, as well as in municipalities with high activity of local governments and other institutions and in rural areas, where special natural and cultural values occur, predisting for tourism development. Therefore, the most important factors stimulating the development of non-agricultural economic activity in rural areas are: location, human, social and financial capital as well as the activities of local governments, and the most important barriers to its development are: demand barrier and adverse demographic structures, especially in peripheral rural areas (Duczkowska-Piasecka, 1997; Wilkin, 1997; Kłodziński, Rosner, 2000; Makarski, 2003; Safin, 2004; Kamińska, 2011; Kłodziński, 2012; Rosner, 2012; Duczkowska-Małysz, Duczkowska-Piasecka, 2014; Wasilewski, 2014; Kopacz-Wyrwał, 2015; Zarębski, 2015; Brodziński, Brodzińska, 2016; Kulawiak, 2022).

Overcoming restrictions in the development of non-agricultural economic activity in rural areas, as well as its further strengthening and the use of opportunities and opportunities in this respect, requires the creation, supply and strengthening of many encouraging factors, facilitating and supporting its undertaking and conducting, with such activities should be such activities to be and are implemented at various levels, i.e. national, regional and local and in a variety of ways. It should be added that local governments are of particular importance here, usually using a wide range of support forms of non-agricultural economic activity, both indirect and direct (Hybel, 2000; Kamiński, 2000; Sawicka, 2000; Rosner, 2000; Firlej, 2003; Zając, Kata, 2004; Gospodarowicz, Kołodziejczyk, Wasilewski, 2007; Zając, 2014).

Therefore, the main factors affecting the development of non-agricultural economic activity are more or less shaped by the development policy conducted by the local government. In this context, you can distinguish various models of supporting this development to which they belong (Filipiak, Kogut-Jaworska, 2009; Błachut, Cierpiał-Wolan, Czudec, Kata, 2018):

1. Model of radical local government interventionism, based on the wide application by local government of income policy instruments (low tax rates and local fees, tax and fees relief, favorable conditions for entrepreneurs to use components of municipal property) and expenditure (infrastructure investments, guarantees, support of institutions operating on business development). The implementation of such a model means far -reaching interference in market rules and may increase the risk of excessive debt.
2. Model of limited local government interventionism, slightly burdening the budget of local government and does not cause distortion of the market mechanism, but also does not create extensive incentives motivating to conduct business.

3. Models oriented to the expectations of entrepreneurs:
    - The extensive development model, consisting of shaping conditions for the full use of the development potential of the small and medium -sized enterprises sector and improving its competitiveness. The concept of this model assumes participation in local initiatives and undertakings not only by representatives of local government, but also by residents and social organisations.
    - The intensive development model, based on dynamizing economic changes using new technologies and innovative solutions offered by local institutions and external investors. The cooperation of the public and private sectors in this model allows for better recognition of specific problems of the local environment (commune), allows one to implement joint investment projects, and facilitates obtaining social support for the concept of economic development adopted by the local authorities.
4. The dual model, connecting the most desirable elements from the point of view of economic development, including the development of non-agricultural economic activity. The actions taken as part of this model are comprehensive and allow for the simultaneous satisfaction of social and economic needs.

The local government is a key institution responsible for the implementation of many tasks to meet the needs of the primary importance for residents, as well as creating social and economic development in regional and local arrangements. The effectiveness of the implementation of tasks by local government units is largely dependent on effective financial management, and the guarantee of their implementation is the appropriate economic potential. Therefore, the quality of the local government finance system, considered a team of institutions, legal norms, and tools that specify the principles of financial management and used to carry out it, is important in this area. (Grzebyk, Sołtysiak, Stec, Zając, 2020; Kata, Czudec, Zając, Zawora, 2022).

The financial economy of the local government is a complex process conducted with respect to legislative requirements within the local government budget. Ensuring the efficient and proper operation of this specific economy, which consists primarily of cash and property resources, requires strict respect for many legal acts, standards, and budgetary principles. As part of the financial economy of local government, various public tasks and financial operations are carried out on individual public finance departments, and various methods and legal and financial instruments are used (Chojna-Duch, 2003; Kosek-Wojnar, Surówka, 2007; Sołtyk, 2017; Sołtysiak, 2017; Sołtysiak, Suraj, 2018).

The financial economy of the commune consists in collecting income and revenues and on making expenses and expenses to perform own and commissioned tasks, with its development and competitiveness, and secures the implementation of the needs of residents. In the income assessment of the municipality's budget, it is important to examine changes in income, its dynamics and structure, and spatial differentiation. On the other hand, based on the expenditure analysis of the budget side, it can be determined to what extent financial resources

are allocated to solving current problems and to which the promotion and development of the commune and to the improvement and increase in its competitiveness. It should be added that the analysis of the spatial differentiation of the level of budget revenues indicates that the high income of municipalities is not only the result of the resourcefulness of local government authorities, but also the result, among others, from the location of capital and enterprises, changes in the population, the state of infrastructure, neighbourhood or also the presence of cities and tourist attractiveness (Podstawka, 2005; Hybel, 2010).

Investment expenses in the financial economy of municipalities, in addition to their own income, are an important factor characterising their development capabilities. The wealth of municipalities clearly affects their investment capabilities. Units with greater budget revenues per capita usually also have greater investment opportunities. In addition, a greater share of own revenues in total budget revenues allows municipal governments to freely dispose of financial resources, and thus creates the opportunity to allocate larger amounts for investments. This is also important from the point of view of the issue of income independence of municipalities. For income independence understood as equipment for local government units with its own sources of income and free disposal, it is measured by the share of own income in the general amount of budget revenues. This type of income, therefore, gives the possibility for the local government to conduct its own income policy, while external power supply for their budgets in the form of subsidies and subsidies is a form of direct impact by the state on local government finances (Gołaszewska-Kaczan, 2005; Sobczyk, 2010; Dziemianowicz, Kargol-Wasiluk, Bołtromiuk, 2018; Czudec, 2021; Szołno-Koguc, 2021).

The implementation of the investment by municipalities is one of their most important public tasks, because it meets the basic needs of local local government communities and contributes to their development. In investment processes implemented by municipalities, there is a great difficulty in the objective assessment of the effective allocation of resources, which results from the complexity of investment projects, the distribution of their effects and expenditure in a long time, the multi -faceted influence of the investment on the environment, multiplicity of investment stakeholders, and the existence of interests between them. The specificity of this type of investment is their continuity, which is why expenditure on their implementation is systematically charged to the budget of a given local government unit, and the growing needs in this area create the need to search for sources of their financing. Therefore, it is important that the investment effectively and effectively satisfies the expectations and social needs, but also does not negatively affect the financial situation of a local government unit, which could result in a reduction in its potential to implement subsequent investments. In this way, a kind of closed system is created in which previously undertaken and implemented investments largely determine the potential and possibilities of implementing subsequent investments. Therefore, it is important that local government units, when implementing a specific investment policy, take into account both its socioeconomic and budgetary effects (Filipiak, 2011; Błachut, Cierpiał-Wolan, Czudec, Kata, 2018).

The financial management of public sector entities should lead to rational spending of public funds and making appropriate decisions in the field of managing these funds. A properly managed unit in the long run should develop the so -called "Good indicators", i.e. those that testify to its development. Particularly noteworthy is the concept of the financial (condition) of the financial unit of the local government interpreted as the ability of the local government to balance repetitive expenditure with repetitive sources of income, while implementing tasks arising from legal provisions, which are to be used to further multiply income and maximize public use for its residents (Mrówczyńska-Kamińska, Kucharczyk, Średzińska, 2011; Adamczyk, Dawidowicz, 2016; Ociepa-Kicińska, Gorzałczyńska-Koczkodaj, Brzozowska, Pluskota, 2022).

In defining the financial (condition) situation of a local government unit, it is most often emphasized: the possibility of financing services in a continuous manner, the comprehensiveness of healthy finances, the ability to repay liabilities, as well as maintaining the current level of services while maintaining resistance to risk of changes occurring in time. It seems that the most accurate interpretation of the situation (condition) of the financial local government unit refers to its ability to manage their financial obligations and to maintain services provided for the benefit of the local community in time (Filipiak, 2009; Dylewski, Filipiak, Gorzałczyńska-Koczkodaj, 2011; Filipiak, 2011; Wiśniewski, 2011; Kopyściański, Rólczyński, 2014; Zawora, 2015; Adamczyk, Dawidowicz, 2016; Kotowska, 2016; Natrini, Taufiq Ritonga, 2017; Ociepa-Kicińska, Gorzałczyńska-Koczkodaj, Brzozowska, Pluskota, 2022).

The financial situation of the commune is its financial status in a certain period of time, resulting from the income held and their structures, expenses and their structures, the degree of use of feedback, activity and effectiveness in obtaining non-budgetary funds, as well as the efficiency of financial and material resources management. Local authorities should depend on the good financial situation of a given territorial unit, because it is a component of its competitiveness. In addition, it is demonstrated, among others, by the ability to perform tasks, achieve budget balance, increase property, and implement and satisfy the needs of residents. Among the series of various conditions shaping the financial economy of local government units, including its financial situation, the generally extends exogenous and endogenous and mixed conditions. In addition, you can also distinguish some common categories, which include social, economic, environmental, and spatial conditions, as well as institutional and political ones. The catalog of such factors can sometimes be expanded to include events whose effects cannot be predicted, and which can fundamentally change the economic situation and the conditions of the operation of local government units. Such an event in 2020 was the appearance of a coronaviru pandemic. It should be added that the analysis of the financial situation of a local government unit provides information about its current and future financial and financial situation and also allows you to determine its possibilities and development perspectives. (Ossowska, Ziemińska, 2010; Zawora, 2015; Świrska, 2016; Bień, 2017; Standar, 2017; Stanny, Strzelczyk, 2018; Wójtowicz, 2018; Czudec, 2021).

2. Research aim, empirical material, and research methods

The purpose of the article is to identify and assess the financial situation of rural communes in Poland depending on the activity of their inhabitants in undertaking and developing non-agricultural economic activity.

The article puts a research hypothesis, which assumes that the financial situation of rural communes in Poland is related to the activity of their inhabitants in undertaking and developing non-agricultural economic activity, with it clearly the best in units with high activity of residents in this area.

The empirical material of the article applies to both the whole country and all rural communes in Poland. Numerical data come from the Local Data Bank of the Central Statistical Office in Warsaw and concerns 2019-2021. The empirical material collected and ordered was developed in a descriptive, tabular, and graphic form, using the comparative analysis method.

Data on the dynamics of new and closing existing business entities is often considered the main source of information about the activity of residents in the development of non-agricultural economic activity, as well as about the condition of the economy in a given area, e.g. in the commune. These indicators take into account not only hard economic growth factors, but also those who are immeasurable, related to the mood of investors and their predictions as to the possibility of undertaking and conducting non-agricultural business activity. The ratio of the growth dynamics of the number of registered business entities indicates the high activity of residents in the development of non-agricultural economic activity, as well as the improvement in the economic situation in a given area, e.g. in the commune, and implies many positive phenomena in the form of multiplier effects in the economy. On the other hand, the decrease in the number of registered business entities indicates a deterioration of the general atmosphere for entrepreneurship and may even mean closing a given area, e.g. municipalities for investments and development of non-agricultural business activity (Zarębski, 2015; Brodziński, Brodzińska, 2016). For the use of the research, the article combined and uses an original indicator of residents' activity in the development of non-agricultural economic activity in a given local government unit (commune) against the background of the country and other local government units (municipalities). The construction of this indicator consists in the fact that the number of business entities per 1000 population of working age in the previous year (i.e. 2020) in the country was added to the number of business entities newly registered per 1000 population of working age in the surveyed year (i.e. 2021) in the country. Then their sum was adopted as a value of 1.0 for the country and the advantage or underweight of this sum was assessed in all rural communes in Poland compared to the country. Subsequently, from such a number, both for the country (i.e. 1.0) and for all rural communes in Poland, % of economic entities deregistered in the surveyed year (i.e. 2021) were subtracted. It should be added that for the value of the indicator of up to 0.50 it was assumed that the activity of

residents in the development of non-agricultural economic activity is poor, for the value of 0.51-0.75, that this activity is moderate, and for 0.76 and more, for 0.76 and more, that it is high. Taking into account the above assumptions, all rural municipalities in Poland were divided into three groups, depending on the activity of their inhabitants in the development of non-agricultural economic activity. It should be emphasised that this is a new approach to the research problem taken in the article.

In turn, for the identification and evaluation of the financial situation of rural communes in Poland, the following diagnostic characteristics that illustrate it in 2019-2021 were analysed:

- total income of municipal budgets per capita (PLN),
- own income of municipal budgets per capita (PLN),
- share of own income in total income of municipal budgets (%),
- total expenditures of municipal budgets per capita (PLN),
- investment expenditures of municipal budgets per capita (PLN),
- share of investment expenses in total expenses of municipal budgets (%).

Additionally, the article has a point assessment of all diagnostic characteristics that illustrates the financial situation of rural communes in Poland in the background of the whole country for the years 2019-2021. Individual diagnostic characteristics were compared with the average for the country, which was adopted as 100 points, and their advantage or underweight in all rural municipalities were properly assessed. Then, all points were summarised and the average (Figure 1).

3. Results

Analysing the economic activity of the inhabitants of rural communes in Poland in the field of undertaking and developing non-agricultural economic activity, it should be noted that the percentage of municipalities characterised by moderate activity of residents in this respect (55.4%) is clearly the largest. In turn, the smaller percentage consists of rural municipalities, in which the activity of residents in the field of undertaking and developing non-agricultural economic activity is high (23.4%) and those where this activity is poor (21.2%) (Table 1).

In rural municipalities in Poland, the average total value of municipalities the budgets of per capita in 2019-2021 is lower as average in the country, where it is PLN 6,555.3. However, there is a differentiation between rural communes in this regard. The average value of total revenues of the budgets of rural communes per capita in 2019-2021 is clearly the highest in a group of municipalities with high activity of residents in the development of non-agricultural economic activity, where it exceeds the average for all rural communes. However, it is the lowest in a group of rural communes with poor activity of residents in the development of non-agricultural economic activity. In all separated groups of rural communes, the diversity of this

feature between individual municipalities is small, so its variability is low, while it is the smallest in a group of municipalities with the poor activity of residents in the field of development of non-agricultural economic activity, i.e. this group of municipalities is the most homogeneous in this respect (Table 1).

Table 1.
Total income of per capita rural municipal budgets in Poland in 2019-2021 (in PLN)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity		
		less then 0,50	0,51-0,75	0,76 and more
Number of municipalities	1523	323	844	356
Mean	5.981,4	5.782,8	5.889,4	6.380,0
Variability V (%)	21,7	13,7	24,9	18,4
Minimum	4.322,2	4.322,2	4.538,7	4.669,5
Maximum	43.632,4	11.433,0	43.632,4	14.273,7

Source: Central Statistical Office in Warsaw.

Rural communes in Poland are characterised by a clearly lower average value of the budgets of per capita communes in 2019-2021, compared to the average for the whole country, which is PLN 3,198.5. It should be noted, however, that there is a differentiation in this regard between rural communes. The average value of the budgets of the rural communes per capita in 2019-2021 is definitely the highest in a group of municipalities with high activity of residents in the field of non-agricultural economic activity, where it exceeds the average for all rural communes. However, it is the lowest in a group of rural communes with poor activity of residents in the development of non-agricultural economic activity. In all separate groups of rural communes, the diversity of this characteristic between individual municipalities is in turn large, i.e., its variability is also high, except that it is the greatest in a group of rural communes with moderate activity of residents in the field of development of non-agricultural economic activity, i.e., this group of communes is the most diverse in this respect (Table 2).

Table 2.
Own revenues of the budgets of rural municipalities per capita in Poland in 2019-2021 (in PLN)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity-		
		Less then 0,50	0,51-0,75	0,76 and more
Mean	2.159,0	1.742,7	2.023,2	2.858,5
Variability V (%)	62,7	46,3	71,8	43,9
Minimum	788,5	897,9	788,5	1.097,5
Maximum	39.046,3	7.977,1	39.046,3	11.710,6

Source: Central Statistical Office in Warsaw.

On average, the share of the own income in the total income of the budgets of rural communes in Poland in 2019-2021 is definitely lower than the average in the country, where it is 48.8%. However, there is a differentiation between rural communes in this regard.

On average, the share of own income in the total income of the budgets of rural communes in 2019-2021 is clearly the highest in a group of municipalities with high activity of residents in the field of non-agricultural economic activity, where it exceeds the average for all rural communes. However, it is the lowest in a group of rural communes with poor activity of residents in the development of non-agricultural economic activity. In all separate groups of rural communes, the diversity of this characteristic between individual municipalities is rather small and similar, so its variability is low (Table 3).

Table 3.
The share of its own income in the total income of the budgets of rural municipalities in Poland in 2019-2021 (in %)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity		
		Less then 0,50	0,51-0,75	0,76 and more
Mean	35,2	29,6	33,7	43,7
Variability V (%)	30,3	29,2	26,3	25,7
Minimum	15,4	15,8	15,4	18,7
Maximum	89,5	69,9	89,5	82,0

Source: Central Statistical Office in Warsaw.

In rural municipalities in Poland, the average value of expenditure in total municipal budgets per capita in 2019-2021 is lower than the average for the country, which is PLN 6,445.4. However, there is a differentiation between rural communes in this regard. The average value of expenditure in total budgets of rural communes per capita in 2019-2021 is definitely the highest in a group of municipalities with high activity of residents in the field of non-agricultural economic activity, where it exceeds the average for all rural communes. In turn, it is the lowest in a group of rural communes with the poor activity of residents in the development of non-agricultural economic activity. In all separate groups of rural communes, the diversity of this feature between individual municipalities is small, so its variability is low, with the smallest it in a group of municipalities with poor activity in residents in the field of development of non-agricultural economic activity, i.e. this group of municipalities is the most homogeneous for in this respect (Table 4).

Table 4.
Total expenditure of rural municipalities' budgets per capita in Poland in 2019-2021 (in PLN)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity		
		Less then 0,50	0,51-0,75	0,76 and more
Mean	5.671,0	5.417,8	5.590,1	6.092,7
Variability V (%)	23,2	15,3	26,6	18,8
Minimum	3.882,0	3.882,0	4.114,6	4.337,9
Maximum	43.601,4	11.721,8	43.601,4	12.833,7

Source: Central Statistical Office in Warsaw.

Table 5.
Investment expenditure in rural municipalities' budgets per capita in Poland in 2019-2021 (in PLN)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity		
		Less then 0,50	0,51-0,75	0,76 and more
Mean	917,2	858,5	874,0	1.072,9
Variability V (%)	62,6	57,9	68,6	51,2
Minimum	48,7	166,6	93,9	48,7
Maximum	12.556,8	3.735,0	12.556,8	3.848,9

Source: Central Statistical Office in Warsaw.

Rural municipalities in Poland are characterized by similar to the country (PLN 941.0), the average value of investment expenditure of the budgets of municipalities per capita in 2019-2021. However, there is a difference in this regard between rural communes. The average value of investment expenditure of budgets of rural communes per capita in 2019-2021 is clearly the highest in a group of municipalities with high activity of residents in the field of non-agricultural economic activity, where it exceeds the average for all rural communes and for the whole country. On the other hand, lower and similar in the other two separate groups of rural communes, depending on the activity of their inhabitants in the field of development of non-agricultural economic activity. In all separate groups of rural communes, the diversity of this feature between individual municipalities is in turn large, i.e., its variability is also high, except that it is the smallest in a group of municipalities with high activity of residents in the field of development of non-agricultural economic activity, i.e., this group of municipalities is The most homogeneous in this respect (Table 5).

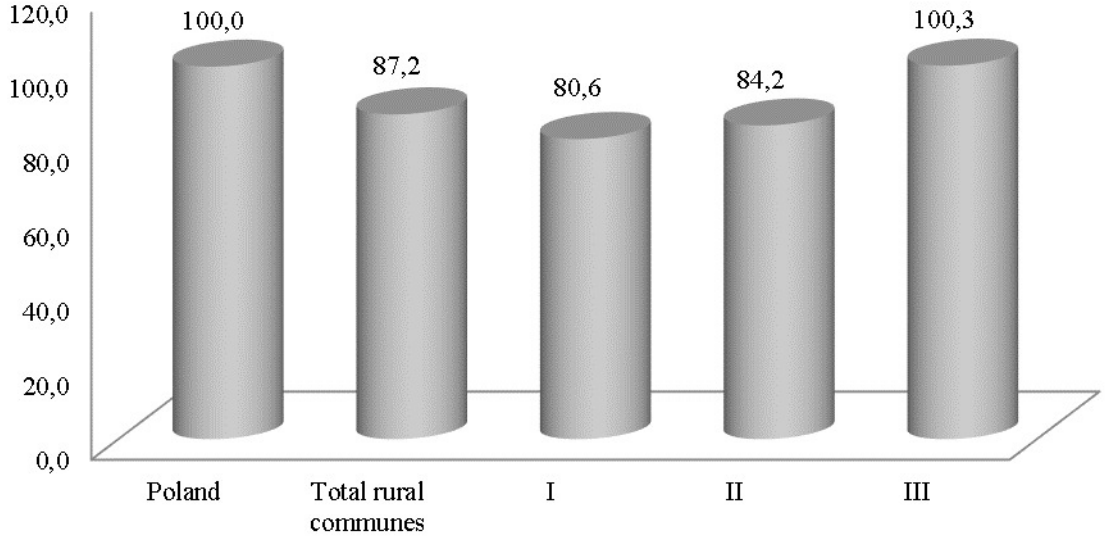
Table 6.
The share of investment expenditure in total expenditure of rural municipal budgets in Poland in 2019-2021 (in %)

Specification	Rural municipalities			
	Total	According to the value of the residents' activity indicator in the development of non-agricultural business activity		
		Less then 0,50	0,51-0,75	0,76 and more
Mean	15,6	15,3	15,1	17,0
Variability V (%)	40,6	44,1	40,3	37,1
Minimum	1,1	3,4	2,0	1,1
Maximum	41,3	38,6	40,6	41,3

Source: Central Statistical Office in Warsaw.

On average, the share of investment expenditure in total expenditure of the budgets of rural communes in Poland in 2019-2021 is similar to the average for the whole country, where it is 14.6%. There are also no major differences in this regard between separate groups of rural communes, with a slightly higher share of investment expenditure in the total budgets of municipalities, a group of municipalities with high activity of residents in the field of development of non-agricultural economic activity, where it exceeds the average for all rural communes. Furthermore, in all separate groups of rural communes, the diversity of this

characteristic between individual municipalities is quite large and similar, that is, its variability is average (Table 6).



Explanations: I - rural communes, in which the value of the residents' activity indicator in the development of non-agricultural economic activity is below 0.51; II - rural communes, in which the value of the residents' activity indicator in the development of non-agricultural economic activity is from 0.51 to 0.75; III - rural municipalities, in which the value of residents' activity indicator in the development of non-agricultural economic activity is 0.76 and more.

Figure 1. Point assessment of the financial situation of rural communes in Poland against the background of the country for the years 2019-2021 (Poland = 100.0 points).

Source: Own study.

Figure 1 presents the results of a point assessment of the financial situation of rural communes in Poland in the context of the whole country for the years 2019-2021. It should be noted that rural municipalities in Poland have an average worse financial situation, compared to the average for the whole country. However, there is quite a large variety in this respect between separate groups of rural communes, depending on the activity of their inhabitants in the field of development of non-agricultural economic activity. The financial situation is definitely the best and comparable to the average for the whole country, in a group of municipalities with high activity of residents in the field of non-agricultural economic activity. In turn, it is the worst in a group of rural municipalities with the poor activity of residents in the development of non-agricultural economic activity. However, in a group of rural communes with moderate activity of residents in the field of development of non-agricultural economic activity, the financial situation is most similar to the average for all rural communes in Poland. All this confirms the research hypothesis presented in the article.

4. Summary and conclusions

The undertaking and conducting of non-agricultural business is the domain of creative and brave people, focused on the desire to achieve the goals and tasks they assumed, and as a consequence of these positive economic effects, especially in the form of profit. This is, of course, also a real manifestation of entrepreneurial attitude, including the ability to use market opportunities and opportunities.

The development of non-agricultural economic activity is particularly important in rural areas, because because of this they become more attractive, richer, and varied and also perform many important functions, both from the point of view of the economy and society. Therefore, this process is supported on the one hand by local authorities and, on the other hand, brings them measurable economic benefits in the form of the influence of financial resources on the budget.

Analysis of statistical data has shown that rural municipalities in Poland have a worse financial situation, compared to the average for the whole country. However, they vary in terms of many diagnostic features illustrating their financial situation, depending on the activity of residents in the development of non-agricultural economic activity. In the case of most comparisons, a group of municipalities with high activity of residents in the field of non-agricultural economic activity, and the worst group of municipalities with poor activity of residents in this respect is the best. Furthermore, this was also confirmed by a point assessment of the financial situation of the local government units against the background of the country.

Therefore, this allows confirmation of the research hypothesis, which assumes that the financial situation of rural communes in Poland is related to the activity of their inhabitants in undertaking and developing non-agricultural economic activity, with it clearly being the best in units with high activity of residents in this area.

It should be added that the presented results of statistical data analysis provide significant and current knowledge, which can be useful primarily for local government officials responsible for public local government finances, as well as for conditions and possibilities and directions of local socio-economic development of rural communes in Poland. At the same time, this justifies the need to continue similar research and analyses.

References

1. Adamczyk, A., Dawidowicz, D. (2016). Wartość informacyjna wskaźników oceny kondycji finansowej jednostek samorządu terytorialnego. *Ekonomiczne Problemy Usług, 25*, pp. 25-36. https://doi.org/10.18276/epu.2016.125-02.
2. Bień, W. (2017). Ocena kondycji finansowej gmin województwa małopolskiego w latach 2007-2016. *ZN UE w Katowicach*. *Współczesne Finanse, 1, nr 345*, pp. 45-62.
3. Błachut, B., Cierpiał-Wolan, M., Czudec, A., Kata, R. (2018). *Wydatki inwestycyjne jednostek samorządu terytorialnego a rozwój przedsiębiorczości w regionie Polski południowo-wschodniej*. Rzeszów: Urząd Statystyczny w Rzeszowie.
4. Brodziński, Z., Brodzińska, K. (2016). Uwarunkowania aktywności społeczno-gospodarczej podmiotów sektora MSP na terenach przygranicznych województwa warmińsko-mazurskiego. *Journal of Agribusiness and Rural Development, 1(39)*, pp. 31-38.
5. Chojna-Duch, E. (2003). *Polskie prawo finansowe. Finanse publiczne*. Warszawa: Lexis Nexis.
6. Czudec, A. (2021). Finanse jednostek samorządu terytorialnego w okresie pandemii. *Finanse Komunalne 5*, pp. 7-18.
7. Drucker, P.F. (1992). *Innowacja i przedsiębiorczość. Praktyka i zasady*. Warszawa: PWE.
8. Duczkowska-Małysz, K., Duczkowska-Piasecka, M. (2014). Rodzinna przedsiębiorczość na obszarach wiejskich wobec wyzwań globalnych. In: R. Sobiecki (ed.), *Przedsiębiorstwo rodzinne w gospodarce globalnej*. Warszawa: SGH, pp. 117-145.
9. Duczkowska-Piasecka, M. (1997). Małe i średnie przedsiębiorstwa na terenach wiejskich (ich rola, znaczenie oraz możliwości i bariery rozwojowe). In: M. Kłodziński, A. Rosner (ed.), *Ekonomiczne i społeczne uwarunkowania i możliwości wielofunkcyjnego rozwoju wsi w Polsce*. Warszawa: SGGW, pp. 245-265.
10. Dylewski, M., Filipiak, B., Gorzałczyńska-Koczkodaj, M. (2011). *Analiza finansowa budżetów jednostek samorządu terytorialnego*. Municipium.
11. Dziemianowicz, R., Kargol-Wasiluk, A., Bołtromiuk, A. (2018). Samodzielność finansowa gmin w Polsce w kontekście koncepcji good governance. *Optimum. Economic Studies, 4(94)*, pp. 209. https://doi.org/10.15290/ oes.2018.04.94.16.
12. Filipiak, B. (2011). *Finanse samorządowe. Nowe wyzwania bieżące i perspektywiczne*. Warszawa: Difin.
13. Filipiak, B. (ed.) (2009). *Metodyka kompleksowej oceny gospodarki finansowej jednostki samorządu terytorialnego*. Warszawa: Difin.
14. Filipiak, B., Kogut-Jaworska, M. (2009). Modele pobudzania przedsiębiorczości na poziomie lokalnym. Gospodarka lokalna i regionalna w teorii i praktyce. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, nr 46*, pp. 193-202.

15. Firlej, K. (2003). Wpływ zarządzania gminą na rozwój przedsiębiorczości lokalnej. In: *Uwarunkowania rozwoju przedsiębiorczości – szanse i zagrożenia*. Tarnobrzeg: PWSZ w Tarnobrzegu, pp. 409-417.
16. Gołaszewska-Kaczan, U. (2005). Partnerstwo publiczno-prywatne a atrakcyjność regionu. In: A. Kopczyk, M. Proniewski (ed.), *Atrakcyjność inwestycyjna regionu*. Białystok: Wyższa Szkoła Finansów i Zarządzania, pp. 545-552.
17. Gospodarowicz, M., Kołodziejczyk, D., Wasilewski, A. (2007). *Działalność samorządów lokalnych na rzecz rozwoju nierolniczych dziedzin gospodarczych*. Raport Programu Wieloletniego 2005-2009 „*Ekonomiczne i społeczne uwarunkowania rozwoju polskiej gospodarki żywnościowej po wstąpieniu Polski do Unii Europejskiej*", nr 70. Warszawa: IERiGŻ-PIB.
18. Gruszecki, T. (1994). *Przedsiębiorca w teorii ekonomii*. Warszawa: Cedor.
19. Grzebyk, M., Sołtysiak, M., Stec, M., Zając, D. (2020). *Społeczne, ekonomiczne i środowiskowe uwarunkowania gospodarki finansowej samorządu lokalnego (przykład województwa podkarpackiego)*. Poznań: Bogucki Wydawnictwo Naukowe.
20. Hybel, J. (2000). Makroekonomiczne uwarunkowania rozwoju małych i średnich przedsiębiorstw. In: *Rola małych i średnich przedsiębiorstw w rozwoju obszarów wiejskich*. Siedlce: Wydawnictwo Akademii Podlaskiej w Siedlcach, pp. 21-26.
21. Hybel, J. (2010). Regionalne zróżnicowanie sytuacji finansowej gmin w Polsce w latach 2005-2009. *Zeszyty Naukowe SGGW w Warszawie, Ekonomika i organizacja gospodarki żywnościowej, nr 86*, pp. 29-39.
22. Kamerschen, D., McKenzie, R., Nardinelli, C. (1992). *Ekonomia*. Gdańsk: NSZZ Solidarność.
23. Kamińska, W. (2011). Pozarolnicza aktywność gospodarcza osób fizycznych na obszarach wiejskich w Polsce. In: W. Kamińska, K. Heffner (ed.), *Obszary wiejskie. Wielofunkcyjność. Migracje. Nowe wizje rozwoju, Tom CXXXIII*. Warszawa: STUDIA KPZK PAN, pp. 103-127.
24. Kamiński, R. (2000). Rola lokalnych organizacji pozarządowych w rozwoju przedsiębiorczości wiejskiej. In: *Rozwój przedsiębiorczości wiejskiej w warunkach integracji z Unią Europejską*. Warszawa: IRWiR PAN, AR w Szczecinie, pp. 45-60.
25. Kata, R., Czudec, A., Zając, D., Zawora, J. (2022). *Gospodarka finansowa jednostek samorządu terytorialnego – wybrane zagadnienia*. Rzeszów: Wydawnictwo Uniwersytetu Rzeszowskiego.
26. Kłodziński, M. (2012). Dywersyfikacja gospodarki ważnym celem polityki wiejskiej. In: M. Drygas, K. Zawalińska (ed.), *Uwarunkowania ekonomiczne polityki rozwoju polskiej wsi i rolnictwa*. Warszawa: IRWiR PAN, pp. 95-115.
27. Kłodziński, M., Rosner, A. (2000). Małe i średnie firmy a rozwój gospodarczy obszarów wiejskich. In: M. Kłodziński, A. Rosner (ed.), *Rozwój przedsiębiorczości na terenach wiejskich wschodniego i zachodniego pogranicza*. Warszawa: IRWiR PAN, pp. 136-147.

28. Kopacz-Wyrwał, I. (2015). Przedsiębiorczość a poziom życia na obszarach wiejskich Polski Wschodniej. *Przedsiębiorczość-Edukacja, vol. 11*, pp. 82-97.
29. Kopyściański, T., Rólczyński, T. (2014). Analiza wskaźników opisujących sytuację finansową powiatów w województwie dolnośląskim w latach 2006-2012. *Studia Ekonomiczne, 206*, pp. 61-73.
30. Kosek-Wojnar, M., Surówka, K. (2007). *Podstawy finansów samorządu terytorialnego*. Warszawa: PWN.
31. Kotowska, E. (2016). Przesłanki racjonalnej polityki budżetowej w jednostkach samorządu terytorialnego. In: A. Gołębiowska, P.B. Zientarski (ed.), *Funkcjonowanie samorządu terytorialnego – uwarunkowania prawne i społeczne*. Warszawa: Kancelaria Senatu RP.
32. Kulawiak, A. (2022). Pozarolnicza działalność gospodarcza a rozwój społeczno-gospodarczy gmin wiejskich województwa łódzkiego. *Przedsiębiorczość-Edukacja, 18(1)*, pp. 64-78. https://doi.org/10.24917/20833296.181.6.
33. Makarski, S. (2003). Subregionalne uwarunkowania przedsiębiorczości w województwie podkarpackim. In: A. Czudec (ed.), *Regionalne uwarunkowania ekonomicznego rozwoju rolnictwa i obszarów wiejskich*, *tom 2*. Rzeszów: Wydawnictwo Uniwersytetu Rzeszowskiego, pp. 166-174.
34. Mrówczyńska-Kamińska, A., Kucharczyk, A., Średzińska, J. (2011). Analiza finansowa w jednostkach samorządu terytorialnego na przykładzie miasta i gminy Środa Wlkp. *Zeszyty Naukowe SGGW w Warszawie. Ekonomika i Organizacja Gospodarki Żywnościowej, 89*, pp. 175-185.
35. Natrini, N.D., Taufiq Ritonga, I. (2017). Design and Analysis of Financial Condition Local Government Java and Bali (2013-2014). *SHS Web of Conferences, 34: 03003* https://doi.org/10.1051/shsconf/20173403003.
36. Ociepa-Kicińska, E., Gorzałczyńska-Koczkodaj, M., Brzozowska, K., Pluskota, P. (2022). Ocena kondycji finansowej jednostek samorządu terytorialnego w obliczu pandemii COVID-19 na przykładzie województw samorządowych w Polsce. *Rozwój Regionalny i Polityka Regionalna, 59*, pp. 149-165.
37. Ossowska, L., Ziemińska, A. (2010). Kondycja finansowa gmin wiejskich i miejsko-wiejskich województwa pomorskiego. *Journal of Agribusiness and Rural Development, nr 4(18)*, pp. 73-85.
38. Podstawka, M. (2005). *Podstawy finansów. Teoria i praktyka*. Warszawa: SGGW.
39. Rosner, A. (2000). Samorządy lokalne i ich wpływ na średnią i drobną przedsiębiorczość lokalną. *Wieś i Rolnictwo, 1*.
40. Rosner, A. (2012). *Zmiany rozkładu przestrzennego zaludnienia obszarów wiejskich. Wiejskie obszary zmniejszające zaludnienie i koncentrujące ludność wiejską*. Warszawa: IRWiR PAN.

41. Safin, K. (2004). Uwarunkowania rozwoju przedsiębiorczości – próba systematyzacji. In: K. Jaremczuk (ed.), *Uwarunkowania przedsiębiorczości*. Tarnobrzeg: PWSZ w Tarnobrzegu, pp. 44-55.
42. Sawicka, J. (2000). *Założenie i prowadzenie małego przedsiębiorstwa*. Warszawa: SGGW.
43. Schumpeter, J.A. (1960). *Teoria rozwoju gospodarczego*. Warszawa: PWN.
44. Sobczyk, A. (2010). Rozwój lokalny – wybrane problemy finansowania. *Zeszyty Naukowe SGGW w Warszawie, Ekonomika i Organizacja Gospodarki Żywnościowej, nr 81*, pp. 125-136.
45. Sołtyk, P. (2017). Uwarunkowania efektywności systemu kontroli gospodarki finansowej jednostek samorządu terytorialnego. *Studia i Prace WNEIZ US nr 47/3*, pp. 381-393.
46. Sołtysiak, M. (2017). Budżet jednostki samorządu terytorialnego a wiedza i aktywność lokalnej społeczności. *Humanities and Social Sciences - Quarterly, Vol. XXII, Research Journal, 24(4)*, pp. 181-193.
47. Sołtysiak, M., Suraj, M. (2018), *Budget of local government unit versus state of art and engagement of young generation of Poles*. Proceedings 16thInternational Scientific Conference "Economic Policy in the European Union Member Countries". I. Majerova (ed.). Silesian University, pp. 327-336.
48. Standar, A. (2017). Ocena kondycji finansowej gmin oraz jej wybranych uwarunkowań na przykładzie województwa wielkopolskiego przy wykorzystaniu metody TOPSIS. *Wieś i Rolnictwo, nr 2(175)*, pp. 69-92.
49. Stanny, M., Strzelczyk, W. (2018). *Kondycja finansowa samorządów lokalnych a rozwój społeczno-gospodarczy obszarów wiejskich. Ujęcie przestrzenne*. Warszawa: Scholar.
50. Strużycki, M. (2008). Przedsiębiorczość i zarządzanie przedsiębiorczością. In: M. Strużycki (ed.), *Podstawy zarządzania*. Warszawa: SGH, p. 212.
51. Szołno-Koguc, J. (2021). Samodzielność dochodowa jednostek samorządu terytorialnego – aspekty teoretyczne. *Studia BAS, nr 1(65)*, pp. 9-13. https://doi.org/0.31268/StudiaBAS.2021.02.
52. Świrska, A. (2016). Czynniki determinujące efektywne zarządzanie finansami samorządowymi (na przykładzie gmin powiatu siedleckiego). *Polityki Europejskie, Finanse i Marketing, 16(65)*, pp. 88-99.
53. Wasilewski, A. (ed.) (2014). *Efektywność instrumentów polityki regionalnej i strukturalnej wspierających rozwój pozarolniczej działalności gospodarczej na obszarach wiejskich*. Raport Programu Wieloletniego 2011-2014 „*Konkurencyjność polskiej gospodarki żywnościowej w warunkach globalizacji i integracji europejskiej*", nr 108. Warszawa: IERiGŻ-PIB.
54. Wilkin, J. (1997). Przedsiębiorczość na wsi - główne determinanty i uwarunkowania. In: S. Makarski (ed.), *Przedsiębiorczość w agrobiznesie, a rozwój terenów wiejskich*. Trzcinica: AR w Krakowie, Wydział Ekonomii w Rzeszowie, pp. 25-33.

55. Wiśniewski, M. (2011). Wyznaczniki sytuacji finansowej gminy. Ocena istotności za pomocą analizy skupień. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu. Nauki o Finansach, 9(215)*, pp. 110-119.
56. Wójtowicz, K. (2018). Znaczenie wybranych czynników ekonomiczno-społecznych dla kształtowania stabilności fiskalnej gmin miejskich w Polsce. *Acta Universitatis Lodziensis. Folia Oeconomica, vol. 334(2)*, pp. 213-234.
57. Zając, D. (2014). Znaczenie pozarolniczej działalności gospodarczej rolników w procesie rozwoju wielofunkcyjności rolnictwa i obszarów wiejskich. *Prace Naukowe Wydziału Ekonomii Uniwersytetu Rzeszowskiego, Seria: Monografie i Opracowania, nr 17.* Rzeszów: Wydawnictwo Uniwersytetu Rzeszowskiego.
58. Zając, D., Kata, R. (2004). Możliwości łagodzenia ograniczeń w rozwoju działalności pozarolniczej rolników przez samorządy lokalne. *Roczniki Naukowe SERiA, Tom VI, Zeszyt 4,* pp. 231-236.
59. Zarębski, P. (2015). Typy obszarów wiejskich w Polsce ze względu na poziom rozwoju społeczno-gospodarczego i dynamikę przedsiębiorstw. *Wieś i Rolnictwo, 3(168)*, pp. 63-77.
60. Zawora, J. (2015). Analiza wskaźnikowa w procesie zarządzania finansami samorządowymi. *Zarządzanie Finansami i Rachunkowość, 4*, pp. 33-45.

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DIVERSIFICATION OF THE FINANCIAL SITUATION OF HOUSEHOLDS IN THE EASTERN AND WESTERN REGIONS OF POLAND

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Purpose: The aim of this article is to identify and assess the diversification of the financial situation of households in the eastern and western regions of Poland.
Design/methodology/approach: The article identifies and assesses the diversification of the financial situation of households in the eastern and western regions of Poland. The empirical material used in the article concerns both the whole country and six voivodeships of eastern and western Poland, i.e. Lubelskie, Podkarpackie and Podlaskie as well as Dolnośląskie, Lubuskie and Zachodniopomorskie. The figures come from the Central Statistical Office in Warsaw (Social Cohesion Survey). The empirical material collected and ordered was developed in tabular and graphical form, using comparative analysis. Furthermore, all diagnostic features illustrating the financial situation of households in the eastern and western regions of Poland were scored against the background of the entire country, which is a new approach to the research problem undertaken in the article.
Findings: The statistical data confirmed the research hypothesis presented in the article, assuming that households in the western regions of Poland are in a better financial situation than in the eastern regions, although there is variation in this respect between individual voivodeships of these regions.
Originality/value: The originality of the work lies in the author's approach to the analysis of the research issues and the assessment of the financial situation of households in the eastern and western regions of Poland against the background of the entire country. The work is addressed primarily to politicians at the central level, as well as to local government officials responsible for the conditions, opportunities and directions of regional socioeconomic development, as well as to other decision makers implementing regional development policy in Poland.

Keywords: financial situation, household, eastern and western regions of Poland.

Category of the paper: research paper.

1. Introduction

A household is a farming entity, separated in the economic sense on the basis of personal property and making consumption decisions based on its own preferences and existing objective limitations (i.e. price and income). The basis for making decisions is guided by both subjective factors (i.e. traditions, preferences, habits, etc.) and objective factors (i.e. wages, pensions, interest rates, prices, taxes, etc.). Decisions concerning the choice of the level and direction of education, the choice of place of work and residence, as well as the method of spending the money earned, are the key to the development of households. Each household strives to spend its income in such a way that, in accordance with its own preferences, it achieves the greatest possible utility from the purchased goods and services, and the consequence of decisions made by households is, on the one hand, a certain amount of demand for goods and services, and on the other hand, the size and structure of supply. Additionally, when assigning the attribute of an economic entity to a household, one should pay attention to the fact that its activity is focused primarily on satisfying consumption needs. The main goal of each household is to collect funds that are used to meet individual and common consumption needs. This fundamental goal of the household is the basis for the choices and economic and organisational decisions of the members of the household, both within and outside the household. Satisfying consumption needs takes place through a combination of activities that make up the management process: the time budget of household members, the monetary budget, and the resources of material goods. It follows that a household as an economic entity is made up of its members together with the resources of time, knowledge, skills, money, and material goods. A household has three basic dimensions, i.e. subjective - a household is made up of its members along with their socio-demographic and professional characteristics, such as gender, age, education, professional activity, which indicate the scope of common consumption needs of household members; objective - a household is the economic base of an individual or a group of people, which is made up of means enabling the current satisfaction of consumption needs, i.e. income, cash resources and housing with durable goods, i.e. the so-called home consumption infrastructure, the condition of which significantly affects the structure of current household consumption; functional - a household is a set of activities that make up its functions, and its functioning consists in undertaking a number of various activities both within the household and outside in order to directly meet the common and individual needs of household members. Summarising the above considerations, it can be concluded that a household is an autonomous economic entity separated in the economic sense on the basis of personal property, making decisions in the sphere of consumption based on its own subjective preferences (taste), likes, habits, and traditions, as well as existing objective limitations (i.e., household income and market prices of goods and services) for the maximum and most rational satisfaction of all needs (both consumption and spiritual) of all its members.

Therefore, households are the basic units of the consumption sphere, which have at their disposal cash, material resources, as well as time and work of their members, finance the purchase of goods and services, produce consumption items and services, and organise consumption processes. However, the scope, nature, and manner of their functioning determine the degree to which the needs of household members are met (Zalega, 2007; Kośny, 2013; Grzybowska, 2014; Kozera, Stanisławska, Głowicka-Wołoszyn, 2016; Bywalec, 2017; Bywalec, 2020; Kata, Nowak, Leszczyńska, Kowal, Sebastianka, 2021).

The economic functions of a household result from participation in economic processes in local and global dimensions, which is manifested in two key functions performed by them, i.e., buyer of goods and services on the market and outside the market provided by enterprises and institutions; there is a flow of goods and services from enterprises to households and a stream of payments from households to enterprises; The economic functions of households show their great economic importance as entities operating in the economy, and especially as participants in market exchange (Gutkowska, Ozimek, Laskowski 2001; Zalega, 2007).

The financial situation of households is the financial situation and the state of material resources possessed, which inform about the family's wealth and largely affect the level and quality and conditions of its life. Thus, the financial situation of a household is determined by both the property owned and the level of current income (but the expected future income also plays an important role in consumption decisions of households), and the impact of these two elements on the economic behaviour of households can be not only substitutive, but also complementary , when low current income is compensated by previously accumulated wealth (however, in the case of households without assets, their consumption - apart from current income - also depends on whether they use loans or consumer credits). In turn, the decisions that households make in the sphere of consumption depend not only on their financial situation or the conditions prevailing on the goods and services markets (level of prices of goods and services, supply of goods and services - quantity, assortment, quality, technical, and utility values), and methods of distribution related to the level and organisation of market supply, etc., but also on the policy of the state (government) or the economic condition of the country. Through the tools that the state (government) uses to stimulate growth and socio-economic development and to improve the living conditions of citizens as part of social and economic policy, it also affects the level and structure of household consumption. This applies primarily to fiscal and monetary policy, as to well as income, price, and public spending policies. However, not only the policy of the state but also its condition, in terms of the level and pace of economic growth or broadly understood economic development, influences the decisions of entities in the sphere of consumption. Citizens of highly developed countries usually enjoy a higher standard of living than citizens of developing countries. The higher the dynamics of economic growth, the faster private consumption grows, and the standard of living of citizens improves. In addition, one of the most important processes affecting the modern world economy, and thus individual national economies, is globalisation. Increased flows of goods,

services, labour, and capital, which are manifestations of globalisation processes, largely determine the condition of modern economies, which has its impact on contemporary consumption patterns. For this reason, the concept of globalisation of consumption appears in the literature on the subject, which means the spread of identical or very similar consumption patterns, i.e. the so-called globalisation of consumption. homogenisation of consumption, on a supranational scale, as well as the creation of the so-called global consumer culture. This is manifested in the greater availability of foreign goods, which means a greater variety of goods on the domestic market and thus large opportunities to meet the consumption needs of households. Increased competition on the domestic market also affects the behaviour of domestic producers, which often results in lower prices for goods and services. It is also worth noting that increased flows, especially of goods, services, capital, and people, contribute to the diffusion of information, ideas, and culture, which has a huge impact on changes in consumption patterns. This leads to the emergence of transnational market segments that include homogeneous groups of consumers, on a supranational or even global scale. This means that a group of consumers identified in one country (region) has similar characteristics as the corresponding segment in another country (region). In the case of the global segment, these are recipients waiting for the same (global) product all over the world (Choroś-Mrozowska, Clowes, 2018; Kata, Nowak, Leszczyńska, Kowal, Sebastianka, 2021).

The financial situation of households is traditionally the basic element of analyses concerning the standard and quality of life of the population. Quality of life can be assessed in two dimensions, i.e. comparative (using evaluative and evaluative measures) and descriptive (describing quality of life as a set of features that are not subject to evaluation). The quality of life in the evaluation aspect is reflected in the objective and subjective assessment. Standard and living conditions make up its objective quality, while subjective quality of life is the perception of the individual's mental feelings, satisfaction, contentment, and happiness. The objective quality of life is similar in meaning to the concept of living conditions, which includes: household income, food expenditure, and quality of nutrition, housing conditions, household equipment, including access to modern communication technologies (mobile phone, computer, Internet), the scale of using social assistance, children's education, using various forms of health care, various aspects of social exclusion (unemployment, disability, poverty), participation in cultural life, forms of recreation. The subjective quality of life is assessed on the basis of the degree of people's satisfaction with various objective forms of satisfying their needs, characterising various aspects of life. Quality of life understood in this way means a way or lifestyle. Regardless of what characteristics of the quality of life are the subject of assessment here, they are always related to the subjective perception of one's own life, taking into account social and economic conditions, as well as the system of values characteristic of each person (or group of people). Research on the subjective quality of life boils down to the assessment of residents' satisfaction with various spheres, including: the material standard of living, family relationships, the sense of security in the living environment, the quality of the natural

environment in the place of residence, the state of health, and the health care system, the way of spending free time, professional career development, level of education, the ability to pursue one's own lifestyle and act in accordance with one's personal value system. The most synthetic way of assessing the subjective quality of life is general psychological well-being, including will to live, sense of happiness, satisfaction with life, and lack of symptoms of mental depression. There are two possible approaches to the study of subjective quality of life. One emphasises the positive aspects of life reflected in satisfaction with life and a sense of happiness, while the other focusses on negative feelings (tiredness, anxieties, fears, etc.). It must be added that in the In the Stiglitz report[1], the quality of life covers the full range of factors influencing the assessment of the material and mental state of a person, and the huge role of research illustrating the subjective assessment of each factor of the quality of life by individual people is emphasized here (Sęk, 1993; Kędzior, 2003; Ostasiewicz, 2004; Kryk, Włodarczyk-Śpiewak, 2006; Czapiński, Panek, 2009; Szukiełojć-Bieńkuńska, Walczak, 2011; Sompolska-Rzechuła, 2013; *Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

Quality of life is shaped by many different factors. Some of them are derivatives of economic development processes and are therefore determined by the market mechanism, whereas others are determined by the institutional sphere of the public sector. The first group includes factors related to the labour market (unemployment, employment, and working conditions, job satisfaction), the level of income, and the structure of expenses (food, other consumer goods, including housing and housing expenses). In turn, the second group of factors includes the accessibility and degree of satisfaction of residents with health care facilities, education, the transport network, and cultural facilities. These are factors shaped primarily by local government units as well as state institutions. The same group of factors also includes the condition of the natural environment, which - due to the imperfection of the market in this sphere - depends directly on the activity of public sector institutions and affects not only the quality of life of residents, but also visitors, resting in places with tourist values. Therefore, it can be assumed that the quality of life of the inhabitants is influenced by three groups of economic policy instruments, i.e.: stimulating economic development at the regional and local level and thus influencing the situation on the labor market and the level of household income, supporting the development technical and social infrastructure facilitating the access of residents to health care, education, culture, recreation, as well as improving the transport accessibility of regions and local communities and improving the condition of the natural

[1] This is the Commission's Report on Measuring Economic Performance and Social Progress published in 2009. The 25-member Commission was headed by the 2001 Nobel Laureate, Columbia University professor Joseph E. Stiglitz, former White House adviser and chief economist of the World Bank. His advisor was the Indian economist Amartya Sen, winner of the Nobel Prize in 1998, professor at Harvard University. The report is addressed mainly to high-level politicians who, in times of crisis, should focus their efforts more on improving the living conditions of the population and on ensuring more comprehensive social progress for current and future generations (Szukiełojć-Bieńkuńska, Walczak, 2011).

environment by introducing restrictions on the use of non-renewable natural resources, encouraging economic activity that improves the condition of the natural environment (or at least not worsening environmental values), as well as motivating consumers to pro-ecological behavior (Błachut, Cierpiał-Wolan, Czudec, Ślusarz, 2017).

Research shows that there are clear differences in terms of quality of life between individual countries of the European Union. The countries characterised by the highest quality of life include Scandinavian countries and Luxembourg. These countries have low levels of material deprivation and the highest levels of overall satisfaction with life. The lowest quality of life, much below the average of the European Union, is found in countries such as Romania, Bulgaria, and Latvia. On the other hand, Poland is in the group of countries where quality of life is evaluated lower than average in the European Union (Raczkowska, 2016).

The eastern regions of Poland are voivodeships with a low level of socioeconomic development, characterised by low population density, low quality of human, social and intellectual capital, low level of development of technical, social and institutional infrastructure, limited territorial accessibility, and low level of income of the population and local government units. Therefore, these are voivodeships that meet the definition criteria used for peripheral areas. On the other hand, the western regions of Poland in the geographical and natural sense are the Oder basin stretching between the Sudetes and the Baltic Sea, and in the economic sense they are a more developed and prosperous part of the country, especially in comparison to the eastern regions. The location of the western regions of Poland in the vicinity of Germany and the Czech Republic, as well as in the vicinity of the Scandinavian countries, creates an opportunity for their further socio-economic development, which can be accelerated primarily by establishing and using mutual relations and economic relations (cross-border cooperation) (Mogiła, Zaleski, Zathey, 2011; Kudełko, 2013; Balińska, 2015; Czudec, Majka, Zając, 2018; Grzebyk, Miś, Stec, Zając, 2019; Miś, Zając, 2020).

2. Research aim, empirical material, and research methods

The aim of this article is to identify and assess the diversification of the financial situation of households in the eastern and western regions of Poland.

The article presents a research hypothesis, which assumes that households in the western regions of Poland have a better financial situation compared to the eastern regions, but there is a variation in this respect between individual voivodeships of these regions.

The empirical material used in the article concerns both the whole country and six voivodeships of eastern and western Poland, i.e. Lubelskie, Podkarpackie and Podlaskie,

as well as Dolnośląskie, Lubuskie and Zachodniopomorskie[2]. The figures come from the Central Statistical Office in Warsaw (*Social Cohesion Survey*). Empirical material collected and ordered empirical material was developed in tabular and graphical form, using the method of comparative analysis.

It should be added that in the article it was adopted after the Central Statistical Office in Warsaw (*Social Cohesion Survey*) that the identification and assessment of the financial situation of households should be made in a multidimensional way. Therefore, the income situation, living conditions and the ability of households to maintain budget balance were analyzed (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

To achieve the objective of the work, that is, to identify and assess the financial situation of households in the eastern and western regions of Poland, the following diagnostic features were analysed:

- relatively high income rate (%),
- relative income poverty rate (%),
- indicator of good living conditions (%),
- poverty rate of living conditions (%),
- good fiscal position indicator (%),
- the poverty rate of an unbalanced budget (%).

Furthermore, the article evaluates all diagnostic characteristics that illustrate the financial situation (including income, living conditions, and budget situation) of households in the eastern and western regions of Poland against the background of the entire country. Individual diagnostic features were compared with the national average, which was taken as 100 points, and their advantage or underweight in the eastern and western regions of Poland together and in individual voivodeships was assessed accordingly. Then all points were summed up, and the average was calculated (Figures 1-4).

3. Results

The indicator of relatively high income is understood as the percentage of households with the highest income, i.e. those whose monthly income is higher than 5/3 (approximately 167%) of the median equivalent income for all households in the country. In addition, this indicator is about 2.8 times higher than the adopted relative poverty line (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, *2020*).

[2] One of the administrative borders of these voivodeships is the state border.

The data contained in Table 1 shows that there is a large variation in terms of the value of the relatively high income indicator between the eastern and western regions of Poland. The value of this indicator is definitely higher and at the same time similar to the average for the entire country, in the western regions of Poland in comparison to the eastern regions, where it is clearly lower than the national average. Furthermore, the value of the relatively high income indicator is more differentiated between individual western regions of Poland, with the highest value in the Dolnośląskie Voivodship, where it exceeds the national average. On the other hand, in the Lubuskie Voivodship it is comparable to the average for the whole country, and the lowest is in the Zachodniopomorskie Voivodeship. On the other hand, there are no major differences in terms of the value of the relatively high income indicator between the individual eastern regions of Poland, with the exception that it is the highest in the Podlaskie Voivodeship.

Table 1.
Indicators of the income situation of households in the eastern and western regions of Poland against the background of the country (in %)

Specification	Relatively high income indicator	Relative income poverty rate
Poland	14,9	13,2
Eastern regions of Poland, including provinces:	8,0	20,9
Lubelskie	7,1	25,9
Podkarpackie	7,8	19,3
Podlaskie	9,1	17,6
Western regions of Poland, including provinces:	15,5	11,4
Dolnośląskie	19,6	9,5
Lubuskie	15,6	10,0
Zachodniopomorskie	11,4	14,6

Source: Central Statistical Office in Warsaw (*Social Cohesion Survey*).

The relative income poverty indicator is understood as the percentage of households where the monthly income is lower than the value considered as the poverty threshold, and it is assumed at the level of 60% of the median equivalent income for all households in the country (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, *2020*).

The data in Table 1 show that there is a large variation in terms of the value of the relative income poverty indicator between the eastern and western regions of Poland. The eastern regions of Poland are characterized by a much higher value of this indicator, which also clearly exceeds the average for the entire country, and this applies to all voivodeships, especially Lubelskie. On the other hand, in the western regions of Poland, the value of the relative income poverty indicator is lower, both compared to the eastern regions and to the national average, except that this applies to the Dolnolskie and Lubuskie voivodeships, because in the Zachodniopomorskie Voivodship it is slightly higher than the average for the country.

Figure 1 presents the results of the score assessment concerning the income situation of households in the eastern and western regions of Poland in the background of the country. It should be noted that there is a large variation in this respect between the eastern and western

regions of Poland. The income situation of households in the western regions of Poland is definitely better than in the eastern regions, where it is clearly worse than the average for the whole country. In addition, the income situation of households is also differentiated between individual eastern and western regions. In the case of eastern regions, it is the best in Podlaskie and the worst in Lubelskie. In the case of the western regions, the best income situation is in households in the Dolnośląskie Voivodship, and the worst in the Zachodniopomorskie Voivodship, where it is slightly worse than the average for the whole country.

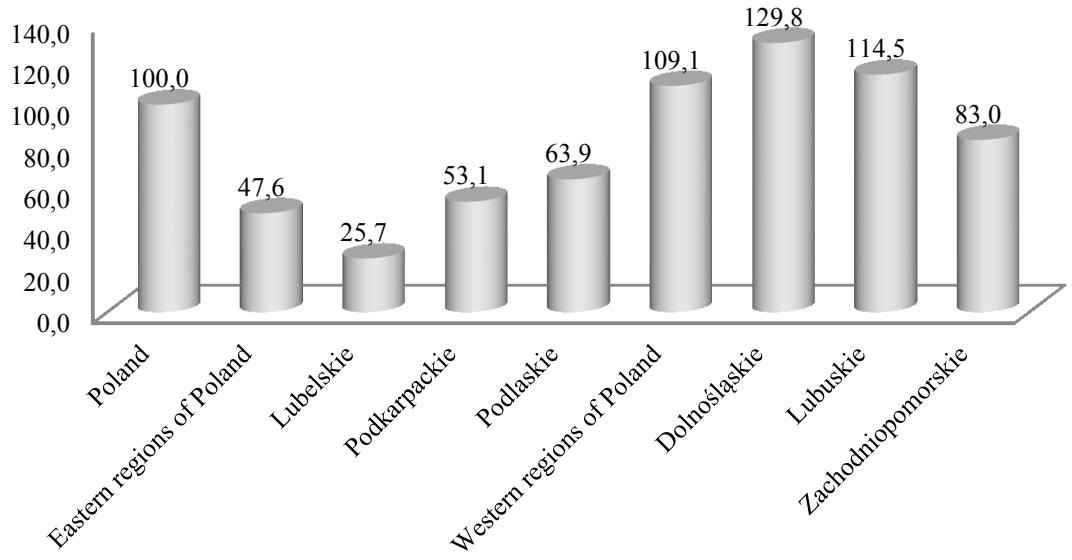

Figure 1. Evaluation of the income situation of households in the eastern and western regions of Poland against the background of the country (Poland = 100.0 points).

Source: Own study.

Indicator of good living conditions is understood as the percentage of households in which no symptoms of poor living conditions from the so-called "a list of 30 symptoms concerning: the quality of housing, the level of equipment with durable goods and the inability to satisfy various types of material and intangible needs for financial reasons" (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

The data in Table 2 show that there are differences in terms of the value of the indicator of good living conditions between the eastern and western regions of Poland. The value of this indicator is slightly lower in the western regions of Poland and in the eastern regions it is slightly higher and similar to the average for the entire country. Furthermore, the value of the indicator of good living conditions is more differentiated between individual eastern regions of Poland, with the highest value in the Podlaskie Voivodship, where it exceeds the national average. On the other hand, in the Podkarpackie voivodeship it is close to the average for the whole country, and the lowest is in the Lubelskie voivodship. However, there are no significant differences in terms of the value of the indicator of good living conditions between the individual western regions of Poland.

The poverty of living conditions indicator is understood as the percentage of households in which at least 10 symptoms of poor living conditions were observed from the so-called "a list of 30 symptoms concerning: the quality of housing, the level of equipment with durable goods, as well as the inability to satisfy various types of material and intangible needs for financial reasons" (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

Table 2.
Indicators of living conditions of households in the eastern and western regions of Poland against the background of the country (in %)

Specification	Index of good living conditions	Living conditions poverty index
Poland	26,5	4,8
Eastern regions of Poland, including provinces:	26,9	4,7
Lubelskie	21,9	6,0
Podkarpackie	26,0	4,3
Podlaskie	32,7	3,7
Western regions of Poland, including provinces:	24,7	5,4
Dolnośląskie	24,9	3,3
Lubuskie	24,9	6,7
Zachodniopomorskie	24,3	6,3

Source: Central Statistical Office in Warsaw (*Social Cohesion Survey*).

Based on the data in Table 2, it should be stated that there are differences in terms of the the poverty index of value of living conditions between the eastern and western regions of Poland. The value of this indicator is slightly higher in the western regions of Poland, and in the eastern regions it is slightly lower and close to the national average. The value of the poverty index for living conditions also differs between the individual eastern and western regions. In the case of the eastern regions of Poland, it is the lowest in the Podlaskie Voivodship and the highest in the Lubelskie Voivodship, where it exceeds the average for the whole country. On the other hand, in the case of the western regions of Poland, the value of the poverty of living conditions indicator is the lowest in the Dolnośląskie Voivodship, and in the Lubuskie and Zachodniopomorskie Voivodeships it is similar and higher than the national average.

Figure 2 presents the results of the score assessment concerning the living conditions of households in the eastern and western regions of Poland against the background of the entire country. It should be noted that there are differences in this respect between the eastern and western regions of Poland. Households in the eastern regions of Poland have slightly better living conditions, where they are similar to the average for the entire country, while in the western regions of Poland they are slightly worse. The living conditions of the households are also clearly differentiated between the individual eastern and western regions. In the case of the eastern regions of Poland, the best situation in this respect is in the Podlaskie Voivodeship, where the living conditions of the households are clearly better than the average for the whole country. On the other hand, in the Podkarpackie voivodeship they are similar to the average for the whole country and the worst in the Lubelskie voivodeship. In the case of the western regions

of Poland, the living conditions of households are the best in the Dolnośląskie Voivodship, where they are better compared to the average for the whole country, and in the Lubuskie and Zachodniopomorskie Voivodships they are similar and worse compared to the national average.

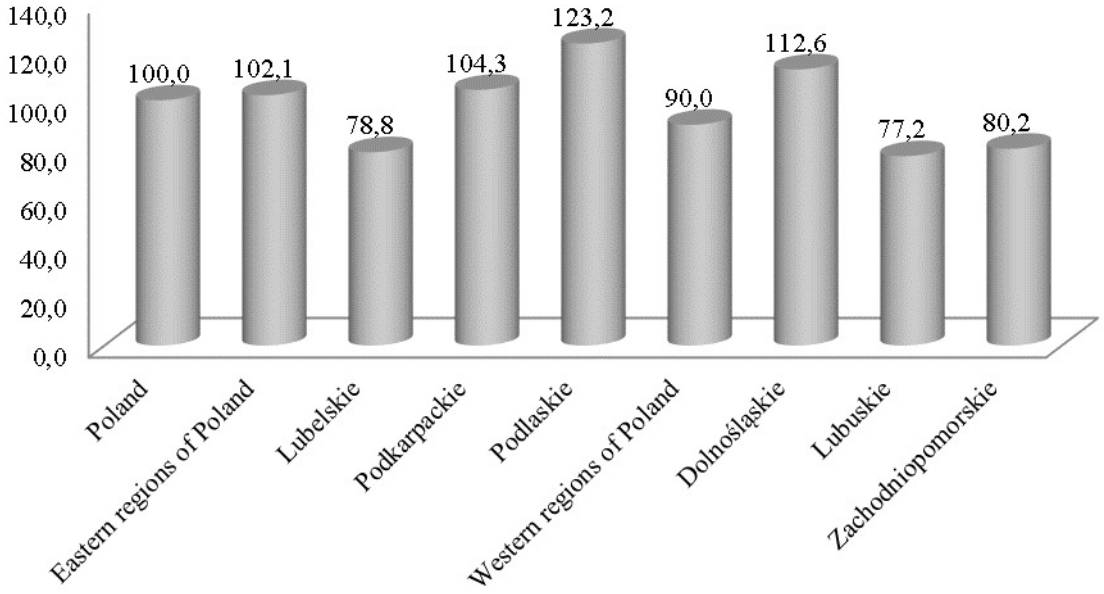

Figure 2. Score of the living conditions of households in the eastern and western regions of Poland compared to the rest of the country (Poland = 100.0 points).

Source: Own study.

The indicator of a good budget situation is understood as the percentage of households with high budget freedom, i.e. those that positively assess the possibility of managing their income and in which none of the so-called "7 symptoms of not managing your budget" (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

The data in Table 3 indicate that there are differences in terms of the value of the good budget indicator between the eastern and western regions of Poland. The value of this indicator is slightly lower in the western regions of Poland, and in the eastern regions it is slightly higher and close to the average for the entire country. In addition, it should be noted that the value of the good budget situation indicator is also differentiated between individual eastern and western regions. In the case of the eastern regions of Poland, it is the lowest in Lubelskie, and in Podkarpackie and Podlaskie it is similar and higher than the national average. In turn, in the case of the western regions of Poland, the value of the good budget situation indicator is the lowest in Zachodniopomorskie, and in Dolnośląskie and Lubuskie it is similar, but in Dolnośląskie it is above the national average.

Table 3.
Indicators of the budgetary situation of households in the eastern and western regions of Poland against the background of the country (in %)

Specification	Good fiscal position index	Poverty index of budget imbalance
Poland	30,7	7,8
Eastern regions of Poland, including provinces:	30,4	6,9
Lubelskie	24,6	8,5
Podkarpackie	32,5	4,7
Podlaskie	34,2	7,4
Western regions of Poland, including provinces:	27,8	8,8
Dolnośląskie	33,6	7,0
Lubuskie	29,8	10,9
Zachodniopomorskie	19,9	8,4

Source: Central Statistical Office in Warsaw (*Social Cohesion Survey*).

The budget imbalance poverty indicator is understood as the percentage of households considered poor from the point of view of the so-called "failing to cope with the budget", i.e. in which at least 4 out of 7 symptoms occurred, including both the subjective opinions of households regarding their financial status and facts about the household's budget difficulties (including arrears in payments) (*Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*, 2020).

The data in Table 3 shows that there are differences in terms of the value of the poverty indicator of budget imbalance between the eastern and western regions of Poland. A slightly lower value of this indicator characterises the eastern regions of Poland, and in the western regions it is slightly higher and exceeds the average for the entire country. The value of the budget imbalance poverty index also varies between eastern and western regions. Among the eastern regions of Poland, it is the lowest in the Podkarpackie voivodship, and in the Lubelskie and Podlaskie voivodships it is similar, but in the Lubelskie voivodship it exceeds the national average. On the other hand, among the western regions of Poland, the value of the budget imbalance poverty rate is the highest in Lubuskie, and in Dolnośląskie and Zachodniopomorskie it is similar, while in Zachodniopomorskie it is above the national average.

Figure 3 presents the results of the score evaluation on the budget situation of households in the eastern and western regions of Poland against the background of the entire country. It should be noted that there are differences in this respect between the eastern and western regions of Poland. A slightly better budget situation is characteristic of households in the eastern regions of Poland, where it is similar to the average for the entire country, while in the western regions of Poland it is slightly worse. Additionally, the budgetary situation of households is also clearly differentiated between the individual eastern and western regions. In the case of the eastern regions of Poland, the best budgetary situation is characteristic of households in the Podkarpackie Voivodship, where it is clearly better compared to the national average. On the other hand, in the Podlaskie Voivodship it is slightly better than the national average, and it is the worst in the households in Lubelskie Voivodship. On the other hand, in the case of

the western regions of Poland, the budget situation of households is the best in the Dolnośląskie Voivodship, where it is slightly better compared to the national average, and in the Lubuskie and Zachodniopomorskie Voivodships it is very similar and worse compared to the national average.

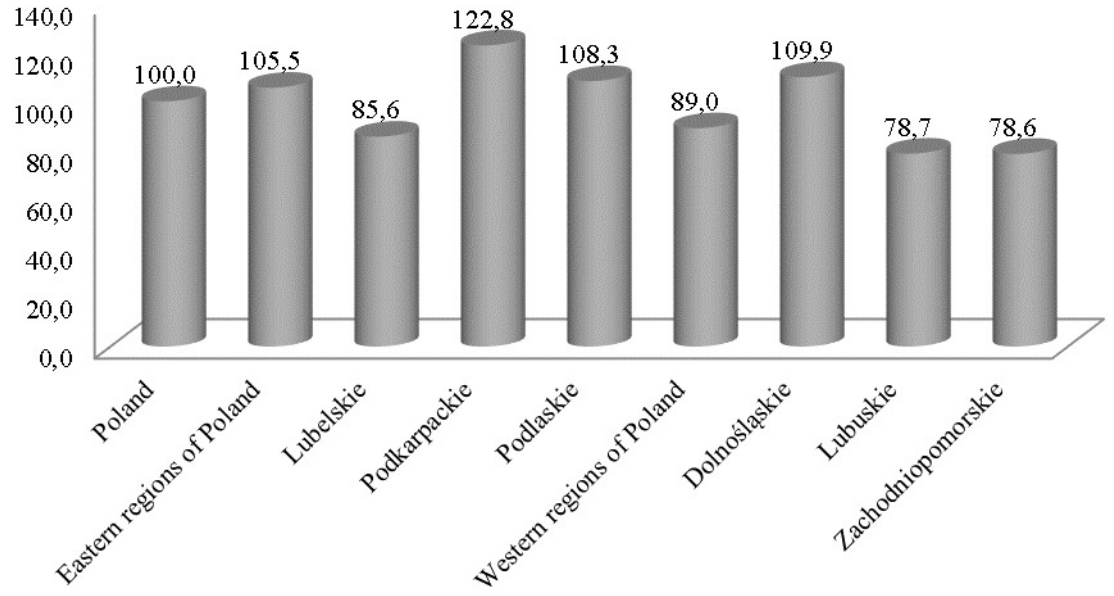

Figure 3. Evaluation of the score of the budget situation of households in the eastern and western regions of Poland compared to the rest of the country (Poland = 100.0 points).

Source: Own study.

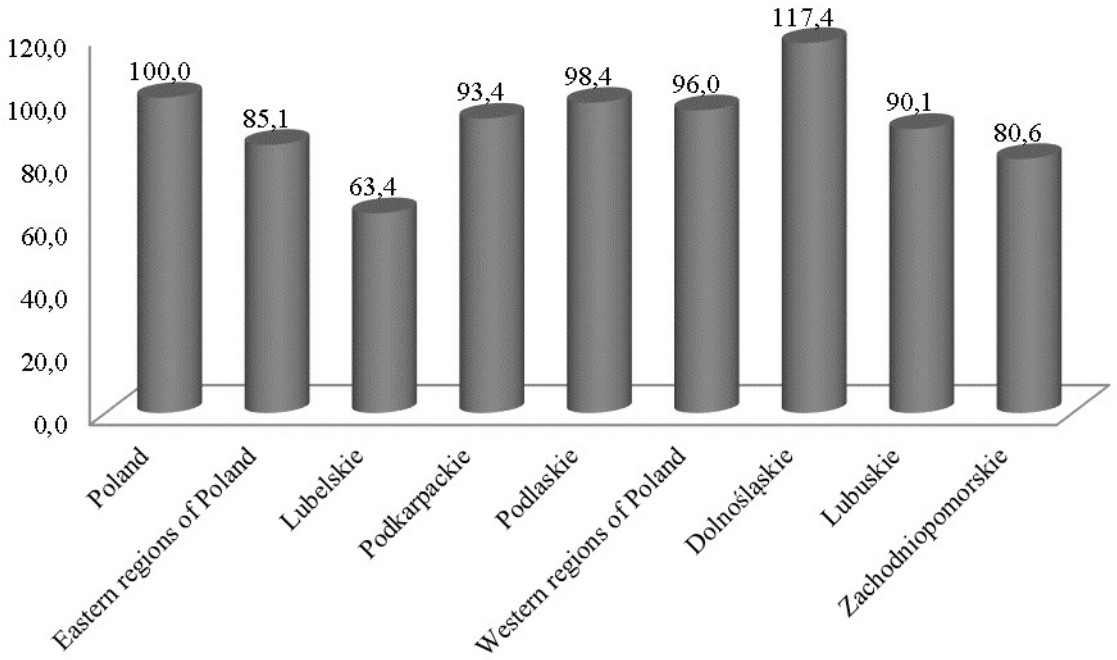

Figure 4. Evaluation of the score of the financial situation of households in the eastern and western regions of Poland compared to the rest of the country (Poland = 100.0 points).

Source: Own study.

Figure 4 presents the results of the score evaluation on the financial situation of households in the eastern and western regions of Poland against the background of the entire country. On this basis, it can be seen that there are differences in this respect between the eastern and western regions of Poland. The financial situation of households is slightly better in the western regions of Poland than in the eastern regions, where it is clearly worse than the national average. Additionally, the financial situation of households is clearly differentiated between individual eastern and western regions. In the eastern regions, the best financial situation is in the households of the Podlaskie voivodship, where it is close to the national average, it is slightly worse in the Podkarpackie voivodship, and the worst in the households of the Lubelskie voivodship. On the other hand, in the western regions, the financial situation of households is clearly the best in the Dolnośląskie voivodeship and there it is better compared to the national average, and in the Lubuskie and Zachodniopomorskie voivodships it is worse than the national average, with the worst in households in the Zachodniopomorskie voivodeship.

4. Summary and conclusions

In Poland, there is a large variation in the income situation of households between the eastern and western regions, with households of the western regions clearly having a better income situation. Furthermore, there is also a large differentiation in terms of the income situation of households between the individual eastern and western regions. In the case of eastern regions, it is the best in Podlaskie and the worst in Lubelskie. However, in the case of western regions, it is the best in Dolnośląskie and the worst in Zachodniopomorskie.

There are differences between the eastern and western regions of Poland in terms of living conditions of households, with the exception that they are slightly better in the eastern regions. The living conditions of the households are also clearly differentiated between the individual eastern and western regions. In the eastern regions, the best situation in this respect is in Podlaskie and the worst in Lubelskie. On the other hand, in the western regions, the living conditions of households are the best in the Dolnośląskie voivodship, where they are better compared to the averages for the whole country, and in the Lubuskie and Zachodniopomorskie voivodeships they are similar and worse than the national averages.

In Poland, there is a diversification in terms of the budgetary situation of households between the eastern and western regions, with it slightly better in the eastern regions. Furthermore, the budgetary situation of households is also clearly differentiated between individual eastern and western regions. In the case of the eastern regions of Poland, it is the best in the Podkarpackie Voivodship and the worst in the Lubelskie Voivodeship. On the other hand, in the case of the western regions, the budget situation of households is the best in the Dolnośląskie Voivodship, where it is slightly better compared to the national average,

and in the Lubuskie and Zachodniopomorskie Voivodships it is very similar and worse than the national average.

The analysis carried out in the article shows that in Poland there is a diversification in terms of the financial situation of households between the eastern and western regions, with the fact that it is slightly better in the western regions. Furthermore, the financial situation of households is also clearly differentiated between individual eastern and western regions. In the eastern regions, the best financial situation is in the households of the Podlaskie Voivodship, while the worst is in the households of the Lubelskie Voivodeship. On the other hand, in the western regions, the financial situation of households is clearly the best in the Dolnośląskie voivodeship and there it is better compared to the national average, and in the Lubuskie and Zachodniopomorskie voivodships it is worse than the national average, with the worst in households in the Zachodniopomorskie Voivodeship. Therefore, this confirms the research hypothesis presented in the article, which assumes that households in the western regions of Poland have a better financial situation compared to the eastern regions, although there is variation in this respect between individual voivodeships of these regions.

It should be added that the results of the statistical data analysis presented in the article provide important and up-to-date knowledge that can be useful both for politicians at the central level and for local government officials responsible for the conditions, opportunities and directions of regional socio-economic development, as well as for other decision-makers implementing regional development policy in Poland. At the same time, it justifies the need to continue similar research and analyses.

References

1. Balińska, A. (2015). Czynniki rozwoju terenów peryferyjnych Polski Wschodniej. *Journal of Agribusiness and Rural Development, 2(36)*, pp. 153-160.
2. Błachut, B., Cierpiał-Wolan, M., Czudec, A., Ślusarz, G. (2017). *Jakość życia w województwie podkarpackim w latach 2004-2015*. Rzeszów: Urząd Statystyczny w Rzeszowie, Uniwersytet Rzeszowski, p. 172.
3. Bywalec, Cz. (2020). *Ekonomika i finanse gospodarstw domowych*. Warszawa: PWN, p. 232.
4. Bywalec, Cz., (2017). *Gospodarstwo domowe. Ekonomika, finanse, konsumpcja*. Kraków: Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie, p. 310.
5. Choroś-Mrozowska, D., Clowes, D. (2018). Ekonomiczne uwarunkowania zachowań konsumpcyjnych gospodarstw domowych w Polsce w latach 2006-2015. *Zeszyty Naukowe UEK, 1(973)*, pp. 27-45. https://doi.org/10.15678/ZNUEK.2018.0973.0102.

6. Czapiński, J., Panek, T. (2009). *Diagnoza społeczna. Warunki i jakość życia Polaków*. Warszawa: Wyższa Szkoła Finansów i Zarządzania.
7. Czudec, A., Majka, A., Zając, D. (2018). Impact of European Union Cohesion Policy at Local Level (Rural Areas of Eastern Poland Case Study). *Lex localis - Journal of Local Self-Government, Vol. 16, No. 4*, pp. 785-803.
8. Grzebyk, M., Miś, T., Stec, M., Zając, D. (2019). *Skala, kierunki i dynamika zmian społeczno-gospodarczych na obszarach wiejskich wschodniej Polski po przystąpieniu do Unii Europejskiej*. Poznań: Bogucki Wydawnictwo Naukowe, p. 232.
9. Grzybowska, A. (2014). Gospodarstwo domowe a działalność parabanków. *Zeszyty Naukowe Wyższej Szkoły Bankowej we Wrocławiu, 4(42)*, p. 119-129.
10. Gutkowska, K., Ozimek, I., Laskowski, W. (2001). *Uwarunkowania konsumpcji w polskich gospodarstwach domowych*. Warszawa: Wydawnictwo SGGW, p. 255.
11. *Jakość życia i kapitał społeczny w Polsce. Wyniki Badania spójności społecznej 2018*. (2020). Warszawa: GUS, p. 396.
12. Kata, R., Nowak, K., Leszczyńska, M., Kowal, A., Sebastianka, B. (2021). *Bezpieczeństwo finansowe gospodarstw domowych – wybrane zagadnienia*. Rzeszów: Wydawnictwo Uniwersytetu Rzeszowskiego, p. 322.
13. Kędzior, Z. (2003). Metodologiczne aspekty badania jakości życia. In: *Jakość życia w regionie*. Szczecin: Uniwersytet Szczeciński.
14. Kośny, M. (2013). *Determinanty bezpieczeństwa ekonomicznego rodzin*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, p. 196.
15. Kozera, A., Stanisławska, J., Głowicka-Wołoszyn, R. (2016). Wewnętrzne społeczno-ekonomiczne determinanty bezpieczeństwa ekonomicznego gospodarstw domowych rolników. *Roczniki Naukowe SERiA, t. XVIII, z. 6*, pp. 110-116.
16. Kryk, B., Włodarczyk-Śpiewak, K. (2006). Wybrane aspekty jakości życia na przykładzie województwa zachodniopomorskiego. In: *Zachowania rynkowe gospodarstw domowych i przedsiębiorstw w okresie transformacji systemowej w Polsce*. Szczecin: Uniwersytet Szczeciński.
17. Kudełko, J. (2013). Uwarunkowania i kierunki rozwoju województw Polski Wschodniej jako regionów słabo rozwiniętych. *Studia KPZK PAN, t. CLI*. Warszawa.
18. Miś, T., Zając, D. (2020). Results of European Union Cohesion Policy in Terms of Quality of Life Improvement on a Regional Level (as Exemplified by Eastern Poland). *Lex localis - Journal of Local Self-Government, Vol. 18, No. 1*, pp. 53-69.
19. Mogiła, Z., Zaleski, J., Zathey, M. (2011). *Wykorzystanie przygranicznego położenia terenów znajdujących się w zachodniej części Polski dla rozwoju społeczno-gospodarczego*. Wrocław, p. 197.
20. Ostasiewicz, W. (2004). *Ocena i analiza jakości życia*. Wrocław: Akademia Ekonomiczna we Wrocławiu.

21. Raczkowska, M. (2016). Jakość życia w krajach Unii Europejskiej. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu. Ekonomia, 449*, pp. 511-521.
22. Sęk, H. (1993). Jakość życia a zdrowie. *Ruch prawniczy, ekonomiczny i socjologiczny, z. 2*, pp. 110-116.
23. Sompolska-Rzechuła, A. (2013). Jakość życia jako kategoria ekonomiczna. *Folia Pomeranae Universitatis Technologiae Stetinesis, Oeconomica, 301(71)*, pp. 127-139.
24. Szukiełojć-Bieńkuńska, A., Walczak, T. (2011). Statystyczny pomiar postępu społeczno-gospodarczego w zmieniającym się świecie. *Wiadomości Statystyczne, 7-8*, pp. 9-29.
25. Zalega, T. (2007). Gospodarstwo domowe jako podmiot konsumpcji. *Studia i Materiały, Wydział Zarządzania, Uniwersytet Warszawski, 1*, pp. 7-24.

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THE BUSINESS DIMENSION OF METAVERSE

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Purpose: This paper aims is to identify the key business opportunities and potential threats to companies that arise as Metaverse-like platforms development. The focus is on companies which can use the functionalities Metaverse offers and on the fact that their customers may soon be spending their time there in great numbers.
Design/methodology/approach: From company perspective, the purposes set out in this paper are pursued under strategic analysis. In this context, SWOT analysis comes as an appropriate method. This paper does not pertain to a specific company or industry; therefore, the analysis will be confined to Opportunities and Threats that are, in essence, independent of the business sector and concern Metaverse's impact on the business world. The source materials for the said analysis derive from the latest research literature and reports of consulting companies.
Findings: This paper identifies the fundamental business opportunities in the context of the envisaged Metaverse development. They were confronted with issues and risks associated with the practical development and use of such platforms.
Research limitations/implications: Metaverse is in its initial development phase; therefore, the identification of opportunities and threats is tentative and it should be revised as the technology progresses and the practical solutions become established. Moreover, the analysis in question is based on the projected development of Metaverse, hence the ensuing conclusions should be approached with caution.
Practical implications: This paper provides a list of the fundamental business opportunities and threats which should be taken into account by companies devising their strategy concerning the use of Metaverse platforms.
Social implications: The pertinent threats fundamentally affect the situation of the society in the digital world. Hence, it is too important to be aware of the threats, pursue appropriate polices of privacy, ethical business, social responsibility, and finally to adopt relevant legal regulations on the state level.
Originality/value: One of the first research papers discussing the business potential and threats surrounding the development of Metaverse.

Keywords: Metaverse, E-commerce, Digital Transformation, Virtual World.

Category of the paper: General review.

1. Introduction

Metaverse became pronounced in public communication in the autumn of 2021 when Mark Zuckerberg announced a strategic shift in Facebook's development directions (Enter, 2023). This subject is far more serious than just being a remedy to salvage a digital giant. Market estimates show that the potential economic value generated by Metaverse-linked products and services will reach USD 5 trillion (10^{12}) in 2030, half of which will relate to e-commerce in the broad sense (McKinsey, 2022). This envisaged business potential implies immense interest on the part of business leaders and investors. As early as in 2022, the scale of investment reached USD 120 billion and it concerns both the digital market giants (Meta, Microsoft, Apple, Alphabet, etc.), venture capital funds (Andreessen Horowitz, Coatue, Soft Bank, etc.) as well as big corporations (Disney, Lego, Nvidia, etc.).

The concept of Metaverse was first articulated in sci-fi literature, in a book by Nel Stephenson, as a portmanteau of "meta" and "universe" (Stephenson, 1992). Ten years later, the virtual world platform Second Life was often described as the first metaverse. In the context of initial inspirations, it is also worth going back to a book entitled *Ready Player One* which is a 2011 science fiction novel, and the debut of Ernest Cline (2011). The book was a basis for an influential film of the same title which hit the cinema screens in 2018 and inspired many entrepreneurs who thought about creating a Metaverse in practice.

According to McKinsey (2022, p. 11) the metaverse should have three features: a sense of immersion, real-time interactivity and user agency. Additionally the full vision of the metaverse will also include the following: interoperability[1] across platforms and devices, concurrency with thousands of people interacting simultaneously and use cases spanning human activity well beyond gaming. From the technological point of view this concept is defined by (Lee et al., 2021, p. 1): we consider the metaverse as a virtual environment blending physical and digital, facilitated by the convergence between the Internet and Web technologies, and Extended Reality (XR). According to Milgram (Milgram et al., 1995) Extended Reality integrates digital and physical continuum to various degrees, e.g., augmented reality (AR), mixed reality (MR), and virtual reality (VR). It should be noted in the context of the latter definition that the understanding of the Metaverse concept should not be reduced to the mere use of VR headsets. Construing the concept as only regarding computer games is yet another misunderstanding. The success of such gaming platforms as Fortnite leads to Metaverse being quite naturally identified with them. That is, however, grossly oversimplified. Finally, the last myth is identifying Metaverse with Web3.

Web3 might potentially contributes to the Metaverse by espousing decentralization and potential interoperability. Being more specific: community governance through a foundation decentralized autonomous organization (DAO), digital assets that could be potentially owned

[1] Interoperability is a characteristic of a product or system to work with other products or systems.

through non-fungible tokens (NFT), and payments by cryptocurrencies and tokens. Milieus associated with blockchain and decentralized finance (DeFi) lobby extensively in favor of identifying Metaverse with Web3. However, it needs to be clearly emphasized that it is by all means possible to build Metaverse as a centralized platform with no touch of blockchain whatsoever. This strategic choice of a system managing Metaverse is absolutely critical to the future of this technological innovation. For now, it has not been resolved which approach (centralized vs. dispersed) will be commonly adopted. It seems reasonable to claim that the development of Metaverse will be subject to network effects, which will be briefly referred to in the conclusion to this paper.

This paper takes on the perspective of a company which, in the context of its strategic development, recognizes the topical technological trends. Thus, it was assumed that Metaverse will most likely reach its full functionality potential within the forthcoming 10-20 years. Therefore, instead of pondering over technological and business models of such platforms, we will turn to their impact on the development of companies planning to grow in the digital economy ecosystem. In this context, the SWOT analysis comes as an appropriate tool for company strategic analysis. SWOT analysis is a technique used to help a organization identify Strengths, Weaknesses, Opportunities, and Threats related to business competition or challenges in micro/macro environment. This situational assessment approach was firstly described at Harvard Business School (Christensen, 1965), and then extended with detailed procedure for doing a SWOT assessment by Kaplan and Norton (2008). This paper is not business sector/division specific, that is why SWOT analysis is restricted to Opportunities and Threats, which is basically domain independent.

Later in the paper, a brief review of related work will be made. Further, a range of business opportunities related to the emergence of Metaverse will be discussed with finance services as a representative example. The next chapter provides an overview of threats and technical issues. The paper ends with conclusions and summary.

2. Related Work

The concept of Metaverse has become immensely popular. In the last two years, more than 1100 peer-reviewed scientific papers were published on this topic (Google 2023). A very good, holistic approach to the subject is presented in a paper written by Lik-Hang Lee (Lee et al., 2021). A paper by Park and Kim, in turn, provides an incredibly in-depth analysis and a meticulous review of the literature (Park, Kim, 2022). In terms of the business potential and applications, a vast report by McKinsey (2022) comes as noteworthy. For at least two decades have been done a lot of research on technical architecture for virtual worlds in order to resolve scalability issues in the metaverse, such as balancing the workload for reduced response time

in multiplayer online games (Marzolla et al., 2012), or for unsupervised conversion of 3D models between the metaverse and real-world environments (Terrace et al., 2012). Important research field is user interaction across the physical and virtual environments. For instance an interaction technique for users to make high-fiving gestures being synchronized in both physical and virtual environments (Young et al., 2015). Another approach is proposed by Vernaza et al. which is an interactive system solution for connecting the metaverse and real-world environments through smart wearables (Vernaza et al., 2012). Metaverse development topic such are ubiquity, interoperability, scalability are described deeply by Dioniso (Dioniso et al., 2013). Finally it is worth mentioned the achievement in artificial moral agents (Zoshak, Dew, 2021).

3. Business Opportunities

3.1. General overview

In order to properly identify the impact of Metaverse on business development, the areas of human activity which will most likely fall within its functionality area should be defined. According to the report by McKinsey (2022, p. 24), such highly probable areas of activity are the following:

- Gaming, that actually has been driving the development of the metaverse.
- Socializing extends existing consumer behavior through platforms.
- Fitness which often marries gaming and connectivity.
- Remote learning remotely groups individuals in virtual classrooms.

Today virtual worlds, most of which are focused on gaming or social. In the near future there will be at least three business approaches that will populate the metaverse: first-party content, developer content, and user-generated or creator content. Brands are also likely to become creators and participate probably in a very different way from traditional advertising models. Obviously, in this way it is possible to define such industries as gaming or education which will determine the growth of Metaverse and, at the same time, benefit from the advancement of this technology. In turn, it is also possible to identify solutions for the improvement of business processes in other industries which will use Metaverse as a platform supporting their business activity or a place where their customers will be active. From this perspective, the following areas of application can be named:

- **E-commerce**: It creates an ecosystem for sales real and virtual goods and/or services. Table 1 presents the most popular examples product or services based on the extensive survey. It is well worth to distinguished two important dimension of Metaverse e-commerce:

  - **Virtual product trading:** in the context of Web3 it might be considered using of trading platforms for cryptocurrencies and in some cases NFTs, such as OpenSea.
  - **Virtual goods interoperability:** potential great opportunity of metaverse commerce might be an interoperability: users' feasibility to carry their possessions across different virtual worlds. Users can move around numerous virtual worlds to gain different immersive experiences as they desire.
- **Digital twins**: Digital representation of an intended or actual real-world objects that serves as the effectively indistinguishable digital counterpart of it for practical purposes. It might applied for:
  - **Human being:** Digital avatar related to specific person, which might be controlled remotely in the real time. For instance during participation in online meetings. It will be also possible to operate by a such avatar autonomously and being involved in interactions with others using large language models like for instance ChatGPT (Nvidia, 2023).
  - **Physical items**: Such as BMW's effort to build a digital factory twin on Nvidia Omniverse (Caulfield, 2021) which is expected to drive efficiency improvements across its supply chain. By building virtual replicas of physical settings and objects that generate data in real-time, far richer analyses can be generated than previously to enable improved decision making.
- **Remote work and collaboration**: In order to supplement the sense of space lacking in online solutions in B2B solutions and conferences, some companies introduced and supplemented the offline concept. In this way, the sound occurring in the office and physical elements (e.g., desks and conference rooms) is given a sense of space (Park, Kim, 2022). This potential due to an incremental improvement from 2-D screens to an immersive 3-D space as online meetings in the metaverse further enable remote work and potentially diminish the need for co-locating.
- **Learning and development**: Simulations of real-life settings and situations will allow for a far more captivating learning process, opening possibilities both in onboarding new colleagues and developing current personnel, which is increasingly important for organizations competing for talent on a global scale.
- **Product marketing**: Coca-Cola launched digital assets to support several marketing campaigns, such as auctioning NFT collectibles for International Friendship Day (Coca-Cola, 2023).
- **Customer engagement**: Gucci launched its Gucci Garden on Roblox, a set of brand-themed rooms that aligned with the launch of a similar physical space (McDowell, 2021).

- **Customer service**: Helpshift is rolling out solutions for customer-support tools in the metaverse, including user feedback, virtual identity verification, and VR support (Helpshift, 2023).
- **Recruiting**: The Havas Group launched a village within The Sandbox that hosts recruitment services for improved candidate and onboarding experiences (Gessa, Moriconi, 2022).
- **Simulation**: Actually the Metaverse might be applied as a simulation tool to predict the future business models. Based on that companies might see their differences from offline world and other social media and then utilize properly their potential (Kaplan, Haenlein, 2009).

Table 1.
Products/services bought in the Metaverse

Product/Service	Contribution [%]
In-game purchases	47
Virtual cosmetic items	37
Real-word items	33
Nonfungible Token	20
Virtual real estate	13
Others	21

Those results are based on survey with an answer for the question: "When you are participating in activities in the metaverse, have you purchased any of the following products/services in past 12 months?". Number of participants = 2,093.

Source: Intelli Metaverse Consumer Survey in Europe, the Middle East, and Asia (EMEA) and Asia–Pacic (APAC), Remesh Next Gen Consumer, Metaverse Survey in United States, 2021.

3.2. Finance industry as an example

In order to provide more detailed description let us focus on financial services as a representative example. First real live applications are as follows (McKinsey, 2022, p. 45):

- employee training, for example, Bank of America VR training (Bank of America, 2021),
- creating virtual "financial towns," telecommuting centers, and interaction spaces such as South Korea's KB Kookmin Bank (Zelealem, 2021),
- offering virtual investment advisory services (Park, 2022).

There is no shortage of financial services companies exploring the utility of the latest evolution of the metaverse. As its function transitions from primarily consumer entertainment to more commercial applications—and from niche social interactions to become a social network—the opportunities for the sector will only expand, including the following examples (McKinsey, 2022, p. 45):

- **Marketing**: Institutions may create digital branches in the metaverse to build their brand and credibility with users, demonstrate their ability to innovate, and even offer client interactions in a hybrid way with more traditional digital or even physical channels.

- **Infrastructure**: Financial institutions, especially more traditional ones, are uniquely positioned to bridge the trust gap that has traditionally held back wider adoption of services such as digital IDs, digital payments, or custody for NFTs, cryptocurrencies, or other digital assets.
- **Emerging products and services**: As cyber insurance for companies and similar services become more commonplace, insurers and cybersecurity companies are well positioned to capture parts of this emerging value pool, maybe even in novel collaboration and models.

As the metaverse potentially captures a larger share of day-to-day human interactions, digital versions of more sophisticated banking services could emerge to serve these users. Examples could include:

- Embedded bank-like services for wallet owners in native metaverse venues, such as multicurrency cash management.
- Back-end servicing for financial services, like virtual real-estate mortgage origination and warehousing.
- Funds and investing services for metaverse projects, such as metaverse-specific investment funds.
- Customer engagement enhancements, like gamified credit education and unique loyalty experiences.
- Financialization of everything, as more digital assets get created with utility in a metaverse context, such as being employed as collateral for loans

Growth in these use cases will depend on the extent to which the metaverse is adopted. And the value and convenience of financial services in the metaverse must exceed the current utility of online or bricks- and-mortar servicing. If engagement in the metaverse gains momentum, more and more financial service companies will need to decide between investing and entering at scale, establishing a minimal position, or doing nothing for now.

4. Technical Problems and Threads

4.1. Technical Issues

Overall, a technological dimension and an ecosystem can be distinguished in Metaverse. The technological dimension chiefly pertains to underpinning technologies: hardware, network, cloud, and edge computing, as well as application technologies, i.e., computer vision, artificial intelligence, IoT, etc. The ecosystem is made up of such phenomena as avatar concept, virtual economy, content creation, social acceptability, trust, security and privacy. Figure 1 comprehensively illustrates both dimensions of Metaverse. This subchapter focuses on

technology-related problems, whereas the next subchapter addresses the threats and risks within the ecosystem.

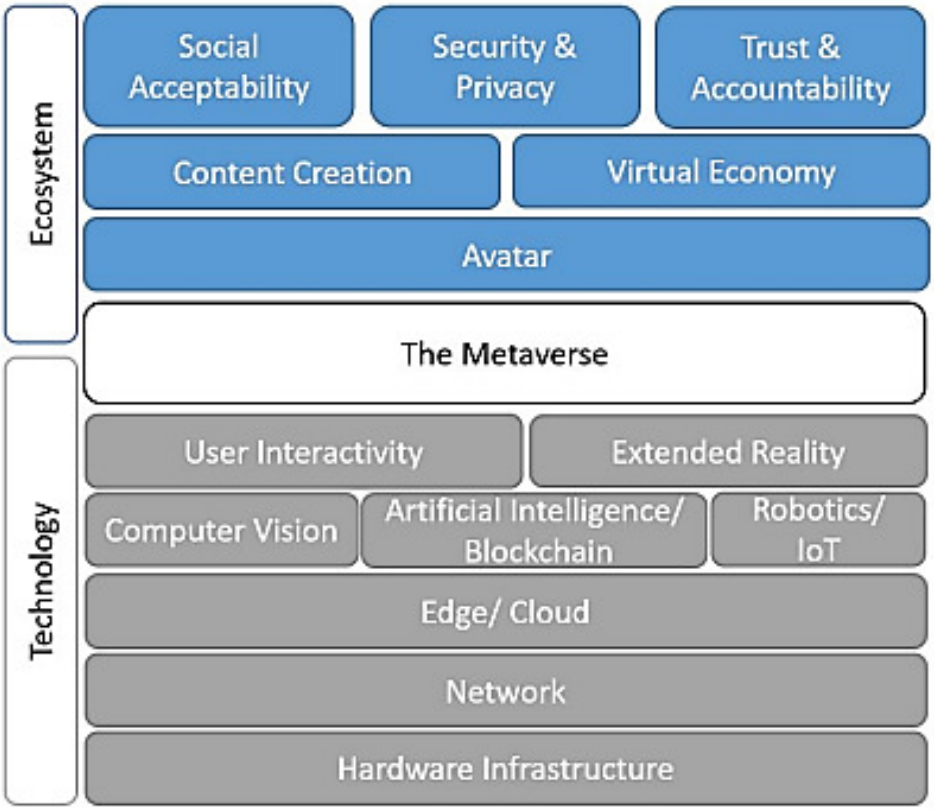

Figure 1. Technology and ecosystem of the Metaverse.

Source: Lee et al., 2021.

The fundamental technical threats and problems in Metaverse development are (McKinsey, 2022; Lee et al., 2021):

- **Hardware infrastructure**. Limits of concurrency today cap the few number of users. In a fully realized metaverse, many more users will need to be able to be online at once. In addition, low-quality rendering devices without graphics processing units (such as smartphones) cannot present the photorealistic environments required to drive immersion. Metaverse environments need to deliver real-time 3-D experiences at scale to millions of individuals.
- **Network throughput**. The metaverse will require massive amounts of bandwidth to transmit very high resolution content in real-time. Many interactive applications consider the motion-to-photon latency, that is the delay between an action by the user and its impact on-screen (Zhao et al., 2017), as one of the primary drivers of user experience. The throughput needs of future multimedia applications are increasing exponentially. The increased capabilities of 5G have opened the door to a multitude of applications relying on the real-time transmission of large amounts of data (AR/VR, cloud gaming, connected vehicles).

- **Network latency**. The most crucial issue is a high-latency "lagging" creates a sensation of video and/or audio being slow when using applications that require a high rate of frames-per-second. Latency is generally seen as the hard problem in delivering these immersive and interactive experiences. Additionally, these experiences will require computational efficiency to improve by two to three orders of magnitude, along with innovation across devices, edge computing, and cloud capabilities. As such, reducing latency is critical for the metaverse, especially in scenarios where real-time data processing is demanded, e.g., real-time AR interaction with the physical world such as AR surgeries (Rhienmora et al., 2010).
- **Interface interactivity devices**. Metaverse access today is primarily through flat screens: televisions, computers (PCs and laptops), and smartphones. But the real challenge is with transitioning to AR/VR and eventually extended reality (XR), and this is exactly the Meta Inc. approach based on the Oculus Quest which is a virtual reality headset (Meta Quest, 2023).

4.2. Ethical Threads

The envisaged development of Metaverse implies a number of ethical related issues. The simulation of a virtual world in real time will most likely completely delude the users into being inside a physical world, with them losing the ability to perceive actually crossing the demarcation line with the physical world. This could mean numerous addictions on a scale only comparable to drug use. Such a pathology can lead to entire societies ending up enslaved. It is an area which largely goes beyond the thrust of this paper; therefore, the focus is on three issues that have already been well examined and have a solid foundation in the research literature:

- Privacy and security are critical issues because Metaverse collects data on behavior that is more detailed than user conversations and internet history. In addition, surveillance actions (e.g., inappropriate chat room surveillance, censorship, and follow-up review) due to the surge in users suggest that organizations that play the same role as police and government are needed in the real world (Park, Kim, 2022). Researchers have already provided their insights on the economics of privacy (Acquisti et al., 2016), and the design for an efficient market for privacy trading (Pal et al., 2020).
- Excessive use with digital environments (i.e., user addictions) would be an important issue when the metaverse becomes the most prevalent venue for people to spend their time in the virtual worlds. In the worst scenario, users may leverage the metaverse to help them 'escaping' from the real world, i.e., escapism (Holsapple, Wu, 2007). Prior works have found shreds of evidence of addictions to various virtual cyberspaces or digital platforms such as smartphones (Lanette et al., 2018), VR (Rajan et al., 2018), AR (Ertel et al., 2017), and so on. User addictions to cyberspaces could lead to psychological issues and mental disorders, such as depression, loneliness, as well as user aggression (Jeong et al., 2015).

- Cyberbullying refers to the misbehaviors such as sending, posting, or sharing negative, harmful, false, or malevolent content about victims in cyberspaces, which frequently occurs on social networks (Chatzakou et al., 2019). We also view the metaverse as gigantic cyberspace. As such, another unignorable social threat to the ecosystem could be cyberbullying in the metaverse. Moreover, considering the huge numbers of virtual worlds, the metaverse would utilize cyberbullying detection approaches are driven by algorithms (Yan et al., 2021).

5. Final conclusions

This paper discusses the phenomenon of Metaverse from the perspective of company strategic analysis. It should be stressed that abandoning the platform is also a strategic decision. It seems that most companies will be closely following the development of Metaverse and making decisions to join it depending on how it grows and whether their customers show interest for it. It is a reasonable approach given the immense technological problems and high costs, of both maintaining Metaverse, as well as being within it. It should be noted that the economy of developing such platforms bears on the already mentioned network effects. Direct network effects arise when a given user's utility increases with the number of other users of the same technology. Finally a limited number of multiple equilibria or a market monopoly are two key potential outcomes in markets that exhibit network effects. What will actually happened will be clear in the nearest decade.

It is worth emphasizing the great significance this technology will have for the society, the economy and the environment. In this context, the ethical dimension and the legal environment are crucial. It follows that it is necessary to professionally examine the technology – not only in the traditional sense, as an early warning system for risk and threats, but also as an interdisciplinary diagnosis of opportunities and potential of new technologies based on the participation approach (Stankiewicz, 2010). What arises is a natural problem of constructing a proper economic and legal ecosystem which was formulated by David Collingridge (1980)[2].

Thus, the scale of challenges associated with a potential development of Metaverse is enormous. We are convinced that the impact on human psyche, behaviors and the development of societies will be far more important that the business context discussed in this paper.

[2] The Collingridge dilemma is a methodological quandary in which efforts to influence or control the further development of technology face two problems. Firstly an information problem: impacts cannot be easily predicted until the technology is extensively developed and widely used. Secondly a power problem: control or change is difficult when the technology has become entrenched.

References

1. Acquisti, A., Taylor, C., Wagman, L. (2016). The economics of privacy. *Journal of economic Literature*, *Vol. 54, Iss. 2,* pp. 442-92.
2. Bank of America is First in Industry to Launch Virtual Reality Training Program in Nearly 4,300 Financial Centers, Bank of America (2021).
3. Caulfield, B. (2021). *NVIDIA, BMW blend reality, virtual worlds to demonstrate factory of the future*. NVIDIA, April 13.
4. Chatzakou, D., Leontiadis, I., Blackburn, J., Cristofaro, E., Stringhini, G., Vakali, A., Kourtellis, N. (2019). Detecting cyberbullying and cyberaggression in social media. *ACM Trans. Web*, *Vol. 13, Iss. 3, No. 17*, pp. 1-51.
5. Christensen, E., Roland, C., Kenneth, R. (1965). *Business policy: text and cases*. Homewood, Illinois: Richard D. Irwin, Inc.
6. Cline, E. (2011). *Ready Player One*. Crown Publishing.
7. *Coca-Cola to offer First-Ever NFT Collectibles*. Retrieved from: https://www.coca-colacompany.com/news/coca-cola-to-offer-first-ever-nft-collectibles, 9.03.2023.
8. Collingridge, D. (1980). *The Social Control of Technology*. New York: St. Martin's Press, London: Pinter.
9. Dionisio, J., Burns, W., Gilbert, R. (2013). 3D Virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys*, *Vol. 45, Iss. 3, No. 34,* pp. 1-38.
10. *Enter the metaverse: the digital future Mark Zuckerberg is steering us toward*. Retrieved from: https://www.theguardian.com/technology/2021/oct/28/facebook-mark-zuckerberg-meta-metaverse, 9.03.2023
11. Ertel, R., Karakas, O., Dogru, Y. (2017). A qualitative research on the supportive components of pokemon go addiction. *AJIT-e: Online Academic Journal of Information Technology*, *8*, pp. 271-289.
12. Gessa, L., Moriconi, P. (2022). *HAVAS Group opens its first virtual village in the metaverse*. HAVAS Group, February 17.
13. *Google Search*. Retrieved from: https://scholar.google.com/scholar?q=metaverse&hl=en&as_sdt=0%2C5&as_rr=1&as_ylo=2021&as_yhi=2023, 9.03.2023.
14. *Helpshift Wants to Bring Customer Support to the Metaverse.* Retrieved from: https://www.cmswire.com/customer-experience/helpshift-wants-to-bring-customer-support-to-the-metaverse/, 9.03.2023.
15. Holsapple, C., Wu, J. (2007). User acceptance of virtual worlds: The hedonic framework. *ACM SIGMIS Database*, *Vol. 38, Iss. 4, No. 34*, pp. 86-89.
16. Jeong, E., Kim, D., Lee, D. (2015). *Game addiction from psychosocial health perspective*. Proceedings of the 17th International Conference on Electronic Commerce 2015, ICEC ’15. Association for Computing Machinery.

17. Kaplan, M., Haenlein, M. (2009). The fairyland of second life: Virtual social worlds and how to use them. *Bus. Horizons*, *Vol. 52, No. 6*, pp. 563-572.
18. Kaplan, R., Norton, D. (2008). *The execution premium: linking strategy to operations for competitive advantage*. Boston: Harvard Business Press.
19. Lanette, S., Chua, P., Hayes, G., Mazmanian, M. (2018). *How much is 'too much'? the role of a smartphone addiction narrative in individuals' experience of use*. Proc. ACM Human -Computer Interactions, 2(CSCW).
20. Lee, L., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., Hui, P. (2021). All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda. *Journal Of Latex Class Files, Vol. 14, No. 8*. Retrieved from: arXiv:2110.05352v3, 03/01/2023.
21. Marzolla, M., Ferretti, S., D'Angelo, G (2012). Dynamic resource provisioning for cloud-based gaming infrastructures. *Computers in Entertainment*, *Vol. 10, Iss. 1, No. 4*, pp. 1-20.
22. McDowell, M. (2021). Inside Roblox's metaverse opportunity. *Vogue Business, May 17.*
23. McKinsey (2022) *Value creation in the metaverse*. McKinsey & Company. Retrieved from: https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse, 2.02/2023.
24. *Meta Quest*. Retrieved from: https://www.meta.com/pl/en/quest/, 9.03.2023.
25. Milgram, P., Takemura, H., Utsumi, A., Kishino, F. (1995). Augmented reality: a class of displays on the reality-virtuality continuum. In: H. Das (ed.), *Telemanipulator and Telepresence Technologies, Vol. 2351* (pp. 282-292).
26. *Nvidia's Avatar Creation Tool Follows Footsteps of ChatGPT and DALL-E 2*. Retrieved from: https://www.enterpriseai.news/2023/01/03/nvidias-avatar-creation-tool-follows-footsteps-of-chatgpt-and-dall-e-2/, 9.03.2023.
27. Pal, R., Crowcroft, J., Wang, Y., Li, Y., De, S., Tarkoma, S., Liu, M., Nag, B., Kumar, Hui, P. (2020). Preference-based privacy markets. *IEEE Access*, *Vol. 8*, pp.146006-146026.
28. Park, A. (2022). Metaverse' becomes new growth engine of financial industry. *Korea Times, June 1*.
29. Park, S., Kim, Y. (2022). A Metaverse: Taxonomy, Components, Applications, and Open Challenges. *IEEE Access*, *Vol. 10*, pp. 4209-4251.
30. Rajan, A., Nassiri, N., Akre, V., Ravikumar, R., Nabeel, A., Buti, M., Salah, F. (2018). *Virtual reality gaming addiction*. 2018 Fifth HCT Information Technology Trends (ITT), pp. 358-363.
31. Rhienmora, P., Gajananan, K., Haddawy, P., Dailey, M., Suebnukarn, S. (2010). *Augmented reality haptics system for dental surgical skills training*. Proceedings of the 17th ACM Symposium on Virtual Reality Software and Technology, pp. 97- 98.
32. Stankiewicz, P. (2010). Teoria i praktyka oceny technologii. *INFOS. Zagadnienia Społeczno-gospodarcze, Vol. 22, Iss. 92,* pp. 1-4.
33. Stephenson, N. (1992). *Snow Crash*. Bantam Books.

34. Terrace, J., Cheslack-Postava, E., Philip Levis, P., Freedman, M. (2012). *Unsupervised Conversion of 3D Models for Interactive Metaverses*. IEEE International Conference on Multimedia and Expo, pp 902-907.
35. Vernaza, A., Armuelles, V., Ruiz, J. (2012*). Towards to an open and interoperable virtual learning enviroment using Metaverse at University of Panama*. Proceedings of the Technologies Applied to Electronics Teaching (TAEE), pp. 320-325.
36. Yan, R., Li, Y., Li, D., Wang, Y., Zhu, Y., Wu, W. (2021). A stochastic algorithm based on reverse sampling technique to fight against the cyberbullying. *ACM Trans. Knowl. Discov. Data, Vol. 15, No. 4, No. 71.*
37. Young, M., Rieser, J., Bodenheimer, B. (2015) *Dyadic interactions with avatars in immersive virtual environments: high fiving*. Proceedings of the ACM SIGGRAPH Symposium on Applied Perception, SAP ’15, Association for Computing Machinery, pp. 119-126.
38. Zelealem, F. (2021). *South Korea’s KB Bank enters metaverse space*. Yahoo, November 30.
39. Zhao, J., Allison, R., Vinnikov, M., Jennings, S. (2017). *Estimating the motion-to-photon latency in head mounted displays*. 2017 IEEE Virtual Reality (VR) Conference, pp. 313-314.
40. Zoshak, J., Dew, K. (2021). *Beyond Kant and Bentham: How Ethical Theories Are Being Used in Artificial Moral Agents*. CHI '21: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, Association for Computing Machinery, No. 590, pp. 1-15.

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MANAGING SELECTED AREAS OF PREPARATION MILITARY PERSONNEL FOR THEIR ASSIGNED ROLES IN THE STATE

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Purpose: The main objective of the research presented in this paper is to identify the research gap in the management of the process of competence preparation of soldiers in the context of their social roles and expectations of citizens. To achieve this goal, the first part of the paper explains the concepts of professional training and activities that shape a professional serviceman. The second part of the paper is devoted to social competence vs. emotional intelligence in the management of military personnel. The third part analyzes the results of a study of the extent to which military personnel fulfill the roles assigned to this formation in society.
Design/methodology/approach: The research presented in this study is based on the analysis of the literature and critical review of selected areas of professional preparation of military personnel. The literature study also took into account secondary sources, which were research communications in the subject area. Using methods of logical deduction and inference, conclusions and recommendations were derived, which are presented in the final part of the article. The combination of different research methods made it possible to obtain a broader context of the phenomenon under study and ensured a higher quality of the research conducted. Personal experience regarding the training of military personnel was also used, as the author is professionally involved in the academic training of military personnel, as discussed in this paper.
Findings: The dynamics and high level of complexity in the modern world of VUCA, moreover the expectations of societies force the continuous improvement of the process of competence preparation of military personnel. Studies indicate that the profession of a soldier is oriented towards fulfilling the basic needs of the other which are the needs for security and protection of private property and more broadly of society as a whole. In the research, those interviewed presented that they feel a moral responsibility to fulfill their role primarily to society and their own conscience. This is confirmed by the awareness of military personnel as to their choice of vocation in their professional life and service, as well as the properly conducted process of professional development of cadres and the correct direction of competence development. However, in areas such as the opinions of subordinates, one can find opinions suggesting demonstrated deficiencies in social behavior, especially in superiors, which should be monitored in professional development and supplemented as necessary.
Research limitations/implications: Continuous changes in the sphere of security, customs, trends and in the structure of societies result in the emergence of new expectations and needs addressed to military personnel. This is a contribution to continuing research on the directions

of development in the field of competence development in a dynamically changing environment.
Practical implications: The recommendations developed on the basis of the research is the identified need to develop professional competence in the emotional intelligence (competence) of military personnel, especially in the cognitive and social aspects, ensuring the adaptation of soldiers to function under threat conditions. This should result in the expansion of the periodic evaluation questionnaires, to which soldiers are subjected, with indicators and measures relating to the individual assessment of competence preparation in relation to social and emotional competence, and the preparation of a program to improve the diagnosed shortcomings in this area.
Originality/value: Based on the conducted research, the article proposes original system solutions for managing the competence development of military personnel in their roles in society.

Keywords: human factor, military personnel.

Category of the paper: Research paper.

1. Introduction

The dynamic changes taking place in the world and situation in Poland's surroundings enforces the need to maintain adequately prepared national armed forces, capable of performing the tasks of guaranteeing the inviolability of the borders and the independence of the Polish nation, entering the area of threats of a military as well as non-military nature. Poland's active involvement in shaping security also determines the readiness to participate in multifaceted and multidimensional operations conducted in diverse operating environments. The developing process of reconstruction of the European and global security architecture implies the need for new forms of management of military personnel training.

To meet the need for security, this aspect is fulfilled by specialized state services, also known as state services. They were created to operate internal and external security systems, the national rescue system or the border traffic control system. They are tasked with preventing disasters, responding during threats caused by accidents and natural disasters, defending the sovereignty and independence of borders. The development of state services should be adequate to the needs and requirements of the environment of which the social system is composed. This is because these groups, in their essence, serve society in principle. In order for the effectiveness of the activities undertaken by various types of state services to be high, it is important for them to cooperate closely and relentlessly with local authorities and citizens. This is because it is important to communicate on both sides, to recognize the threats and needs of citizens, to work together and to be responsible for them. If the sense of security is low, automatically the trust of citizens in the state and public authority decreases, which also affects attitudes towards the law, citizens' duties, electoral decisions, self-organization of society. So the public interest is mutual in this case.

The state also has other formations for the defense of the public. They also protect against espionage, sabotage, damage or theft. Every person expects help, support and intervention from other people, institutions and groups in an emergency situation. In order to help effectively, the dispatch groups should have the required equipment, armaments and logistical facilities. It is also important that the dispatch groups interact with each other. Coordination of activities at the national or provincial level plays a key role in the effectiveness and efficiency of their operations. The issue of disposition groups was developed relatively recently, and their division was described and systematized. State services are such composite social structures, the disposition of which we can talk about in a narrow sense due to their specialized and specific nature of activities in a well-defined range.

The army is one of those groups with an important role in the organization of the state. Its originality is supported by the peculiar combination and significant intensification of certain features. It constitutes an organization:

- with the predominance of formal ties over personal ties,
- bureaucratic institution with a hierarchical structure,
- social environment with its own system of stratification,
- set of specific norms and traditions,
- group of purposeful action established to meet specific needs.

The main purpose of this publication is to identify the research gap in the management of the process of competence preparation of soldiers in the context of their social roles and expectations of citizens. Against this background, on the basis of literature studies and available research, as well as logical deduction and inference, conclusions and recommendations are brought out, which are presented in the final part of the article. This knowledge should contribute to complementing the theory in the field of security management functions at the level of preparation of specialized personnel, and in practical terms make recommendations on the directions of changes in the process of military personnel management at the stage of formation of professional competence.

2. Professional training of military personnel - conceptual issues.

As the researchers note, *the profession of soldier requires specific knowledge, specific skills and appropriate personality predispositions. The more important the function in the armed forces, the greater the knowledge and skills must be* (Szulc, Mazurek, 2011). In its conceptual area, professional preparation includes such elements as the educational process, which is, for example, the basis for the implementation of the studies of professional soldiers in a military academy, and the process of upbringing, which is, so to speak, complementary to the former. However, its role in the area of shaping the personal profile of a future officer is not at all less.

According to Kupisiewicz, *the process of education simultaneously includes all conscious, planned and systematic didactic and educational influences on students, providing them with general and professional education* (Kupisiewicz, 2000). However Okoń, on the other hand, defines the process of upbringing as *a system of activities of educators and educators that enable the pupils to change in the desired direction, and thus shape and transform feelings, beliefs and social, moral, aesthetic attitudes, the formation of will and character, and the comprehensive development of personality* (Okoń, 1984). It is also necessary at this point to define the term education, which this researcher describes as *not only conscious interactions aimed at ensuring that someone (or oneself) acquires a certain system of knowledge, skills and habits, but also at forming a view of the world and developing cognitive abilities and interests* (Okoń, 1984). In terms of the research problems under consideration, it seems necessary to clarify the concepts of vocational training and professional qualifications. Vocational training is described in the literature as *the specialized preparation of people, properly educated in general, for their chosen profession, which is carried out by higher, lower and secondary vocational schools, as well as (...) vocational courses organized and conducted also outside education by workplaces* (Huzarski, Wołejszo, 2014).

Continuing with considerations in the area of professional preparation of personnel, professional qualifications are *closely related to professional standing and result from formal recognition of professional knowledge and skills* (Huzarski, Wołejszo, 2014). Thus, one of the primary tasks of schools and vocational courses is to equip future graduates with the appropriate professional skills necessary for their professions. Phrases such as student, teacher, formation or personality indicate that the terms cited refer to classic concepts in the field of pedagogy in the broadest sense, as well as to its individual divisions, such as didactics - including military didactics and college didactics. Pedagogy (*paidagogikė*) is *the science of upbringing, the subject of which is educational activity aimed at equipping the whole society - and especially the young generation - with knowledge, general and professional skills, interests, value systems attitudes and beliefs, as well as preparing them to influence their own development* (Okoń, 2007). In the conceptual area, we can distinguish between general pedagogy and specific pedagogies, among which is military pedagogy. As a sub-discipline, it emerged from general pedagogy in the second half of the 20th century and is the result of the need to improve the functioning of the military as a social institution, to professionalize it and deepen its ties with society. This is because the defense of any state is based on its economic strength, military potential and the patriotic consciousness of a society ready to defend its sovereignty, independence and territorial integrity. One of the factors that determines the efficient, effective and in accordance with the traditions of a given nation, the functioning of the military as a state defense force is military, patriotic and civic education. The emergence of military pedagogy is therefore associated with *the need to form such views of the military and such attitudes towards this institution that reflect an understanding of its enormous social role as an agent of defense against aggression and territorial expansion of adversaries (enemies)*

and as a guarantor of preserving the independence of the state (Okoń, 2007). On another hand, the "Leksykon obronności" defines military pedagogy as *a branch of general pedagogy dealing with education, training and formation of personality (upbringing) of all soldiers, treating of the goals, contents, forms, methods and the didactic and educational process in the military environment* (Huzarski, Wołejszo, 2014). The objects of study of military pedagogy are the goals, content, methods, forms, systems and organization of the process of military education and training, describes the goals of upbringing from the point of view of their suitability for the realization of those values that, in the minds of young people, strengthen the role and importance of the military as an institution for the defense of the nation's rights to independence and freedom.

The term didactics comes from Greek, in which *didakticos* meant "instructing" and *didasko* meant "I learn". The evolution of the term throughout history has led to the present state, where didactics is treated as a science of teaching and learning, and therefore as a system of correctly substantiated theorems and hypotheses about the process, dependencies and regularities of teaching-learning and the ways in which humans shape this process (Kupisiewicz, 2000). Overall didactics deals with the analysis of all learning and teaching, organized in a conscious, systematic and planned manner, in other words, the analysis of all activities that make up the learning and teaching process. In addition to general didactics, there are also specific didactics. Among them can be identified defense didactics and military didactics. Defense didactics focuses on *the teaching and learning of defense knowledge and skills in various spheres of the defense system and the state security system* (Huzarski, Wołejszo, 2014). Military didactics, on the other hand, deals with *the processes of individual and team education (teaching and learning) in the military. It is part of defense didactics* (Huzarski, Wołejszo, 2014).

The specificity of education and training in the military is determined by its peculiar organization, consisting of a complete regulation of the service life of soldiers. In military training should take into account the relationship and interrelationships with other sciences, especially with general didactics, war science and war doctrinal assumptions, determining the characteristics of military training and defining its scope. The subject of military didactics includes the principles of determining the objectives, the criteria for selecting the content of education and training, the organization of the didactic and training and educational process in military institutions and the principles of its implementation, as well as all varieties of forms and methods of teaching and learning.

Shaping the silhouette of a soldier, in addition to education, also includes upbringing. Commonly described by educators in the literature as a conscious influence of the educator (teacher, commander) on the pupil (student) aimed at producing a certain change in his personality. These changes are to include both the cognitive and instrumental side. They are supposed to enable the alumni to change in the direction planned by the educators, transform the ways of perceiving the world, shape moral and aesthetic feelings, create certain social attitudes and beliefs, shape the personalities and characters of the alumni. In this area, the term

method of upbringing additionally appears, understood as *a consciously and systematically applied way of pedagogical influence, which makes it possible to achieve the intended educational goals* (Bieńkowski, Stępień, 2003). In the methodology of education, there are three groups of concepts: *personal influence, situational influence and environmental influence* (Stępień 2001).

An area that also remains in the author's sphere of interest, in relation to professional development of military personnel, is the management of the process of improving human resources, that is, the process of improving qualifications (professional competence) through various forms of education and self-education (Krakowski, Leśniewski, Wiśniewski, 2011). Competence management means a practical activity, oriented towards achieving the set goals of the organization. It must be conducted rationally, using the rules of economics, effort and ethics (Moczydłowska, 2008). Personnel management is a way of conducting the organization's personnel policy, where the concept of competence becomes the main link between activities in the field of recruitment, selection, career path, employee evaluation, training or motivation systems. It should be conducted in a rational method. Competence management is a set of activities leading to an increase in the value of human capital and the effectiveness of an organization. Mastering management is not easy, as it requires a certain interdisciplinary knowledge, the necessary information resources and good communication within the organization.

The professional training gained will become outdated as the environment changes and as a result of work demands, technology change and the introduction of new procedures or processes. Accordingly, professional development has become a necessary and permanent process, which applies to both organized forms of education and training and self-education, which should be understood as a didactic process carried out independently with and without the assistance of others (Kuźma, 2003). A special place in the system of managing the competencies and qualifications of Polish soldiers is occupied by personnel development, and in this case, an organized and formalized system of professional development for officers and non-commissioned officers.

3. Professional (social) competence versus emotional intelligence (competence) in management of military personnel

Another conceptual aspect that is important in the process of managing the military personnel improvement system is social behavior, otherwise seen as social competence and related emotional intelligence. From the point of view of considerations of the effectiveness of human functioning in society, the most useful seems to be the definition, which by social-emotional competence understands *the complex skills that determine the effectiveness of*

emotional regulation and coping with various types of social situations (Matczak, 2007). This definition indicates that it is not possible to speak of one general social competence, but of many types of them. Among them should be mentioned, among others:

- social perception skills (accurately perceiving others, such as their experiences or intentions, and understanding and correctly assessing social situations),
- social sensitivity,
- empathy and interpersonal decentering,
- knowledge of social rules and the ability to behave appropriately in social situations,
- ability to solve specific interpersonal problems and control social situations,
- skills conditioning to deal with conflict situations and requiring assertiveness,
- effective self-presentation and ability to influence others,
- communication skills,
- cooperative skills.

Social competence can also be understood as *the ability, possession of the necessary skills to have the desired impact on other people in social situations* (Argyle, 1999). In this understanding, they are a conglomeration of many factors relating to an individual's functioning in the cognitive, motivational-emotional and behavioral dimensions. Social competence can also be defined as processes that include:

- perception/understanding of the social situation,
- the method of behavior and the accompanying feelings,
- sympathies or antipathies.

In addition, they are reflected in human functioning through cognitive, emotional-motivational and social aspects (Szołtysek, Jeż, Twaróg, 2015). Some see their essence in the interaction of elementary abilities used in specific types of situations, while others describe them as a general ability revealed in many different situations (Jakubowska, 1996). Thus, they are described as specific, context-dependent skills manifested in behavior (Biermann, Welsh, 2001), or as the individual's gaining, in the course of social training, of complex skills that determine the effectiveness of coping with certain types of social situations.

Social competence, moreover, can be considered in terms of static and dynamic. The former assumes that the skills that make up social competence are behaviors aimed at establishing, maintaining and ending interpersonal relationships. The dynamic approach, on the other hand, describes them as purposeful behaviors, adapted to the situation, learned and controlled by the individual (Spitzberg, Cupach, 2002). It should be noted, however, that the need for a holistic view of the nature of competencies is now increasingly emphasized. Such a view of them indicates that they are the result of the totality of experiences acquired by the individual in the process of socialization, and are developed in both formal and informal education systems (Karl-Heinz, Lindner-Müller, 2012). Thanks to high social competence, individuals find their way better and function more effectively in a wide variety of social situations (Martowska,

2012). Thus, social competence is a key component of life and professional skills, necessary for proper functioning in today's dynamic world, which should be possessed by every person, functioning both socially and professionally.

Emotional intelligence is one of those determinants that plays an important role in the life of an individual, influences the correct management of one's own emotions and dealing with the emotions of others, builds social relationships, and supports human cognitive development. The turmoil that the world and whole societies have encountered, as well as the new challenges and relationships between workers, especially the provision in many areas of remote work, dictate that special attention be paid to the issue of emotional and social competence, the ability to communicate and cope with work in an isolated, one-person environment. Researchers are increasingly focusing their attention on verifying the importance of emotional intelligence and its impact on efficiency in professional work. Reviewing the research in this area, it can be concluded that a certain level of emotional intelligence in the main has a positive impact on a person's functioning in professional life.

A person begins to accumulate the skills that make up emotional intelligence through the process of primary socialization, of particular importance is the proper course of these relationships in the primary social cell. As such, the family helps one learn to correctly recognize and name one's own feelings and emotions and to skillfully use them in social life (Goleman, 2007). However, the family does not always provide opportunities for an individual to develop correctly. In companies, organizations and even schools, various workshops, trainings and courses are organized with the aim of shaping and developing the competencies that make up emotional intelligence, thus teaching how to maintain correct interpersonal relations, effective action aimed at achieving success (Matczak, Knopp, 2013). According to Goleman, emotional intelligence plays a crucial role in achieving outstanding results in professional work, almost in every position and profession, outstanding performance depends on emotional intelligence.

The mentioned researchers point out two positive aspects of emotional intelligence that promote human functioning in a professional environment:

a) the cognitive aspect, which enables efficient processing of information affecting thinking processes, which also support creativity and ingenuity,
b) the social aspect, ensuring adaptation to functioning in difficult social conditions.

A measurable skill derived from emotional intelligence is emotional competence, broadening, as it were, the discussion of job or professional competence. As Goleman writes, the skills included in emotional competence contribute to professional success. These include the following five components:

- self-awareness – knowledge of one's own internal states, preferences, abilities and intuitive judgments, realistic assessment of one's own abilities and justified belief in one's own capabilities,
- self-regulation – control over one's own internal states, impulses, abilities,

- motivation – emotional inclinations that lead to new goals or facilitate their achievement,
- empathy – becoming aware of the feelings, needs and anxieties of others, the ability to see things from the other person's point of view,
- social skills – arousing desired reactions in others and the ability to control one's own emotions in interpersonal interactions (Goleman, 1999).

The result of researchers' considerations has been various concepts defining models of social competence in close connection with a person's emotional intelligence. In the simplest approach, it can be assumed that social skills co-create together with emotional intelligence, broadly understood social competences.

In close conceptual range moves Greenspan, who proposed a model of social competence, adopting a three-factor structure that includes:

- temperament,
- character,
- social intelligence.

In this model, temperament is responsible for the activity level and dynamism of a person's behavior during life activities. It forms the basis of psychological and autonomous responses to impulses and social situations. It includes such elements as reflexivity/impulsivity and equilibrium/excitability (Pilecka, Pilecki, 1990).

Character, on the other hand, is defined as the basis of moral responses to stimuli and social situations. It is responsible for the ability to focus on various tasks and coping with stress. It includes such aspects as:

- social activity-passivity,
- pleasant-unpleasant personality disposition.

Social intelligence, in this view, allows one to understand the rules of behavior of other participants in life while performing tasks and to adjust one's own behavior to ensure maximum success in achieving the organization's goals. According to Greenspan, it is the ability of an individual to understand other people, the social events taking place and the processes that determine the direction of these events. The structure of the model of such competencies according to Greenspan is shown in Figure 1.

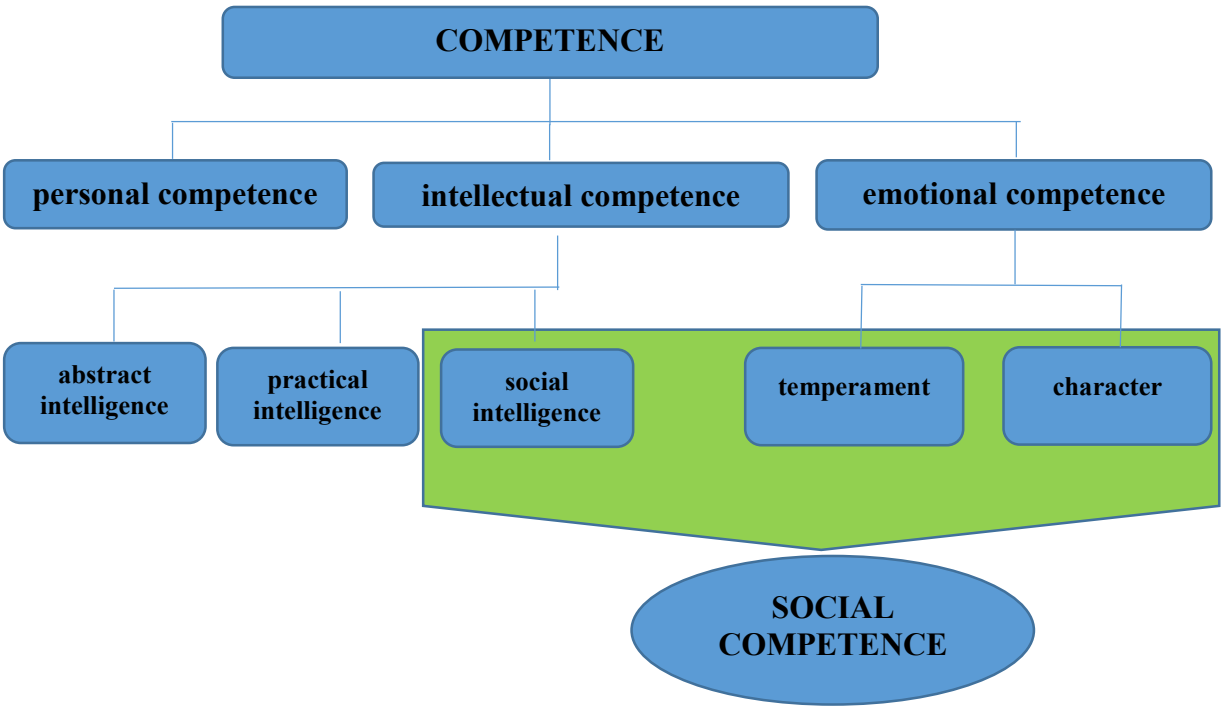

Figure 1. Model of social competence according to Greenspan.
Adapted from: Pilecka, W., Pilecki, J., 1990.

Available scientific research clearly indicates that emotional intelligence, the resulting skills and behaviors have a positive impact on a person's functioning at work. Referring to empirical studies of emotional intelligence, Matczak and Knopp write that people with higher emotional capabilities manage better in their professional lives and are more likely to succeed, are also more effective leaders, and perform better during job interviews (Matczak, Knopp, 2013). The results of the research between the relationship between the emotional intelligence of managers and the effectiveness of their work have shown that there is a relationship between emotional intelligence and the factors for increasing work effectiveness. Internal factors are directly related to the knowledge, competence of employees, their motivation to work while external factors are related to the organization, its structure and processes (Gofman, 1975). For example, soldiers with high emotional intelligence are those with high career ambitions, satisfied with their jobs, who have the skills to cope with setbacks at work, while soldiers with low emotional intelligence are more likely to develop burnout syndrome in their lives (Basińska, Jaskólska, Piórowski, 2007). In today's labor market, emotional intelligence is a key component of business management, especially when it comes to improving team effectiveness and team productivity. Also, numerous studies by consulting companies prove the value and importance of emotional intelligence, treating the skills and abilities constituting it as particularly desirable in the labor market. Employers expect from modern employees, first of all, interpersonal skills, teamwork skills and the ability to work under time pressure, motivation to work, self-organization. In today's global labor market, emotional competencies are

becoming an extremely valuable asset. Identifying and developing the individual competencies and abilities that make up emotional intelligence can bring many benefits to today's organizations and the employees who comprise them. By supporting the development of the emotional competence of employees, it becomes possible to maintain proper interpersonal relations between colleagues, achieve high work efficiency, shape the desired, on the job, behavior. Modern organizations are trying to develop their emotional intelligence. Emotional intelligence of an organization means such a way of managing the organization, in which the communication process and interpersonal relations contribute to its efficient and effective operation and problem solving. An organization's team emotional intelligence defines the extent to which it uses the intellectual capital of its employees. Goleman highlights that maximizing intellectual capital boils down to the proper formation of interactions between people who have expertise and professional skills. The four main skills included in team emotional intelligence are:

- self-awareness,
- managing the emotions of the group - involves the proper recognition and control of emotions so that they do not have a negative impact on the work of the entire team; the ability to manage emotions affects the effectiveness of the work of an organization,
- internal relationship management - means the ability of individual team members to interact with each other in difficult situations,
- external relationship management - is the ability of a group to work effectively within a larger organization (Bradberry, Greaves, 2006).

Professional knowledge demonstrates competitiveness, while it is the relationships between employees that allow an organization to succeed in the market. It seems interesting to ask to what extent does emotional intelligence affect an employee's career trajectory? The answer to this question can be found in large part in Bradberry and Greaves. The main conclusion is interesting - emotional intelligence (emotional quotient - EQ) is much more important for career success than rational intelligence (intelligence quotient - IQ). Indeed, the level of emotional intelligence is responsible for as much as 58% of performance in any profession. Of the people surveyed, 90% with good job performance also had high levels of EQ. The authors prove that there is also a close relationship between the level of emotional intelligence and the amount of income. Each point more on the EQ scale corresponds to an increase in annual income. In turn, people with high EQ earn more than those with low quotients of this type of intelligence (Bradberry, Greaves, Leoncioni, 2009). Relationships regarding emotional intelligence and income are found all over the world and regardless of the industry and level of the professional hierarchy.

For the purposes of the research process, the author reviewed the literature and available legislation referring to formalized processes for finding or assessing specific social and emotional competence in the management of personnel of the uniformed services. In military structures, this area is regulated by *Rozporządzenie Ministra Obrony Narodowej z dnia z dnia*

4 lipca 2022 r. w sprawie opiniowania służbowego żołnierzy zawodowych and specifies a number of criteria that form the basis for their evaluation. To a large extent, these are competence criteria, included in the universal requirements profile - applicable to all professional soldiers who meet the requirements specified in the regulation. The analysis and evaluation of the social competence of professional soldiers is subject to a common catalog for the army, based on precisely defined behavioral criteria. The catalog of competencies becomes a kind of "communication code" of the organization, which allows people from different areas of the organization to communicate effectively. It is important to take into account the diversity of profiles in different types of the Armed Forces and at different levels of command. It can refer to the content of competencies and their required level, globally, profiles allow to increase the efficiency of managing the development of subordinates. Taking into account the level of requirements in the profiles is possible in the situation of using "tailor-made" competency profiles, but the lack of a defined level of requirements usually results in the overestimation of assessments in the periodic evaluation. In the absence of a requirement level, the supervisor and the employee usually consider that the highest level of competence is the most preferred one and, as a result, try to "nudge" the evaluator's notes closest to the end of the scale. This raises the question of whether the highest level of competence is required to effectively perform the duties of the position. In the case of managerial profiles and the leadership competencies included in them, sometimes their standard (not highest) level is sufficient. Although already in the case of competencies common to specialized and managerial profiles, such as "communicativeness", usually higher requirements are placed on the supervisor than on the employee. It seems reasonable to implement officer profiles by the participatory method - with the participation of officers. The participatory method increases the acceptance of the requirements set, since it is the employees themselves who participate in their development, taking into account their experiences in carrying out their professional duties.

In the process of professional evaluation (in terms of social competence) carried out on the basis of the said regulation, each soldier is evaluated:

1. Performance of the appraised person in his official duties (in strictly defined areas).
2. Competencies and aptitudes of the appraised person - among others:
   - communication skills,
   - ability to work in a team,
   - responsibility,
   - personal culture and attention to personal appearance.
3. Character and behavior of a soldier outside duty hours.

Interesting research results in the area of evaluation of selected aspects of personnel management in hierarchical organizations can be noted from Szulc, Mazurek, Majewski - where it was presented that military commanders (officers) are often perceived by subordinates as having specialized and organizational competence, striving to develop their skills, firm in action, rather hardworking and committed to performing tasks. However, on the other hand,

subordinates rated their superiors less favorably in terms of skills typical of leaders, and concerning personal example, winning over subordinates, and showing interest in subordinates. The results shown in Figure 2 clearly reveal deficiencies in selected social behaviors within the personnel management process.

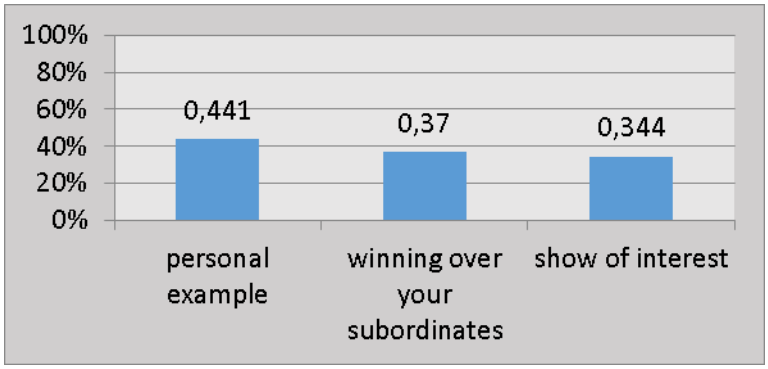

Figure 2. Evaluation of supervisors in terms of more important skills typical of leaders.
Adapted from: Szulc, Mazurek, Majewski, 2002.

Another interesting research results in the area of developing professional competence of military personnel can be noted by R. Balcerzyk and D. Balcerzyk. When asked about the values conducive to competence development, respondents listed creativity and innovation in a positive sense in first place (29.4% of officers), readiness to make sacrifices (26,3%), avoiding responsibility (12.6 %), deception, (12.1%), patriotism (8 %), feeling of social mission (7,7 %), no competence (3,6%). Those with such views were soldiers serving in command positions, with a length of service of 5 to 10 years. The results are shown in Figure 3.

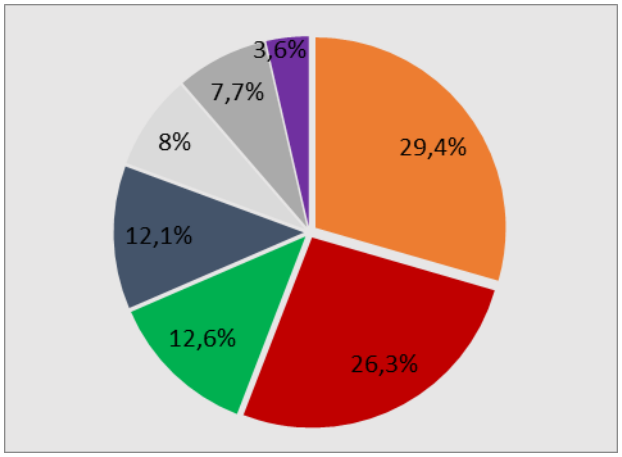

Figure 3. Values that foster competence growth.
Adapted from: Balcerzyk, D., Balcerzyk, R., 2017.

4. Citizens' expectations of military personnel

By reason of its functions, the army is understood as a total institution, penetrating with its actions and filling all areas of a soldier's life, creating certain groups, patterns of behavior (situational, institutional, integrative), which can be distinguished by the roles they play in the overall organization of military life. According to researchers, total institutions are distinguished primarily by their function of meeting the many different needs of the population (Gofman, 1975). According to Gofman's concept within the functional paradigm, the concept of function is alternatively used with the concept of role. A soldier, as a member of a total institution such as the army, has certain social roles to fulfill - he is supposed to defend independence, the inviolability of borders, he is supposed to serve society with his daily work and service, to ensure the highest possible level of security. The concept of social role is linked to the concept of social position. Social position is a certain way of situating a person in a collective, in a group. In modern society, every person, and therefore a soldier, belongs to many collectivities, in each of which he occupies a different position, or even multiple positions. However, in the interpersonal space there is a multiplicity of such positions and roles, in various configurations and connections. In this context, Szacka mentions two basic types of positions - ascribed positions and attained positions. Ascribed positions are those that a person obtains automatically, without the participation of his will, for example, with birth. Achieved positions are those over which a person himself has some influence. In democratic, modern societies, attainable positions definitely dominate. In feudal, authoritarian or totalitarian societies, ascribed positions are much more common. At the same time, a social role, is a set of rights and obligations associated with a given position, or a pattern of behavior associated with the position, a scenario of the position, its dynamic, behavioral element, or normatively defined duties and permissions (Szacka, 2003). In other words, a role is defined as a determinant of how a person who occupies a given position behaves. Thus, a role is a dynamic element of the position occupied. The various roles differ in what is commanded, forbidden and an element of freedom. As Szacka notes, the script for some positions is more rigidly defined and leaves less room for improvisation than for others. Certainly, the role of an officer in the military has less freedom than the role of a student, for example. It is not only the margin of freedom that differentiates the role of an officer from that of a student. As an institution, the military defines in meticulous detail a range of permissible and impermissible behavior. Regulations, a code of honor, military ceremonial or norms of discipline serve this purpose. Reviewing the available surveys in the area of citizens' expectations of the state and its organs, according to the survey, almost all believe that it should provide every citizen with security (99%) and respect for their private property (98%). There is also a common opinion that the role of the state is to provide every citizen with a minimum income (95%) and free medical care (95%). Slightly fewer people (88%) believe that citizens should have the right to free higher education. The majority of respondents (84%) expect the state to guarantee every citizen some kind of housing, shelter, a roof over their heads, as well as a job that is in line with their qualifications (81%) or any job

(80%). Less people express the view that the state should ensure the welfare of every citizen (53%). Thus, society's expectations of the state, in the main, are provided by the military and its formalized structures. Thus, it performs a key function of the state in relation to its citizens. Respondents' responses are shown in Figure 4.

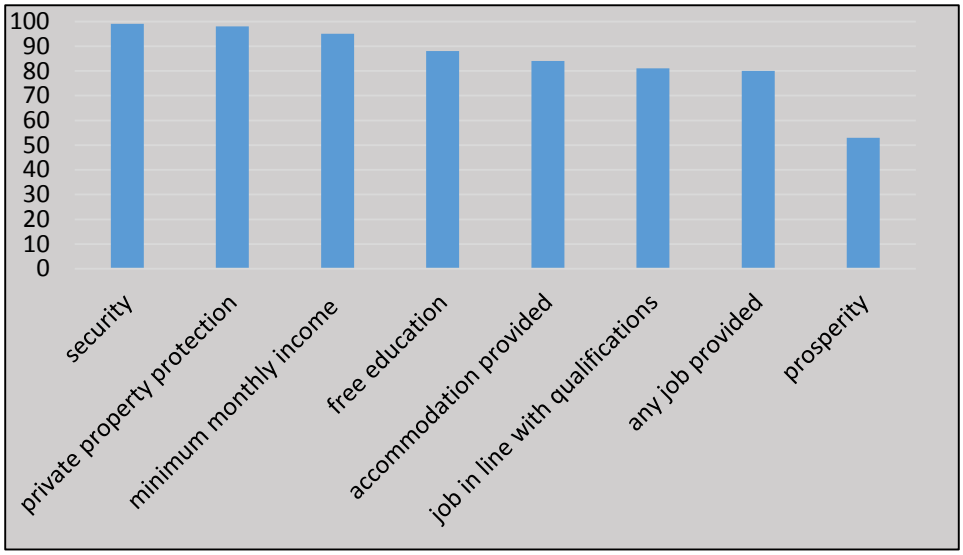

Figure 4. Expectations of Poles towards the state.

Adapted from: CBOS, 2013.

At the same time, interesting research is provided by the data presented by professional soldiers themselves, among whom, when asked the question "To whom/whom is the soldier morally responsible for his service actions?" The answers also showed this moral and service responsibility to society. In the present analysis, the responses of officers, as the professional group that manages human teams in military structures, thereby having a fundamental influence on the implementation of statutory tasks in relation to citizens, were taken as relevant. The results of the surveys cited are shown in Figure 5.

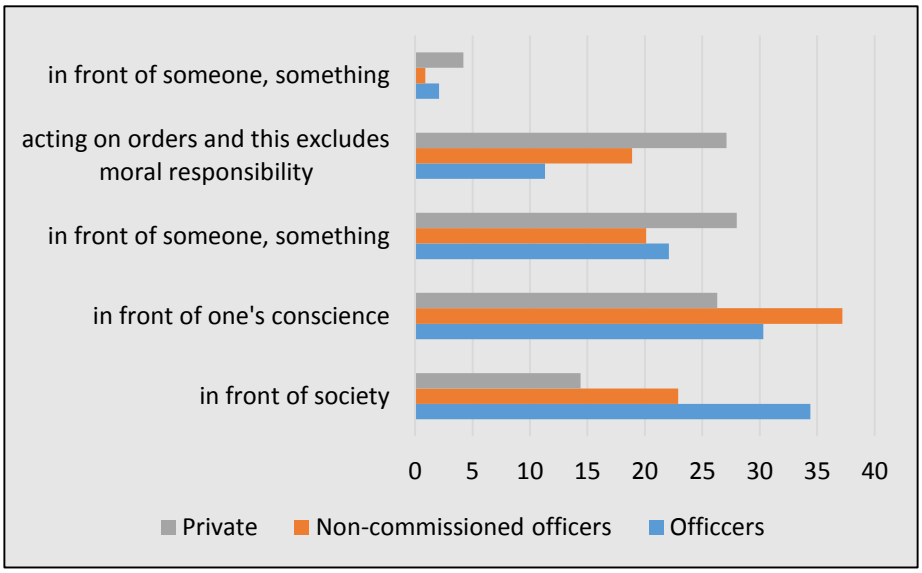

Figure 5. Responses of soldiers in terms of moral responsibility.

Adapted from: Zajdzik, 2010.

5. Conclusions

The main objective of this publication was to identify the research gap in the management of the process of competence preparation of soldiers in the context of their social roles and expectations of citizens. Against this background, on the basis of literature studies and available research, as well as logical deduction and inference, the final conclusions are identified. As the results of the research have shown, the dynamics of change in the modern security environment and the behavior and expectations of societies force the improvement of the management of the process of competence preparation of military personnel. The research has revealed that the soldier's profession is oriented towards fulfilling the basic needs of the other which are the needs for security and protection of private property, towards fulfilling the needs of the local community and society as a whole more broadly. Based on this, the first conclusion was drawn that an important area of professional preparation that is currently not being implemented adequately is the improvement of social competence among military personnel. Moreover, in the research, the interviewees themselves (soldiers) articulate that they feel a moral responsibility to fulfill their role first and foremost to society and their own conscience. This confirms the awareness of military personnel as to their choice of vocation in their professional life and service, as well as the proper selection of personnel for these organizations into their structures and the right direction for competence development. However, in areas such as the opinions of subordinates, one can find opinions suggesting the deficiencies in social behavior shown above, especially in superiors, which should be remedied within the framework of an organized system of professional development.

Another recommendation developed on the basis of the research is the identified need to develop professional competence in the emotional intelligence (competence) of military personnel, particularly in the cognitive and social aspects, ensuring the adaptation of soldiers to function under threat conditions. This should result in the expansion of the periodic evaluation questionnaires, to which soldiers are subjected, with indicators and measures relating to the individual assessment of competence preparation in relation to social and emotional competence.

A practical solution in the area of competence management of military personnel, developed on the basis of the research carried out, is the need to implement in the stage of academic training and in-service courses a program of practical classes involving the development of social and emotional competence. Thus, during academic training at the military academy, it will be an additional subject with a practical dimension within the group of classes of the direction module in the fourth or fifth year of the master's degree program, amounting to 30 didactic hours. During in-service courses, this will be implemented in the general military training module. The subject area of such classes will be the subject of the author's upcoming research.

The above considerations show the occurrence of further expectations and needs addressed to military personnel, as well as other uniformed services or disposition groups. This is a contribution to continuing research on the directions of development in the field of military personnel management, especially in such a dynamically changing environment.

References

1. Argyle, M. (1999). *Psychologia stosunków międzyludzkich.* Warszawa: PWN.
2. Balcerzyk, D. Balcerzyk, R. (2017). Rozwój kompetencji zawodowych oficerów, *Przedsiębiorczość i zarządzanie.* Łódź-Warszawa: SAN, p. 431.
3. Basińska, M., Jaskólska, J., Piórowski, K. (2007). *Inteligencja emocjonalna a typy zachowań i przeżyć w pracy w grupie żołnierzy zawodowych*. Polskie Forum Psychologiczne.
4. Bieńkowski, J., Stępień, R. (2003). *Edukacja pedagogiczna w wyższej uczelni wojskowej.* Warszawa: AON, p. 89.
5. Biermann, K.L., Welsh, J.A. (2001). Social Competence. In: J. Kagen, S. Gall, *Encyclopedia of Childhood and Adolescence.* Farmington Hills, MI: Thomson Gale Publishing.
6. Bradberry, T., Greaves, J., Leoncioni, P. (2009). *Emotional Intelligence 2.0*.
7. Bradberry, T., Greaves, J. (2006). *Podręcznik inteligencji emocjonalnej*. Helio – One Press.
8. Dudzińska-Głaz, J. (2012). Zarządzanie kompetencjami pracowników jako jeden z elementów strategicznego zarządzania zasobami ludzkimi. In: W. Harasim, *Zarządzanie kapitałem intelektualnym w organizacji inteligentnej*. Warszawa: Wyższa Szkoła Promocji.
9. Filipowicz, G. (2016). *Zarządzanie kompetencjami. Perspektywa firmowa i osobista*. Warszawa: Wolters Kluwer.
10. Gofman, E. (1975). *Charakterystyka instytucji totalnych.* In: W. Derczyński, A. Jasińska-Kania, *Elementy teorii socjologicznych*. Warszawa: PWN.
11. Goleman, D. (1999). *Inteligencja emocjonalna w praktyce.* Poznań: Media Rodzina.
12. Goleman, D. (2007). *Inteligencja emocjonalna*. Poznań: Media Rodzina.
13. Huzarski, M., Wołejszo, J. (2014). *Leksykon obronności. Polska i Europa.* Warszawa: Bellona SA, p. 196.
14. Jakubowska, U. (1996). Wokół pojęcia „kompetencja społeczna" - ujęcie komunikacyjne. *Przegląd Psychologiczny, no. 39,* 29-40.
15. Karl-Heinz, A., Lindner-Müller, C. (2012). Assessment and Development of Social Competence: Introduction to The Special Issue. *Journal for Educational Research Online*, *4(1).*

16. Kołodziejczyk, A. (2015). O kształtowaniu kompetencji społecznych w wojsku. Perspektywa socjologiczna. *Bezpieczeństwo, obronność, socjologia, no. 1(3)*. Warszawa: WCEO/WBBS.
17. Krakowski, K., Leśniewski, Z., Wiśniewski, J. (2011). *Rozwój zawodowy kadr*. Warszawa: AON, p. 7.
18. Kupczyk, T., Stor, M. (2017). *Zarządzanie kompetencjami. Teoria, badania i praktyka biznesowa.* Wrocław: Wyższa Szkoła Handlowa we Wrocławiu.
19. Kupisiewicz, Cz. (2000). *Dydaktyka ogólna.* Warszawa: Graf Punkt, pp. 29-30.
20. Kuźma, J. (2003). Doskonalenie i samokształcenie nauczycieli. In: *Encyklopedia pedagogiczna XXI wieku*, t. II. Warszawa: Żak, p. 772.
21. Martowska, K. (2012). *Psychologiczne uwarunkowania kompetencji społecznych*. Warszawa: Liberi Libri.
22. Matczak, A. (2007). Inteligencja emocjonalna – kierunki i metody badań. *Psychologia, Edukacja i Społeczeństwo, no. 4*.
23. Matczak, A., Knopp, K.A. (2013). *Znaczenie inteligencji emocjonalnej w funkcjonowaniu człowieka*. Warszawa: Liberi Libri.
24. Moczydłowska, J. (2008). *Zarządzanie kompetencjami zawodowymi a motywowanie pracowników.* Warszawa: Difin.
25. Okoń, W. (1984). *Słownik pedagogiczny.* Warszawa: PWN, p. 243.
26. Okoń, W. (2007). *Nowy słownik pedagogiczny.* Warszawa: Żak, p. 300.
27. Oleksyn, T. (2014). *Zarządzanie zasobami ludzkimi w organizacji*. Warszawa: Oficyna a Wolters Kluwer business.
28. Pilecka, W., Pilecki, J. (1990). Model kompetencji społecznych w ujęciu Greenspana. In: J. Pańczyk, *Roczniki pedagogiki specjalnej, tom 1*. Warszawa: WSPS.
29. Pocztowski, A. (2001). Wokół pojęcia kompetencji i ich znaczenia w zarządzaniu zasobami ludzkimi. In: B. Urbaniak (ed.), *Gospodarowanie pracą*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
30. Spitzberg, B.H., Cupach, W.R. (2002). *Handbook of Interpersonal Communication*. H.L. Knapp, J.A. Daly. Thousand Oaks: Sage.
31. Stępień, R. (2001). *Kompetencje zawodowe kadry dowódczo – sztabowej w aspekcie wymogów współczesnej pedagogiki wojskowej.* Warszawa, p. 21.
32. Szacka, B. (2003). *Wprowadzenie do socjologii.* Warszawa, p. 137.
33. Szołtysek, J., Jeż, R., Twaróg, S. (2015). *Kompetencje społeczne w okresie kształcenia zawodowego na potrzeby logistyki społecznej*. Uniwersytet Ekonomiczny w Katowicach.
34. Szulc, B., Mazurek, Z. (2011). *Determinanty implementacji perspektywicznych metod kształcenia w zastosowaniach wojskowych.* Warszawa, p. 73.
35. Turos, L. (1999). *Pedagogika ogólna i subdyscypliny.* Warszawa: Żak, p. 369.

36. Whiddett, S., Hollyforde, S. (2003). *Modele kompetencyjne w zarządzaniu zasobami ludzkimi.* Oficyna ekonomiczna.
37. Zajdzik, J. (2010). Wybrane elementy etosu żołnierzy zawodowych WP w świetle badań empirycznych. In: M. Baran-Wojtachnio, J. Dziedzic, M. Kloczkowski, J. Maciejewski, W. Nowosielski, *Społeczne aspekty zawodu wojskowego.* Toruń: Adam Marszałek.

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GREEN PUBLIC PROCUREMENT FROM THE CONTRACTOR'S PERSPECTIVE

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Purpose: Governments in many countries are trying to prevent climate change. One way of doing this is through green public procurement that consists of procuring goods, services and works with a reduced environmental impact during their life cycle compared to goods, services and works with an identical purpose that might otherwise have been procured. So the paper aims to examine private companies' readiness to provide green goods and services in response to demands of green public procurement. This may encourage public entities to wider use of green public procurement because they may be afraid of an inadequate amount of companies that can meet the procurement criteria. The paper provides tips on how to organize the work of a public institution to make green public procurement more widespread.
Design/methodology/approach: The methods used in this study were literature analysis, statistical survey, static analysis and case study. By means of a statistical survey and analysis, the relationship between the knowledge of employees of a given company regarding the knowledge of concepts related to green public procurement and the type of position was demonstrated. On the other hand, with the help of a case study, it was shown how an existing public procurement can easily be transformed into a green public procurement.
Findings: In order to achieve sustainable outcomes, it is necessary to introduce internal regulations of public organisations relating to the integration of environmental considerations into tendering procedures. Public organisations should realise how easy it is to turn a public procurement into a green public procurement and that companies are already ready to do it. Almost any company can meet the environmental requirements to participate in green public procurement, the criteria depend on the ingenuity of the public organisations' staff. The main difficulties in including environmental aspects in tendering procedures include insufficient knowledge and experience of the contracting authorities in their practical application.
Originality/value: The paper discusses the role of green public procurement, as well as how to manage a public organisation, what to do to make green public procurement widely used. Relevant knowledge of public employees, political will, as well as the fashion for green public procurement are important in the introduction of the above mentioned procurement. The paper also focuses on the private company's point of view.

Keywords: carbon footprint, public procurement, green public procurement, climate change.

Category of the paper: research paper.

1. Introduction

Human activity is the cause of the climatic changes taking place on the globe, leading, among other things, to the melting of glaciers in Greenland and Antarctica. This is due to an increase in the production of electricity, which is necessary to improve living conditions. This increase has been particularly evident since the end of the 20th century. However, this is not only a positive phenomenon, its negative effect is the increase in greenhouse gas emissions (e.g. CO_2 by 68%), resulting from the burning of fossil fuels to produce electricity.

Thanks to the collaboration of scientists from around the world with the Intergovernmental Panel on Climate Change (IPCC), the issue of climate change has been publicised. A carbon footprint has been introduced as a tool to guide appropriate emission reductions and facilitate understanding of the risks of global warming (Climate Change: The Physical Science Basis, 2021). Governments in many countries are now trying to prevent climate change by introducing green changes that make the functioning of society greener.

There are many ways to make green changes in society. One of these is green public procurement (GPP). With these, any public entity can aim to reduce its carbon footprint. Among public institutions, local and regional governments in particular must be part of an immediate and sustainable reduction in greenhouse gas emissions, as they are the ones performing the bulk of public tasks.

The basic concept of green public procurement is to integrate environmental criteria in public procurement of products and services. Across the world, green procurement is a market liberator that allows more environmentally friendly goods and services to come to market (Cheng et al., 2018). Green public procurement can be seen as a catalyst for change, making contractors interested in finding and developing innovative environmental technologies (Chrisidu-Budnik, 2022). Most of the literature focuses on the perspective of the contracting authority. This work presents the contractor's perspective.

The main hypothesis of the study is the assumption that most contractors can fulfill the requirements to participate in GPP and that all employees are familiar with the concept of green public procurement.

2. Human-induced climate change

To date, human activity has led to a temperature rise of 1.1°C. Studies covering the period between 1850 and 1990 lead to this conclusion. In 2021, the Intergovernmental Panel on Climate Change (IPCC) published a new report 'Climate Change 2021: The Physical Science Basis', which contains the state of the art on climate change. It has been endorsed by

195 national governments and presents rapid human-induced changes. The key findings of the report are that CO_2 concentrations in the atmosphere are the highest in 2 million years, sea level rise is the fastest in 3,000 years and Arctic sea ice is the lowest in at least 1,000 years. This entails extreme weather events such as forest fires in North America and Southern Europe, extreme flooding in China and Western Europe and devastating tropical cyclones on the Indian and Atlantic coasts (Vigran, 2021).

According to various climate models, the Earth's temperature will continue to rise. Each of the scenarios studied assumes a further increase of at least 1.5°C, and this will happen by 2040 at the latest, the most optimistic scenario. In the most pessimistic one, if no systemic changes are made, the temperature could rise by as much as 4.4°C by the end of the century. At present, however, a temperature rise of 2.7°C is the most likely scenario, thanks to the regulations and greenhouse gas reductions being introduced (Vigran, 2021).

An important step towards reducing emissions is to quantify the amount of greenhouse gas emissions caused by different human activities. This is done through the carbon footprint, introduced as a tool to guide appropriate emission reductions and verifications to facilitate understanding of global warming risks (Awanthia, Navaratnea, 2018). According to the simplest definition, the carbon footprint is the total amount of CO_2 and other greenhouse gases (e.g. nitrous oxide, methane) that are emitted by various products and processes, resulting from the entire life cycle of a product; this includes storage and disposal. It is a measurable indicator that can be used for a specific company, organisation, product, service, process, region or country. Calculating an organisation's carbon footprint can be an effective tool for continuous energy and environmental management (Kijewska, 2017).

Over 90% of all greenhouse gas emissions come from sectors that are central to our daily functioning. Major emitters include industries such as agriculture, heavy industry, construction, transport and energy. Energy was responsible for 77.01% of GHG emissions, agriculture for 10.55%, industrial processes and product use for 9.10% and waste management for 3.32% (Europarl.europa, 2021). It is therefore very important to adopt practices that reduce greenhouse gas emissions. In the construction industry, the use of non-conventional and environmentally friendly materials and technologies is becoming increasingly popular, which will enable the reduction of material and energy consumption in buildings (Geneidy et al., 2021). In the energy sector, the use of renewable energies such as hydropower, wind and solar energy, which can serve as an alternative to fossil fuels, is increasingly developing (Esquivel-Patiño, Nápoles-Rivera, 2021). In transport, the easiest way to reduce emissions is to use public transport. Thanks to the awareness of an increasing number of citizens and through growing concerns about pollution, more and more people are paying attention to how they can reduce their carbon footprint themselves (Europarl.europa, 2021).

3. Green public procurement

Procurement spending averages between 13 and 20 per cent of gross domestic product (GDP) in most countries, equivalent to an annual global expenditure of around US$9.5 trillion (The World Bank, 2020). Public procurement is defined as the acquisition of goods, services and works by government institutions and state-owned enterprises from private sector suppliers. Public procurement can also be done as green public procurement. This consists in giving preference to goods, services and works whose environmental impact during their life cycle is limited compared to goods, services and works with an identical purpose that could have been procured through other means. The most important aspect in green public procurement is the compliance of contractors and subcontractors with environmental law. Through the implementation of such procurements, mistakes that were made earlier can be rectified and a better future life can be pursued for the entire population (Johnson, Klassenof, 2022). It is therefore not surprising to conclude that green procurement is a demand-side policy tool that can contribute to reducing environmental impact and a circular economy (Lindfors, Ammenberg, 2021).

Green procurement has been implemented worldwide for more than a decade and is oriented towards green production and consumption. As early as 2004, the Chinese government acknowledged that green procurement should foster energy conservation, environmental protection and awareness of the resource crisis throughout society (Wang et al., 2021). Green procurement typically provides public organisations with financial savings, especially when considering the life-cycle costs of the products or services procured, rather than considering only the acquisition price. This is because the acquisition price is only one part of the cost in the whole procurement and ownership process. Life-cycle costing takes into account all costs that occur during the life cycle, such as: operating costs, including fuel and water consumption, as well as maintenance and all costs associated with the operation (supplies, insurance, etc.), end-of-life costs, such as the cost of disposal or decommissioning. In this way, it is possible to purchase something more expensively, but then in the overall calculation it turns out to have been the cheaper choice.

For example, when purchasing green buses, a life-cycle costing model can be used, taking into account the purchase price, operating and maintenance costs and fuel consumption and costs. The total procurement cost may be higher than the cost of purchasing non-environmentally friendly buses, but this will be offset by lower operating costs (Vidal, Sánchez-Pantoj, 2019).

There are also obstacles to the implementation of green procurement. Information on the calculation of the life-cycle cost of products is not widely known, the same applies to the cost of environmentally friendly products/services. There is low awareness of the benefits of environmentally friendly products and services. There is a lack of adequate political support for

the implementation and promotion of green procurement, which limits the availability of resources (e.g. too little training), and there is a lack of coordinated exchange of best practices and information between regional and local institutions. States should focus on promoting and supporting green public procurement as much as possible. The initiative of public authorities is crucial for the start and continuation of the green economy (Ekologiczne zakupy, 2016).

4. The role of public organisations

Public organisations can make a significant contribution to reducing greenhouse gas emissions, as well as to protecting the environment. Part of the activity of public organisations is the procurement of goods and services. The purchasing power of public authorities makes green public procurement an important tool in the fight to achieve sustainable development. In many countries, green public procurement is considered one of the most important contributors to green consumption. As a direct result of green procurement, public authorities can spend less on energy, pollute less and create a green image for the government. In this way, public authorities can play a leading role in the transition from traditional to green consumption. As the most authoritative consumer in the country, a public authority can effectively serve as an example and guide for its followers - individual consumers (Wang et al., 2021).

Green public procurement is a driver of innovation. They stimulate industry to create green products and services. For example, timber procurement in Europe has stimulated the consumption and production of certified timber. In addition, environmental criteria and requirements can also promote the circular economy and related business models. In industries where public procurement has a large market share, such as construction, medical services or transport, it is a major source of innovation through the creation of green products and services (Nissinen et al., 2009).

In Poland, purchases by public entities are regulated by the Act of 11 September 2019 - Public Procurement Law (Journal of Laws of 2020, item 1710 as amended). This act makes it possible to take care of environmental protection by introducing sustainable public procurement, where the award of a contract can be made subject to environmental criteria.

Green procurement requires collaboration between different departments and staff within an organisation. To make green procurement more common and easier to use, it is necessary to: identify an appropriate scope of procurement activities, include targets and timeframes, and include a mechanism to adequately monitor the performance of the procurement. The support of senior people is also considered an important factor in the implementation of green procurement (Ekologiczne zakupy, 2016).

5. Research methods

The research covered two interrelated topics. The first part focused on conducting a survey among the employees of a cleaning company. Based on the results, a static analysis was carried out. The static survey was conducted among 30 employees of the company. The main aim of the survey was to compare the employees knowledge of green procurement according to their job position. The study presented here used a survey questionnaire as a research tool. The questionnaire was anonymous and, for a complete characterisation of the situation, information on the sociological characteristics of the respondents was included. The survey was followed by a statistical test. For this study, the choice was Pearson's chi-square χ test. The chi-square test can be used as a chi-square test of one variable or a concordance test, used in practice to check the equality of groups and to estimate whether the distribution of the study variable differs from the theoretical distribution we indicated. The test can also be used as a chi-square test of two variables or an independence test used to examine the existence of a relationship between two variables (Mider, Marcinkowska, 2013).

The χ^2 test is particularly useful in studies where two variables are measured on nominal scales. A nominal scale is one where its values represent categories, with no internal ranking, i.e. it is not possible to determine which of the cases is, for example, greater, better, more important than the other (Słowińska, 2019). The calculation procedure of the chi-square test consists of four steps. The first stage consists in presenting the observed numbers in the form of a contingency table in which the respondents answers are counted for particular categories of variables. The second step is to create a table with expected numbers. A table analogous to the table with observed numbers is created. Expected counts are calculated assuming that the variables are independent. The third step is to calculate the value of the χ^2 statistic. The last step is to compare the calculated value of the χ^2 statistic with the critical value ${\chi_\alpha}^2$. Critical values are read from the tables of chi-square distribution for the assumed level of significance ($\alpha = 0.05$) and appropriate degrees of freedom (Aczel, 2000). Based on the χ^2 and ${\chi_\alpha}^2$statistic values, hypotheses are verified. The null hypothesis - the tested variables are independent and the alternative hypothesis - the tested variables are dependent. If the value of $\chi^2$is lower than the critical value, there are no grounds for rejecting the null hypothesis i.e. the independence of the variables is assumed, while when the value of $\chi^2$is greater than the critical value, the null hypothesis should be rejected, which allows us to conclude that the tested variables are dependent (Łapczyński, 2015). The significance level was $p = 0.05$, indicating also statistically significant results for the levels $p = 0.01$ and $p = 0.001$, p-values indicating a statistically significant result are in bold.

The second part of the survey concerned the analysis of the surveyed company's participation in a public tender. The analysis focused on how public procurement can easily be transformed into green public procurement, which can then be used to formulate rules for managing public procurement to make it greener. A case study method based on public procurement tender documents was sed. Document-based case analysis is the dominant method in scientific analysis, the documents used in the study can be external information such as reports and minutes, as well as coming from inside the organisation, i.e. balance sheets, regulations, payroll, etc. (Pizło, 2009).

6. Results

Based on the survey, it is possible to find out how many people are familiar with the term green procurement. Out of the 30 people surveyed, almost 70% are familiar with the term, that is 21 employees, of these people 13 are office staff and eight are non-office staff (Table 1). The objective of the survey was to compare the knowledge of employees according to the type of position. The research group in this study was the group working outside the office, as it is mainly these employees who most often do not have a say in the decisions made regarding participation in a new project. Also, they are not involved in the daily conversations of the employees, so they have less access to information exchange than office workers. Those working outside the office are also more likely to be uninterested in climate change, according to the results. Awareness of environmental protection and related concepts is higher in the office-based group, as these employees are often more educated and have more knowledge about climate change, which is occurring at a very fast pace.

Table 1.
Results of the statistical test for the relationship between education, interest in climate change, care for the environment, knowledge of the concepts of sustainable development, public procurement and green public procurement - the place of employment

Variable	Parameter	Total (N = 30)	Office's workers (N = 13)	Employees working outside the office (N = 17)	p-value
Education	Primary education	3,33% (N = 1)	0% (N = 0)	5,88% (N = 1)	**0,0057**
	Vocational education	13,33% (N = 4)	0% (N = 0)	23,53% (N = 4)	
	Secondary education	16,67% (N = 5)	0% (N = 0)	29,41% (N = 5)	
	Higher education	66,67% (N = 20)	100% (N = 13)	41,18% (N = 7)	

Cont. table 1.

Interest in climate change	Definitely yes	36,67% (N = 11)	38,46% (N = 5)	35,29% (N = 6)	**0,0295**
	Rather yes	20,00% (N = 6)	23,08% (N = 3)	17,65% (N = 3)	
	I don't know	13,33% (N = 4)	30,77% (N = 4)	0,00% (N = 0)	
	I don't think so	23,33% (N = 7)	0,00% (N = 0)	41,18% (N = 7)	
	Definitely not	6,67% (N = 2)	7,69% (N = 1)	5,88% (N=1)	
Care for the environment	Definitely yes	40% (N = 12)	46,15% (N = 6)	35,29% (N=6)	0,4272
	Rather yes	30% (N = 9)	30,77% (N = 4)	29,41% (N=5)	
	I don't know	10% (N = 3)	0% (N = 0)	17,65% (N=3)	
	I don't think so	16,67% (N = 5)	23,08% (N = 3)	11,77% (N=2)	
	Definitely not	3,33% (N = 1)	0% (N = 0)	5,88% (N=1)	
Knowledge of the concepts of sustainable development	Definitely yes	40% (N = 12)	69,23% (N = 9)	17,65% (N=3)	**0,0413**
	Rather yes	26,67% (N = 8)	23,08% (N = 3)	29,414% (N=5)	
	I don't know	16,67% (N = 5)	7,69% (N = 1)	23,53% (N=4)	
	I don't think so	13,33% (N = 4)	0% (N = 0)	23,53% (N=4)	
	Definitely not	3,33% (N = 1)	0% (N = 0)	5,88% (N=1)	
Knowledge of the concepts of public procurement	Definitely yes	40% (N = 12)	69,23% (N = 9)	17,65% (N=3)	**0,0332**
	Rather yes	36,67% (N = 11)	30,77% (N = 4)	41,18% (N=7)	
	I don't know	13,33% (N = 4)	0% (N = 0)	23,53% (N=4)	
	I don't think so	6,67% (N = 2)	0% (N = 0)	11,76% (N=2)	
	Definitely not	3,33% (N = 1)	0% (N = 0)	5,88% (N=1)	
Knowledge of the concepts of green public procurement	Definitely yes	33,33% (N = 10)	61,54% (N = 8)	11,76% (N=2)	**0,0147**
	Rather yes	36,67% (N = 11)	38,46% (N = 5)	35,3% (N=6)	
	I don't know	13,33% (N = 4)	0% (N = 0)	23,53% (N=4)	
	I don't think so	13,33% (N = 4)	0% (N = 0)	23,53% (N=4)	
	Definitely not	3,34% (N = 1)	0% (N = 0)	5,88% (N=1)	

Source: own studies.

All office staff are familiar with the terms procurement and green procurement, a similar number are familiar with the concept of sustainability. Better familiarity with these concepts is therefore dependent on position. This was also confirmed in another study (Faracik, Szymonek, 2015). According to this study, the majority of the 16 people surveyed were familiar with the

term green procurement. However, the people surveyed were those involved in public procurement, so familiarity with the concept was due to the fact that respondents to the survey were selected from among those involved in public procurement.

The survey showed statistical differences between variables such as education, interest in climate change, familiarity with the terms public procurement and green public procurement. The statistical differences may be due to the difference in education of the respondents. Office workers tend to be more highly educated people who care about the environment and what is happening around them. Employees working outside the office are a broader group of employees. This group can include regional and shop managers, but also people who do manual work. Among this diverse group, there may be people without higher education or people who are simply not interested in these topics.

Further education on environmental protection and green procurement should therefore be carried out. It is important that as many people as possible are environmentally aware and that they support the organisation's commitment to green procurement. The results from the survey (Faracik, Szymonek, 2015) showed that knowledge regarding green public procurement is mainly based on which sector the respondents work in and whether they participate in various trainings and conferences. The second part of the research concerned the analysis of a public contract awarded by a public entity. The surveyed company entered a tender for the cleaning of selected university facilities in Podlaskie Voivodeship. The main criterion of the contract was the price of the service. The contract description presented the scope of the service to be provided. The contract description also presented the conditions of participation in the proceedings.

This analysis shows how procurement can easily be transformed into green procurement in line with good green procurement practices. The company makes use of various green technological innovations, and is constantly trying to keep up with changes in the market. Pro-ecological procedures not only reduce costs but, most importantly, contribute to environmental protection. The company uses environmentally friendly cleaning products manufactured on the basis of natural plant and mineral raw materials, and purchases them in large containers. This reduces the amount of waste generated, but also results in savings. Energy-efficient machines use less electricity, which leads to them being cheaper to use. The equipment used in the company also has all the necessary certificates. It is also important to segregate waste, which allows one waste bag to be used multiple times. The company also works with a paper towel manufacturer that recycles its own products. This service reduces the waste and carbon footprint of paper towels. In this way, the company contributes to the development of a circular economy society. It reduces the carbon footprint by at least 40% and reduces waste by 20% compared to other waste treatment options. New hygienic paper products are created from the towels recycled. As can be seen from the above, in order to transform procurement into green procurement, environmental requirements could be added to the criteria. A proposed solution for a transformed procurement is presented below (Table 2).

Table 2.
Green procurement proposal that could be awarded by a public university

Employer	**University**
Type of order	service
Subject of the contract	Cleaning service for University buildings
Procedure (procurement mode)	open tender
CPV	90910000 Cleaning services
Pro-environmental instruments used in the proceedings	requirements in the description of the subject of the contract
Object requirements:	1.1 The subject of the contract is a service concerning the cleaning of the university's buildings. The contract includes the cleaning of specific faculties, but also of the administration building and the library. 1.2 All services must be environmentally friendly: • Use eco-friendly preparations, cleaning products should be produced on the basis of natural plant and mineral raw materials and meet the requirements for marketing in the EU, use toilet paper and towels derived from recycled paper, • use of energy-efficient cleaning machines (e.g. hoovers, washing machines) that have low power consumption and all the necessary certifications, as well as cleaning machines with a defined maximum noise level, • separating waste, separate rubbish bags, reusing bags, and recycling paper towels. The Contractor must be aware of all environmental regulations and apply them when carrying out the services.

However, it can be done in yet another way by providing for different ecological criteria, such as the electricity consumption of machines, the percentage of use of ecological preparations, the use of innovative methods for separating rubbish or the measurement of CO2 and pollutants. There can be many ways, it all depends on the creative ingenuity of those preparing the order.

The requirements outlined above are not excessive. Expectations such as segregating waste or using green products are basic conditions and do not require special preparation. Everyone is obliged to separate waste, so why should public organisations not go further and encourage contractors to use energy-efficient machines or natural products. The criteria presented are not a more expensive option for contracting authorities or contractors. By ordering products made, for example, from recycled material (paper towels), we are contributing to the effective and efficient separation of waste, as well as its reuse. The use of energy-efficient equipment by contractors reduces the need for electricity production and contributes to lower greenhouse gas emissions. By procuring services and products produced in an environmentally friendly way, the demand for those whose production uses, for example, many harmful chemicals is reduced. Achieving an environmental effect therefore depends on the qualitative and functional requirements placed on the subject of the contract and defined in the initial phase of the tendering procedure, which requires knowledge on the part of the contracting authority regarding the technical aspects of eco-innovation (Pożarowska, Olejarz, 2017).

An important element of good practice is a certain level of awareness and involvement of individuals on the part of the contracting authority. Involvement concerns those directly involved in the various stages of the procedure, those overseeing the implementation of the procurement contract, but also the decision-makers who have an impact on the overall functioning of the institution. Public employees' knowledge of sustainability, proficiency in applying mandatory solutions, ability to use non-mandatory tools and a broad perspective linking sustainable procurement with other areas of an institution's functioning can lead to significant results. Public organizations that invest in employee training will achieve their sustainability goals faster. It will also lead to sustainability innovation in the private sector (Darnall, Edwards, 2006).

A company bidding for an exemplary green public procurement contract would not incur additional costs, as it has already applied all good green practices for a long time. In this case, the type of tender would not make much difference to the contractor, thus commissioning the contract would not require an increase in expenditure for the public organisation. However, the use of green procurement could have a positive impact on the surrounding environment. Greening this procurement would therefore not affect the price of the service, but would have a positive environmental effect.

7. Conclusions

The study found statistical differences between a variable such as education and interest in climate change. More office workers are interested in climate change, which is linked to their education and the training provided for them. Place of employment and education therefore influence the level of interest in green procurement, a concept that all office employees are familiar with, while only a subset of non-office employees are also familiar with the concept, which didn’t confirm the research hypotheses. Interest in green public procurement, depending on the place of employment, was also confirmed in another study (Faracik, Szymonek, 2015), but due to limited number of respondents the survey results should be confirmed on the wider population.

In addition, it has been shown that in fact any company can meet the environmental requirements to take part in green public procurement, as the criteria do not always have to be demanding, which confirmed the research hypothesis. Above all, it depends on the willingness and knowledge of the employees of public organisations about what green criteria they can include in the tender. Of course, other issues of greening public procurement in other areas (not only the cleaning services) should also be examined

In order to achieve sustainable results, it is necessary to introduce internal regulations of public organisations regarding the integration of environmental considerations into tender procedures. Public organisations will be more willing to use green procurement if they are also aware (in addition to their own awareness of the role of climate protection) that companies are ready for such procurement.

Public organisations should realise how easy it is to turn a public contract into a green public contract, as demonstrated in the contract under review. Of course, each procurement should be considered individually. Adding green criteria generally does not require additional time or resources from public organisations or contractors. Of course, there are also procurements that require more financial resources, such as the purchase of electric buses or the construction of a road with additional solutions favouring the movement of animals, e.g. corridors and passageways.

The main difficulties in including environmental aspects in tendering procedures include the insufficient knowledge and experience of contracting authorities with regard to their practical application. Therefore, it is very important to promote good practice in the development of model records of procedure documentation. Those responsible for the implementation of sustainable procurement should participate in thematic training, conferences and courses. This should have a positive impact on the frequency of green public procurement, which was confirmed in other studies (Darnall, Edwards, 2006; Faracik, Szymonek, 2015). Unfortunately, in Poland, the share of green public procurement in the total number of contracts was 1 per cent in 2020, which translates into only 384 contracts of an environmental or innovative nature (State Purchase Policy, 2022).

For wider promotion and widespread use of green procurement, the following are essential:

- motivation for the use of green procurement by senior figures in public organisations, including or especially by politicians,
- greater intensity of thematic training and courses for staff in public organisations, as staff should have the relevant practical skills, knowledge and access to the information they need,
- to correctly identify the objectives and priorities they want to achieve through green public procurement,
- inclusion of a mechanism for monitoring the execution of contracts,
- promoting green public procurement to residents so that they can see the positive changes coming from it,
- interest of a larger part of the population in climate change, so that during elections they elect people who will favour slowing down climate change.

References

1. Aczel, A. (2000). *Statystyka w zarządzaniu*. PWN.
2. Awanthia, M., Navaratnea, C. (2018). Carbon Footprint of an Organization: a Tool for Monitoring Impacts on Global Warming. *Procedia Engineering*, *Vol. 212*, pp. 729-735. doi: 10.1016/j.proeng.2018.01.094.
3. Cheng, W., Appolloni, A., D'Amato, A., Zhu, Q. (2018). Green Public Procurement, missing concepts and future trends – A critical review. *Journal of Cleaner Production, Vol. 176*, pp. 770-784. doi: 10.1016/j.jclepro.2017.12.027.
4. Chrisidu-Budnik, A. (2022). Zielone zamówienia publiczne w perspektywie transformacji energetyczno-klimatycznej. *Folia Iuridica Universitatis Wratislaviensis, Vol. 11, Iss. 2,* pp. 73-83. doi: 10.34616/145040.
5. Darnall, N., Edwards, D. (2006). Predicting the cost of environmental management system adoption: the role of capabilities, resources and ownership structure. *Strategic Management Journal, Vol. 27, Iss. 4,* pp. 301-320. doi: 10.1002/smj.818.
6. Esquivel-Patiño, G., Nápoles-Rivera, F. (2021). Environmental and energetic analysis of coupling a biogas combined cycle power plant with carbon capture, organic Rankine cycles and CO_2 utilization processes. *Journal of Environmental Management*, *Vol. 300*. doi: 10.1016/j.jenvman.2021.113746.
7. *Europarl.europa*. Retrieved from: https://www.europarl.europa.eu/news/pl/headlines/society/20180301STO98928/infografika-emisje-gazow-cieplarnianych-w-unii-europejskiej, 14.12.2021.
8. *Europarl.europa*. Retrieved from: https://www.europarl.europa.eu/news/pl/headlines/society/20190313STO31218/emisje-co2-z-samochodow-fakty-i-liczby-infografika, 15.12.2021.
9. Faracik, B., Szymonek, J. (2015). *Zrównoważone zamówienia publiczne w Polsce. Możliwości, bariery, straty (Report No. 1.).* Warszawa: Creative Commons.
10. Geneidy, S., Baumeister, S., Govigli, V., Orfanidou, T., Wallius, V. (2021). The carbon footprint of a knowledge organization and emission scenarios for a post-COVID-19 world. *Environmental Impact Assessment Review*, *Vol. 91*. doi: 10.1016/j.eiar.2021.106645.
11. Johnson, P., Klassenof, R. (2022). New directions for research in green public procurement: The challenge of inter-stakeholder tensions. *Cleaner Logistics and Supply Chain*, *Vol. 3*, p. 100017. doi: 10.1016/j.clscn.2021.100017.
12. Kijewska, A. (2017). Analiza poziomów śladu węglowego dla świata i krajów UE. *Systemy wspomagania w inżynierii produkcji*, *Vol. 6, Iss. 2*. Retrieved from: http://docplayer.pl/67718611-Analiza-poziomow-sladu-weglowego-dla-swiata-i-krajow-ue.html. 10.10.2022.
13. Komisja Europejska (2016). *Ekologiczne zakupy! Podręcznik dotyczący zielonych zamówień publicznych*. Luksemburg: Urząd Publikacji Unii Europejskiej.

14. Lindfors, A., Ammenberg, J. (2021). Using national environmental objectives in green public procurement: Method development and application on transport procurement in Sweden, *Cleaner Production*, *Vol. 280, Iss. 2*, pp. 124821. doi: 10.1016/j.jclepro.2020.124821.
15. Łapczyński, M. (2015). Analiza porównawcza tabel kontyngencji i metody CHAID. *Zeszyty Naukowe Akademii Ekonomicznej w Krakowie*. pp. 149-163.
16. Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, A., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J., Maycock, Y., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. United Kingdom-New York: Cambridge University.
17. Mider, D., Marcinkowska, A. (2013). *Analiza danych ilościowych dla politologów. Praktyczne wprowadzenie z wykorzystaniem programu GNU PSPP*. Warszawa.
18. Nissinen, A., Parikka-Alhola, K., Rita, H. (2009). Environmental criteria in the public purchases above the EU threshold values by three Nordic countries: 2003 and 2005. *Ecol. Econ*., *Vol. 68, Iss. 6*, pp. 1838-1849. doi: 10.1016/j.ecolecon.2008.12.005.
19. Pizło, W. (2009). Studium przypadku jako metoda badawcza w naukach ekonomicznych, *Stowarzyszenie ekonomistów rolnictwa i agrobiznesu*, *Vol. 11, Iss. 5*, pp. 246-251. Retrieved from: http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.ekon-element-000168016855. 19.11.2022.
20. Polityka zakupowa państwa. Monitor Polski (2022).
21. Pożarowska, J., Olejarz, M. (2017). *Dobre praktyki w zakresie zrównoważonych zamówień Publicznych*. Warszawa: Urząd Zamówień Publicznych.
22. Słowińska, M. (2019). Wykorzystanie testu chi-kwadrat w badaniach preferencji żywieniowych konsumentów. *Nauki inżynierskie i technologie*, *Vol. 1, Iss. 32*, doi: 10.15611/nit.2019.1.0.
23. Vidal, R., Sánchez-Pantoj, N. (2019). Method based on life cycle assessment and topsis to integrate environmental award criteria into green public procurement, *Sustainable Cities and Society*, *Vol. 44, Iss. 1*, pp. 465-474. Retrieved from: http://repositori.uji.es/xmlui/bitstream/handle/10234/181859/63627.pdf?sequence=1. 16.10.2022.
24. Vigran, D. *Faster, more intense, with more devastating impacts: New IPCC report lays out the scientific basis of the climate emergency.* Retrieved from: https://talkofthecities.iclei.org/fastermore-intense-with-more-devastating-impacts-new-ipcc-report-lays-out-the-scientificbasis-of-the-climateemergency/?gclid=CjwKCAiAwKyNBhBfEiwA_mrUMj2Pt6g56JRviHRlCfowemkH-w6vagpfWTlJ2LjIgrhcCiDN4DW8UhoCCOYQAvD_BwE, 10.12.2021.

25. Wang, Q., Wang, S., Zhang, M., Bu, Z., Liu, J. (2021). Green public procurement as a promoter for green consumption: From the perspective of individual's knowledge. *Cleaner and Responsible Consumption*, *Vol. 3*, p. 100035. doi:10.1016/j.clrc.2021.100035.
26. *World bank online.* Retrieved from: https://www.worldbank.org/en/news/feature/2020/03/23/globalpublic-procurement-database-share-compare-improve, 20.01.2022.

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IMPLEMENTATION OF EU LAW INTO THE POLISH CONSUMER PROTECTION LAW, WITH PARTICULAR EMPHASIS ON THE OMNIBUS DIRECTIVE

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Purpose: On 1 January 2023, provisions implementing the Omnibus Directive, along with the Digital Content and Safe of Goods Directives, came into force in Poland. The aim of the implementation is to adjust consumer protection in response to advancing digitisation and new business models. This article focuses on the changes introduced to consumer protection laws as a result of the amendment of 1 December 2022 implementing the Omnibus Directive into the Polish law.
Design/methodology/approach: The deliberations are based on the related subject literature and an analysis of the legal provisions applicable in the area under discussion.
Findings: With the implementation into the Polish legal order of the Directive 2019/2161, legislators introduced numerous changes in consumer law, including new obligations for the providers of online trading platforms, and rules for the provision of information about price reductions of goods and services. The main implication of the implementation of the Omnibus Directive is the change from physical and legal defects to compliance (or non-compliance) of the goods with the contracts, and the extension of the limitation period for consumer claims. Adjusting their business to the new legal requirements, entrepreneurs will need to implement far-reaching organisational changes, which paradoxically, from the consumer's point of view, could lower the traditionally perceived level of protection. With respect to the legal aspects of some of the implemented provisions selected in this article, it should be concluded that the transposition of most of the solutions of the Omnibus Directive was carried out correctly, although certain inconsistencies could not be avoided.
Practical implications: Adjusting their business to the new legal requirements, entrepreneurs will need to implement far-reaching organisational changes. For these reasons, the importance of knowledge about the consumer protection, has been increasing in value.
Originality/value: The article raises the issue of consumer law, which is important not only from the point of view of the customer but also from the entrepreneur's perspective.

Keywords: consumer law, implementation, digital market, entrepreneurs' obligations.

Category of the paper: viewpoint, literature review.

1. Introduction

Consumer protection is a priority matter within the EU. An adequate level of consumer protection can undoubtedly improve the living conditions of the Community's citizens, hence the developments in consumer policies that have been observed for many years (Kaczorowska, Kurzyńska-Lipniewicz, 2019).

Directive (EU) 2019/2161 (hereinafter the Omnibus Directive) of the European Parliament and of the Council of 27 November 2019, amending Council Directive 93/13/EEC and Directives 98/6/EC, 2005/29/EC and 2011/83/EU of the European Parliament and of the Council as regards the better enforcement and modernisation of Union consumer protection rules, entered into force on 7 January 2020 (Directive, 2019, Item 136.28).

The main purpose of the directive, a legislation package called *New Deal for Consumers*, was to "strengthen the enforcement capacities of member states, enhance product safety and increase international cooperation and new possibilities for redress notably through representative actions by qualified entities" (Regulation, 2021, Item 153.1, Motif 48). Without a doubt, the directive was also aimed at the improvement of the damage compensation system in response to unfair commercial practices engaged in by entrepreneurs (Miś, Miś, 2021).

The said regulation was also aimed at strengthening consumer protection mechanisms related to online transactions (Sieradzka, 2019). A definition of online services was introduced; specific protection was given to providing consumer's personal data for unpaid delivery of digital services; and finally, new information obligations (e.g., on informing consumers about price reductions) were placed on online trading platform providers (Sobczyńska, 2022).

Almost concurrently with the Omnibus Directive, two subsequent directives were passed aimed at strengthening consumer legal protection. These are Directive (EU) 2019/770 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the supply of digital content and digital services (Directive, Item 136), called a Digital Content Directive; and Directive (EU) 2019/771 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the sale of goods, amending Regulation (EU) 2017/2394 and Directive 2009/22/EC, and repealing Directive 1999/44/EC, called a Sale of Goods Directive (Directive, 2019, Item.136.28).

The Digital Content Directive, for example, extends consumer protection to unpaid services for access to which consumers provide their personal data. If consumers opt out of the digital content or services offered, based on this directive, they have right to access the content or data created by them while using such content or services. The provider, in turn, has the right in such a situation to prevent further use of the service, in particular by removing the users' accounts. In this type of digital service, consumers can use them within a 14-day period during which withdrawing from the contract is possible, if they declare that they made an explicit request for such and that they understand that they lose the right to withdraw from the contract upon its full performance by the seller.

The adopted regulations will allow for the rules of consumer protection within the EU to be unified, as well as reducing the costs on the side of entrepreneurs involved in cross-border operations, as they will help in avoiding additional costs of adjusting contracts concluded with consumers to meet the requirements in individual member states.

In accordance with Article 7(1) of the Omnibus Directive, member states will be obliged to adopt and publish the provisions necessary to implement this directive by 28 November 2021. The above regulations should apply from 28 May 2022 (Directive, 2019, Item. 136.28). As of today, this is the case in nine member states. Aside from Poland, the provisions have still not been implemented by Italy, Ireland, Malta, Luxembourg, Slovenia, and Slovakia. It was only in July 2021 that the Government Legislation Centre published on its website the Act Amending the Act on Consumer Rights and Certain Other Acts (Projekt, 2021), which was to lead to the implementation of the Omnibus Directive. In July 2022, the bill was submitted to the Sejm.

As for the Sale of Goods and Digital Content Directives, adoption and publication by member states of provisions necessary to implement them was to take place by 1 July 2021, and the provisions should have been applied from 1 January 2022.

The implementation of the above legal acts into the Polish legal system was carried out by the passing of an act on 4 November 2022 on changes to the Consumer Rights Act, the Civil Code Act, and the International Private Law Act (The Act, 2022, Item 2337), and the Act of 1 December 2022 on Amending the Act on Consumer Rights and Certain Other Acts (The Act, 2022, Item 2640).

It was necessary to amend, in particular, the Act of 20 May 2014 on Consumer Rights (u.p.k.) (The Act, 2020, Item 287); the Act of 9 May 2014 on Information on Prices of Goods and Services (u.i.c.t.u.) (The Act, 2023, Item 168); the Act of 23 August 2007 on Combating Unfair Commercial Practices (u.p.n.p.r.) (The Act, 2017, Item 2070); and the Act of 23 April 1964 – Civil Code (The Act, 2022, Item 1360). The amendments came into force on 1 January 2023.

This article focuses on changes implemented in consumer protection law based on the amendment of 1 December 2022 implementing the Omnibus Directive into the Polish law.

2. Online platforms

Until the Omnibus Directive was implemented, the term *online platform* had not been legally defined. The attempts to create a legal definition of such a term met with numerous difficulties. It was especially troublesome to specify the criteria differentiating this term from others similar in nature (Wyrwińska, Wyrwiński, 2018).

On 4 November 2022, Item 8, including the definition of an online trading platform, was added to Article 2 of the Consumer Rights Act. According to this item, an online trading platform is "a service using software, including a website, part of the website or application, operated by or for the entrepreneur, within which it is possible a) for the consumers to remotely conclude contracts with other entrepreneurs, or b) for the natural persons, who are not entrepreneurs, to remotely conclude contracts with other natural persons, who are not entrepreneurs" (The Act 2020, Item 287).

The introduced definition was the result of numerous consultations, and the original wording included in the Act Amending the Act on Consumer Rights and Certain Other Acts was subject to harsh criticism. The Act defined an online platform as a "service using software, including a website, part of the website or application, operated by or for the entrepreneur, which enables consumers the remote conclusion of contracts with other entrepreneurs and consumers" (Projekt, 2021). This wording was contrary to the definition of a consumer in Art. 22^1 of the Civil Code, which defined a consumer as "any natural person performing a legal act with an entrepreneur which is not directly related to the business or professional activity of the consumer" (The Act 2022, Item 1360).

The provisions of the Consumer Rights Act do not define the concept of consumer separately (Osajda, Mikłaszewicz, 2022). "According to the literal wording of this definition of the consumer, the transaction concluded between two natural persons with no business activity precludes awarding them a consumer status. The phrase contained in the article: 'it is possible for the consumers to remotely conclude contracts with other (…) consumers' is contrary to the above-quoted definition" (Miś, Miś, 2021). In this wording, the provision would allow for the conclusion of contracts via an online platform between a consumer and an entrepreneur, and between consumers.

To avoid excluding from the scope of the online platform definition the situation in which a contract is concluded between natural persons without any business activity, it was necessary to introduce changes in the Act Amending the Consumer Rights Act. The wording "within the platform it is possible for the consumers to remotely conclude contracts with other consumers" was replaced with the clause "it is possible for the natural persons, who are not entrepreneurs, to remotely conclude contracts with other natural persons, who are not entrepreneurs".

3. Obligation to inform about Price Reduction

The term of the secret of an entrepreneur is used in Article 5(2) of the Act of 6 September 2001 on the Access to Public Information (Act, item 902, 2022), which states that the right to public information is subject to limitation based in view of the privacy of a natural person or an entrepreneur's secret. However, the Act does not introduce a legal definition of this term.

Until the Omnibus Directive was passed, the obligations of entrepreneurs related to communication of prices were based on the Directive 98/6/EC (1998, Item 080). The entrepreneur was obliged to provide a product selling price and price per unit (i.e., per kilogram, litre, etc.). The Omnibus Directive added to the Directive 98/6/EC a new Article 6(a) introducing an additional obligation to regulate the issue of price transparency in the event of price reduction and promotional offers (Directive, 1998, Item 080).

In accordance with Article 4 of u.i.c.t.u., the place of retail sale and service provision must provide the prices or unit price of a product or a service in an unequivocal manner that does not raise doubts and makes price comparison possible. Moreover, whenever information is given about a price reduction for a product or service, one should also provide information next to the reduced price information about the lowest price of such a product or service applicable for 30 days before the reduction (The Act, 2023, Item 168). The above provision raises some interpretative concerns. The Office of Competition and Consumer Protection takes the position that the benchmark price (usually with a strikeout) should be the lowest price from the previous 30 days (UOKiK, 2023). This interpretation is consistent with the regulation discussed herein, but it does not result from its wording (Keler, 2023).

If the given products or services are offered for sale for a period shorter than 30 days, the information about the lowest price should include the lowest price of the product or service that was applicable in the period between when such product or service was first offered for sale and when the reduction was applied (Article 4(3) of u.i.c.t.u.). For goods with a short expiration period or shelf life, adjacent to the reduced price, one should provide information about the price before the first reduction was applied. The above regulations also apply to advertisements for goods or services including prices.

The obligation to share the lowest price from before the price reduction should thus be carried out in any retail setting or place where services are provided (whether stationary or online). In this regard, the Polish legislator went further than the EU legislation, as the Omnibus Directive is only applicable to the price reduction for goods (Patryk, Patryk, 2014).

It is worth emphasising that the value of the offer or its duration does not affect the obligation to provide information. It is sufficient that the entrepreneur provides information about the reduction in any form. It could be a promotional slogan suggesting a price reduction (e.g., “Now for less”, “Up to 50% less”, “Up to 200 zł off!”) or expressions such as Sale, Clearance, etc. Then, next to the current price, the entrepreneur must show the lowest price applicable in the given sales channel for 30 days before the promotional offer. Such pricing information can be presented on a price tag, on an electronic screen, on a price list, in a catalogue, or on the cover, or it can be printed or handwritten on the product or its packaging.

Concurrently with the Act of 1 December 2022 on Amending the Act on Consumer Rights and Certain Other Acts, a new resolution of the Minister of Development and Technology of 19 December 2022 on making prices of goods and services visible came into force.

The resolution specifies the way in which prices should be presented, including information about price reductions. In view of § 3(1) of this resolution, the price, unit price, or information about price reduction for the product should be presented on the product directly above it or in its vicinity, in a place that is publicly accessible and well visible to consumers (The Act, 2022, Item 2776); and in the event of a price reduction for a service, information about the reduced price should be placed next to the price and the unit price of the service (The Act, 2022, Item 2776, §10(3)). The resolution does not include specific guidelines on indicating the lowest price, although it mentions it should be provided in a visible, clear, unambiguous, and customer-accessible manner (It cannot be written in smaller font than the reduced price, or using an illegible color or low contrast.)

The scope of the introduced changes is also problematic. The obligation of informing about the lowest price before the price reduction was added to the act on informing about prices of goods and services, which is also applicable in the entrepreneur–consumer (B2C) relationship, as well as between entrepreneurs (B2B). In accordance with Article 2 of u.i.c.t.u., the provisions of this act do not apply to prices in trade between natural persons who are not entrepreneurs (The Act 2023, Item 168). Furthermore, this obligation should be met at a retail sales point. Although there is no legal definition of the term *retail*, the assumption that it includes only sales addressed to consumers seems incorrect.

In light of the above, the view that in this respect also, the Polish legislator went one step further than the EU legislator, who limits this obligation only to trading with consumers, seems justified (Chomiczewski, 2022).

4. Contracts Requiring the Transfer of Goods to the Consumer

The Act of 4 November 2022 amending the Act of 30 May 2014 on Consumer Rights introduced Chapter 5a, including regulations on contracts requiring the transfer of ownership of goods to the consumer. Thus, with respect to this type of contract, the provisions of the Civil Code on the warranty connected with the sale for consumers (except for goods that are only a digital content media) are excluded (The Act 2020, Item 287, Article 43(a)(1)). Article 43(a) of u.p.k. specifies that such contracts are sales contracts, delivery contracts, and "task as a commodity" contracts. *Commodity* is defined as a movable property, but also includes water, gas and electricity in cases where they are offered for sale in a specific volume or amount (The Act2020, Item 287, Article 2(4)).

Consequent to the above, the period for limitation of consumer claims has been extended from 2 years to 6 years as of 1 January 2023 (General rules of Art. 118 and n.k.c. apply here). Also extended to 2 years (calculated from the moment the product is delivered) was the period in which the burden of proof with respect to the compatibility of the product with the contract

is shifted onto the entrepreneur. In the previous legal state, this period was 1 year (Kukuryk, 2022).

The adopted implementation introduces the term of *compatibility of the product with the contract*, as defined in Article 43(b) of u.p.k. The product is compatible with the contract if the following elements, among others, are in accordance with the contract: product description, type, amount, quality, completeness, and functionality; and with respect to goods with digital elements, also their compatibility, interoperability, and update availability. The prerequisite for considering a product as compatible with the contract is also its fitness for a particular purpose for which the consumer needs it, about which the consumer informed the entrepreneur in the moment of concluding the sales contract at the latest, and which the entrepreneur accepted.

It could therefore be assumed that the assessment of product compatibility with contracts is based on objective criteria on the one hand, and on subjective criteria on the other (Habryn, 2021). This regulation is a shift from the notion of physical and legal defect to the notion of compatibility (or non-compatibility) of the product with the contract (Bezwińska, 2023).

The list of consumer rights has been modified for cases of product incompatibility with the contract (Czech, 2020). In accordance with Art. 43(d) of u.p.k., a consumer can initially request the product to be returned to compatibility with the contract by means of repair or replacement. The other rights (i.e., requesting a price reduction or withdrawal from the contract), can be exercised by the consumer subsequently if the entrepreneur, at the very least, refused to bring the product to compatibility, or if from entrepreneur's statement or circumstances it is clear that they will not bring the product back to compatibility with the contract within a reasonable time without excessive inconvenience for the consumer (The Act, 2020, Item 287). The entrepreneur is obliged to return to the consumer the amounts due as a result of exercising the right to withdraw from the contract or to reduce the price immediately, not later than 14 days from receipt of the statement from the consumer.

5. Conclusion

With respect to the legal aspects of some of the implemented provisions selected in this article, it should be concluded that the transposition of most of the solutions of the Omnibus Directive was carried out correctly, although certain inconsistencies could not be avoided.

From the consumer's perspective, the most important solution is covering by the regulation the Act of 30 May 2014 of the Act on Consumer Rights in the respect of the warranty. The new provisions will be applicable to contracts requiring the transfer of ownership of goods to the consumer, including in particular sales contracts, delivery contracts and "tasks as a commodity" contracts, as well as contracts requiring the transfer of ownership of goods and provision of services, and contracts requiring the transfer of ownership of goods with digital elements.

One problematic aspect is the fact that from 1 January 2023, the provisions on warranty in the Civil Code, as well as new provisions on warranty added to the Act of 30 May 2014 on Consumer Rights by the Act of 1 December 2022 on Amending the Act on Consumer Rights and Certain Other Acts are applicable concurrently. In the current legal state, it should be individually specified which of the above regulations should be applied. Considering the fact that other responsibility systems for sales contracts exist, this could make exercising consumer rights in practice significantly more difficult, or perhaps entirely impossible.

It should nevertheless be emphasised that extension of the warranty period in contracts requiring the transfer of ownership of goods to the consumer, and the period in which the burden of proof relating to the compatibility of the goods with the contract lies on the entrepreneur, is beneficial for the consumer.

However, the change in the hierarchy of means of legal protection to which the consumer is entitled (first replacement or repair, then price reduction or withdrawal) should be assessed negatively.

The new provisions are to counteract the practice of apparent price reductions for goods by entrepreneurs following previous significant increases in the price. The act imposes on the entrepreneur the obligation to disclose information about the lowest price of the given product or service that was applicable in the period of 30 days before the reduction (This applies to the price of the product or service as well as to information included in the advertisements). This should have a significant impact on the increase in consumer awareness with respect to modulating prices of given products. However, there is still the potential for abuse; e.g., by forcing price increases 31 days before price reductions.

Adjusting their business to the new legal requirements, entrepreneurs will need to implement far-reaching organisational changes, which paradoxically, from the consumer's point of view, could lower the traditionally perceived level of protection (Wiewiórowska, 2023).

Due to the short period within which the discussed regulations are binding, it is difficult to assess their functioning in practice. Only time will tell whether and to what extent they require further amendments and improvement.

References

1. Bezwińska, D. (2022). *Zmiany w zakresie ochrony konsumentów od 01.2023*, https://www.kpgio.pl/blog/zmiany-w-zakresie-ochrony-konsumentow-od-01-2023/ (12.02.2023).

2. Chomiczewski, W.(2022). *Zmiany w regulacjach dotyczących ochrony konsumentów ze szczególnym uwzględnieniem przepisów implementujących dyrektywę Omnibus, LEX/el,* https://sip.lex.pl/#/publication/470192775/chomiczewski-witold-zmiany-w-regulacjach-dotyczacych-ochrony-konsumentow-ze-szczegolnym...?keyword=Chomiczewski%20Witold,%20Zmiany%20w%20regulacjach%20dotycz%C4%85cych%20ochrony%20konsument%C3%B3w%20ze%20szczeg%C3%B3lnym%20uwzgl%C4%99dnieniem%20przepis%C3%B3w%20implementuj%C4%85cych%20dyrektyw%C4%99%20Omnibus&cm=SFIRST, 16.02. 2023.
3. Czech, T. (2020). *Stosowanie przepisów dotyczących konsumenta do osoby fizycznej prowadzącej działalność gospodarczą*, LEX/el.
4. Dyrektywa 98/6/WE Parlamentu Europejskiego i Rady z dnia 16 lutego 1998 r. w sprawie ochrony konsumenta przez podawanie cen produktów oferowanych konsumentom, Dz.U. L 080, z późn. zm. (1998).
5. Dyrektywa Parlamentu Europejskiego i Rady (UE) 2019/770 z dnia 20 maja 2019 r. w sprawie niektórych aspektów umów o dostarczanie treści cyfrowych i usług cyfrowych, Dz.U. UE. L.136, z późn. zm. (2019).
6. Dyrektywa Parlamentu Europejskiego i Rady (UE) 2019/771 z dnia 20 maja 2019 r. w sprawie niektórych aspektów umów sprzedaży towarów, zmieniająca rozporządzenie (UE) 2017/2394 oraz dyrektywę 2009/22/WE i uchylająca dyrektywę 1999/44/WE, Dz.U.UE.L.136.28) (2019).
7. Habryn, E. (2021). *Niezgodność towaru konsumpcyjnego z umową sprzedaży konsumenckiej*. Wolters Kluwer.
8. Kaczorowska, S., Kurzyńska-Lipniewicz, A. (2009). *Prawne aspekty ochrony konsumenta w Polsce i w Unii Europejskiej*. Legnica: Państwowa Wyższa Szkoła Zawodowa im. Witelona.
9. Keler, G. (2023). *Nowe zasady informowania o cenach w promocji nie zawsze sprawiedliwe*, https://sip.lex.pl/#/external-news/1795681743?keyword=Nowe%20zasady%20informowania%20o%20obniżeniu%20ceny&cm=STOP, 2.02 2023.
10. Kukuryk, P. (2022). Uwagi o zasadach rozpatrywania reklamacji na podstawie art 7 a ustawy o prawach konsumenta. *PPH, no.6*, pp. 40-48.
11. Miś, G., Miś, M. (2021). *Implementacja dyrektywy Omnibus do polskiego porządku prawnego - kilka wybranych uwag do projektu ustawy o zmianie ustawy o prawach konsumenta oraz niektórych innych ustaw. IKAR, no. 6*, pp. 132-140.
12. Motyw 48 Rozporządzenie Parlamentu Europejskiego i Rady (UE) 2021/690 z dnia 28 kwietnia 2021 r. ustanawiające program na rzecz rynku wewnętrznego, konkurencyjności przedsiębiorstw, w tym małych i średnich przedsiębiorstw, dziedziny roślin, zwierząt, żywności i paszy, oraz statystyk europejskich (Program na rzecz jednolitego rynku) oraz uchylające rozporządzenia Parlamentu Europejskiego i Rady (UE)

nr 99/2013, (UE) nr 1287/2013, (UE) nr 254/2014 i (UE) nr 652/2014, Dz.U.UE.L.153.1 (2021).
13. Osajda, K., Mikłaszewicz, P. (2022). *Ustawa o prawach konsumenta.* Komentarz 2022 r. Beck Online Komentarze.
14. Patryk, A., Patryk, T. (2014). *Ustawa o informowaniu o cenach towarów i usług. Komentarz.* LEX.
15. *Projekt ustawy o zmianie ustawy o prawach konsumenta oraz niektórych innych ustaw* (2021). https://legislacja.gov.pl/projekt/12348651/katalog/12800316#12800316, 10.02.2023.
16. Rozporządzenie Ministra Rozwoju i Technologii z 19 grudnia 2022 r. w sprawie uwidaczniania cen towarów i usług, Dz.U. poz. 2776 (2022).
17. Sieradzka, M. (2019). *Lepsza ochrona konsumenta w sklepie, sieci i w domu*, LEX/el., https://sip.lex.pl/#/publication/470125167/sieradzka-malgorzata-lepsza-ochrona-konsumenta-w-sklepie-sieci-i-w-domu?keyword=lepsza%20ochrona%20konsumenta&cm=STOP, 14.02.2023.
18. Sobczyńska, M. (2022). Wybrane aspekty prawne i interpretacyjne przepisów implementujących dyrektywę 2019/2161 z dnia 27 listopada 2019 r. w sprawie lepszego egzekwowania i unowocześnienia unijnych przepisów dotyczących ochrony konsumenta (Omnibus). *Kwartalnik Prawa Międzynarodowego, no II(II)*, pp. 97-113.
19. UOKiK - Urząd - Informacje ogólne - Aktualności - *#PrawaKonsumenta2023 - Prezes UOKiK mówi "sprawdzam"* (2023). https://uokik.gov.pl/aktualnosci.php?news_id=19234, 1.02.2023.
20. Ustawa z dnia 1 grudnia 2022 r. o zmianie ustawy o prawach konsumenta oraz niektórych innych ustaw, Dz.U. poz. 2640 (2022).
21. Ustawa z dnia 23 kwietnia 1964 r. – Kodeks cywilny, Dz.U. poz.1360 (2022).
22. Ustawa z dnia 23 sierpnia 2007 r. o przeciwdziałaniu nieuczciwym praktykom rynkowym, Dz.U. poz. 2070 (2017).
23. Ustawa z dnia 30 maja 2014 r. o prawach konsumenta, Dz.U poz.287 (2020).
24. Ustawa z dnia 4 listopada 2022 r. o zmianie ustawy o prawach konsumenta, ustawy – Kodeks cywilny oraz ustawy – Prawo prywatne międzynarodowe oraz ustawy z dnia 1 grudnia 2022 r. o zmianie ustawy o prawach konsumenta oraz niektórych innych ustaw, Dz.U. poz. 2337 (2022).
25. Ustawa z dnia 9 maja 2014 r. o informowaniu o cenach towarów i usług, Dz.U. poz. 168 (2023).
26. Wiewiórowska, A. (2023) *Polski konsument jako niebyt*, https://www.rp.pl/opinie-prawne/art37713141-aneta-wiewiorowska-domagalska-polski-konsument-jako-niebyt, 15.02.2023.

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RELATIONSHIP BETWEEN ENVIRONMENTAL INNOVATION AND SUSTAINABLE OUTCOMES – EMPIRICAL EVIDENCE FROM POLAND

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Purpose: The article refers to a valid and current research area related to business sustainability. The main objective of this article is to identify the relationship between different types of environmental innovations and sustainable outcomes.
Design/methodology/approach: For the needs of this article, the researches were conducted in 293 companies operating in Poland. In the course of the research, an additional division of environmental innovations derived from the Oslo Manual classification was taken into account, and the following were distinguished: environmental process innovations, environmental product innovations, environmental organizational innovations, and environmental marketing innovations. In addition, for the analysis of sustainable business performance, it was divided into economic, environmental, and social performance. The relation between the level of types of innovation and organizational outcomes is examined for each of these categories, and three models are presented.
Findings: Empirical research confirmed that different types of environmental innovations are essential factors for sustainable outcomes and, as a result, their growth. Research also revealed differences and similarities between different sustainable outcomes and their relationship to innovations of different types.
Research limitations/implications: First, although outcomes were measured using subjective indicators consisting of a limited number of items, using objective indicators or collecting data through in-depth interviews would have provided more detailed data. Second, increasing the size of the research sample and expanding the research to include companies operating in other countries (replication of research) would allow for generalization of the results, as the results obtained may be specific to companies operating in Poland.
Originality/value: The main value of this article is a broad and holistic view, which made it possible to use the four types of environmental innovations and link them in the model to organizational outcomes and clarify the relationship between them. It seems crucial to take a systemic view of what innovations collectively build the model and to note that organizational innovation appears as an element present in each of the models obtained. Thus, it is an indication that organizational activities should support process, marketing, or product innovations to lead to sustainable results of environmental innovation implementation.

Keywords: business sustainability, environmental innovations, sustainable outcomes, management.

Category of the paper: Research paper.

1. Introduction

In recent years, the relationship between the activities of companies and the environment has become increasingly complex. The reason for this is an increased awareness of the need to care for the environment, linked to the recognition that companies have a measurable impact on the environment in their operations, and this impact is usually negative. This results in an increasing pressure to look for new and innovative solutions that will generate some positive effects on the environment. For these reasons, the sustainability issue, understood as the ability to guarantee a dignified future for future generations (Faber et al., 2009), is becoming more and more topical and is increasingly related to the innovation activities of companies, and the relationship between environmentally friendly innovations or environmentally friendly directions of sustainable business development is attracting the attention of researchers. Companies, in turn, responding to these challenges are seeking new innovative solutions, developing new business and management models, new services or products, and new production processes and marketing solutions that can protect and improve environmental quality (Berry, Rondinelli, 1998; Savitz, Weber, 2006; UN, 2017; Walecka-Jankowska et al., 2017). This means implementing environmental innovations into their operations with the aim of achieving not only better economic, but also social and environmental results. These three perspectives: economic, social, and environmental, are the basic dimensions of sustainable business outcomes (Ch'ng et al., 2021; Fernando et al., 2019; Larbi-Siaw et al., 2022; Tumelero et al., 2019; Wagner, Llerena, 2011). For these reasons, the relationship between environmental innovations, or more precisely its different types (environmental process innovations, environmental product innovations, environmental organizational innovations, environmental marketing innovations) and sustainable outcomes (economic, social, and environmental) is the subject of this article. It presents the results of a survey of 293 Polish companies to examine the impact of types of environmental innovations on organizational outcomes.

The outline of the article is as follows: The first part is devoted to the literature review, the concepts of environmental innovation, and the relationship between environmental innovation and organizational performance. The second part presents the research methodology, research model, research hypotheses, and gathered data. The results of the study on the impact of environmental innovation types on organizational outcomes in companies operating in Poland are presented. The final section summarizes the results of the research and presents its organizational and future research directions.

2. Environmental innovations

Defining the term environmental innovation is not straightforward because of the lack of consensus among researchers on a common definition. In addition, there is a lack of consensus on the term environmental innovation itself, with researchers using the terms ecoinnovation or green innovation interchangeably. The authors of this paper use the term environmental innovation and, for the rest of the terms, assume that they can be treated interchangeably as synonyms.

Regarding the concept of environmental innovations, similar to other types of innovation, according to their characteristics proposed, for example, in (OECD/Eurostat, 2018) they can be a product, process, service or method, for example, a business model, they should meet the needs of users, affecting the competitiveness of enterprises. Their distinguishing feature, presented in many definitions but to varying degrees, is the environmental aspect. Most definitions explicitly assume that their distinguishing characteristic is the reduction of negative environmental impacts, compared to the use of alternatives – that is, (Fernando et al., 2019; Garcia et al., 2019; Hahn et al., 2010). Some of the definitions highlight additional features of environmental innovation, in addition to those mentioned above, relating to its purpose. Therefore, the purpose of environmental innovation, according to the assumptions presented by (OECD, 2011), are products and services, processes, marketing methods, organizational and institutional changes. Moreover, this goal can be twofold: technological or nontechnological. Product and process innovations are generally associated with technological changes, while marketing, organizational, and institutional innovations are usually based on non-technological changes (Chan et al., 2016; OECD, 2011).

Environmental innovations, therefore, refer to the solution of environmental, economic, and social problems (Melece, 2015), by introducing new innovative solutions to reduce negative environmental impacts. They include technological changes and nontechnological changes, which can be implemented in many forms (e.g., product, process, and organizational and/or marketing methods). This approach to environmental innovation refers to (OECD/Eurostat, 2018) and was adopted as the basis for the research presented in this article.

3. Environmental innovations and organizational outcomes

Environmental innovation is essential to facilitate the global transition to sustainable development (Dogaru, 2020; OECD, 2009). The 2030 Agenda for Sustainable Development of the UN stipulates that the focus should be on making better use of economic resources and promoting socioeconomic stability and business competition precisely by optimizing economic

goods and services to achieve environmental sustainability. However, many companies have not yet taken sufficient steps to achieve sustainability (Redman, 2018). This is not surprising, since the implementation of environmental innovations involves a number of challenges, and the dual goals of creating financial and environmental value produce tension (Garcia et al., 2019), carry a high level of uncertainty regarding organizational effects and the potentially high setup cost of their implementation, especially in the case of technological eco-innovations (Hanelt et al., 2017). Therefore, empirical evidence is needed showing the impact of environmental innovations on firm performance.

This evidence is provided by studies conducted in various countries and economic sectors, showing that environmental innovation has a positive impact on all aspects of economic and environmental performance studied by researchers (Cheng et al., 2014; da Silva Rabêlo, de Azevedo Melo, 2019; Nishitani et al., 2017; Rabadán et al., 2019; Rennings et al., 2006; Vargas-Vargas et al., 2010; Yurdakul, Kazan, 2020). There is also evidence in the literature that environmental innovation contributes to increasing the competitiveness of companies (Chen et al., 2006; da Silva Rabêlo, de Azevedo Melo, 2019) attracting financial investors (Doh et al., 2010), pondering consumer demand (Horbach, 2008), increasing organizational capacity (Aschehoug et al., 2012), and even improving employee engagement and productivity (Dögl, Holtbrügge, 2014).

However, the introduction of environmental innovations can require research and development or changes in production technologies that can be costly, modifications in supply chain management, promotion of new products or services, adoption of new business models and practices, or employee education (Kok et al., 2013). Therefore, investing in environmental innovation requires considering its impact on financial performance. The literature shows that it is ambiguous (Aldieri et al., 2020; Jaggi, Freedman, 1992; Orlitzky et al., 2003; Porter, 1991; Song et al., 2017). According to a meta-analysis presented in (Garcia et al., 2019), 55% of the studies showed a positive association, 15% showed a negative association and 30% showed a nonsignificant or nonlinear association. (Lin, Zheng, 2016), on the other hand, found that there can be a positive relationship between environmental innovation and economic performance, only under conditions in which a combination of economic, organizational, and environmental innovations shows positive effects. Similar conclusions were reached by (Vasileiou et al., 2022), stating that in the case of enterprise-specific environmental benefits, synergies between environmental innovations and other product and process innovations, as well as organizational innovations, increase the profitability of environmental innovations. On the contrary, for consumer-specific environmental benefits, only organizational innovations increase the profitability of environmental innovations. (Tang et al., 2018), on the other hand, showed that product eco-innovation and process eco-innovation positively affect company corporate performance and productivity. However, in the case of product ecoinnovation, it is necessary to take into account both input costs and conversion costs, as well as the risk of consumer acceptance. This is because environmental innovations that positively affect the

financial performance of companies require adequate internal and external resources (Lampikoski et al., 2014), including the development of green products, optimization of the production process, development of environmentally friendly management and the provision of services that meet the needs of consumers who are aware of the importance of sustainability (Tseng et al., 2013). Therefore, this means constantly investing and improving the operations of companies and making a continuous effort to avoid negative interactions that affect their financial performance (Roper, Tapinos, 2016; Zhang et al., 2020). However, some studies and theoretical perspectives show that environmental innovation has a negative impact on financial performance (Aguilera-Caracuel, Ortiz-de-Mandojana, 2013; Driessen et al., 2013) and a study (Liu et al., 2011) even found that environmental innovation leads directly to higher costs. However, these studies contradict the findings of (Przychodzen, Przychodzen, 2013; Santos et al., 2017). On the other hand, according to (Rezende et al., 2019) there is no significant relationship between environmental innovations and financial performance in the short term, while in the long term this type of innovation and a company's financial success are linked, provided there are sufficient resources to implement and sustain them.

As can be seen above, there is little research on the impact of environmental innovations on the performance of companies by type, and the studies mentioned focus only on organizational, product, and process types, leaving out the marketing type. These studies tend to overlook the role of environmental innovation in marketing (Driessen et al., 2013). According to (Vasileiou et al., 2022), this is probably due to the fact that researchers overestimate the role of environmental innovation in relation to other types of innovation (process product and organizational). However, (Medrano et al., 2020) found that managers, in relation to environmental innovation, must transform traditional marketing practices (among which he focuses on marketing innovation), which can be seen as identifying their rather weak relationship with environmental innovation. (Kumar et al., 2013), on the other hand, explicitly stated that the environmental orientation and innovation of marketing of companies are contradictory concepts.

According to our literature survey, the only study on the relationship between types of environmental innovation and sustainable business performance is in the Malaysian technology industry. It examines the relationship between three types of environmental innovation (eco-processes, eco-products and eco-organization) and three dimensions of sustainable business performance (economic, social and environmental) (Ch'ng et al., 2021). Based on these, it can be concluded that only eco-organizational innovations have a direct and positive impact on economic performance (similar findings can be observed in (Cheng et al., 2014; Liao, 2018), while no such impact was observed for other types of innovation, as confirmed by the findings in (Tumelero et al., 2019) for eco-process innovations and in (Boons et al., 2013) and (Driessen et al., 2013) for product innovations, as well as (Cai, Li, 2018) for both eco-process and eco-product innovations. Malaysian research also shows that ecoprocess and ecoproduct innovations showed a positive impact on environmental performance, which is consistent with

previous findings from (Cai, Li, 2018) and (Liao, 2018), while ecoorganisational innovations do not have a direct positive impact on environmental performance, as noted in (Cheng et al., 2014). However, when it comes to sustainable performance in the social dimension, the researchers did not find direct impact for any of the types of environmental innovation analysed. Environmental marketing innovations were not included in this study.

4. Research methodology

4.1. Purpose and methods of the study

The main of the study is to examine the impact of types of environmental innovation on organizational outcomes. The general research model in the context of the hypotheses presented above is presented in Fig. 1.

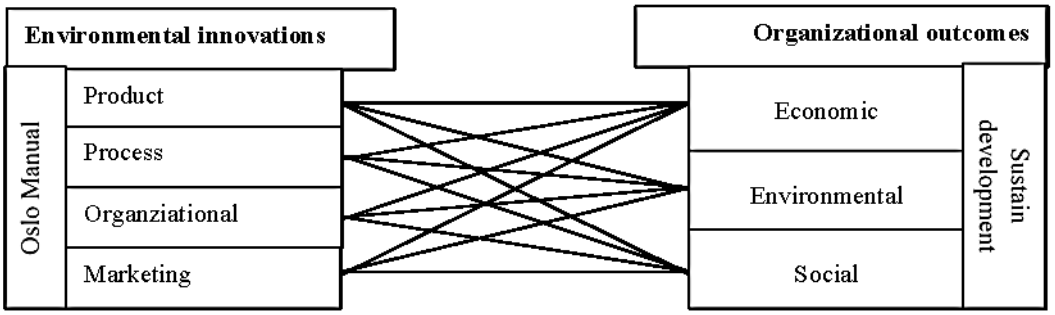

Figure 1. Research hypothesis.

Source: own work.

4.2. Data gathering process and characteristics of the research sample

In order to verify the hypotheses, a survey was conducted, for which the author's questionnaire was used. To verify the relevance of the items in the questionnaire built for the work, the competent judges method was used in the questionnaire development stage. Competent judges, employees of organizations holding senior positions, were engaged to assess the relevance. The judges, independently of each other, individually evaluated the items in the questionnaire.

The study was conducted using a questionnaire that was intended to be appropriate for any organization regardless of size, activity profile, or affiliation to a branch of the economy. Employees with a broad view of the organizations surveyed (each respondent represented a different organization) were asked to complete the survey. The research was carried out at the end of 2020. The general population consisted of companies operating in Poland.

In order to examine the relation between the types of environmental innovations and organizational outcomes, the following key variables were defined separately for data collected in Poland: four environmental innovations (based on Oslo Manual typology): environmental product innovation, environmental process innovations, environmental organizational innovations, environmental marketing innovations,, and three out-of-come variables (based on sustain development dimensions): economical out-of-comes, environmental out-of-comes, social out-of-comes. The reliability of variables (measured by the Alpha-Cronbach coefficient) is higher than 0,6 for innovation variables and near 0,9 for out-comes variables) which indicate a high internal consistency and reliability in the measurement of outcomes variables. The reliability of the innovation variables is lower, but this may be due to the fact that the items that were used to measure relate to different aspects: the purpose of the innovation and the scale of implementation.

Table 1.
Description of the variables

Variable	Description (variables were accessed on 5-point Likert Scale)
Environmental product innovations	How much is your company implementing? - New products and services Please rate on a 5-point scale. - Is the new product/service that your company is launching usually new on a company, national or global scale? To what extent are the product innovations implemented by the company aimed at improving the following outcomes? - Environmental effects (improving the company's environmental impact, reducing waste, reducing energy consumption)
Environmental process innovations	How much is your company implementing? - Process changes (in procedures, operations, tools). Please rate on a 5-point scale. - Is the new technological processes (also machines/ equipment/tools, software) that your company is launching usually new on a company, national or global scale? To what extent are the process innovations implemented by the company aimed at improving the following outcomes? - Environmental effects (improving the company's environmental impact, reducing waste, reducing energy consumption).
Environmental organizational innovations	How much is your company implementing? - Organizational changes (e.g., new organizational methods). Please rate on a 5-point scale. - Are the new ways of organizing business implemented by the company usually new on a company, national or global scale? To what extent are the organizational innovations implemented by the company aimed at improving the following outcomes? - Environmental effects (improving the company's environmental impact, reducing waste, reducing energy consumption).
Environmental marketing innovations	How much is your company implementing? - Marketing changes (e.g., product/service positioning, customer segmentation, pricing strategy). Please rate on a 5-point scale. - Are changes in product/service launch, positioning, customer segmentation, pricing policy) implemented by the company usually new on a company, national or global scale? To what extent are the marketing innovations implemented by the company aimed at improving the following outcomes? - Environmental effects (improving the company's environmental impact, reducing waste, reducing energy consumption).
Economic out-comes	Compared to the competition, your company is worse or better in terms of the following factors? - revenues - productivity (low costs) - quality (reliability, dependability, diligence) - return on investment (ROI) - investments made in regions with high unemployment (poverty) - availability of products or services to those with the lowest incomes

Cont. table 1.

Environmental out-comes	Compared to your competitors, is your company worse or better in terms of the following factors? - emissions, wastewater and waste - consumption of hazardous, toxic, harmful materials - consumption of total resources (materials, energy, water) - environmental impact of products or services sold - impact on biodiversity
Social outcomes	Compared to competition, is your company worse or better in terms of the following factors? - employee satisfaction - occupational health and safety - customer satisfaction - participation in the development of healthy and livable communities - compliance with social and environmental criteria by suppliers

Source: own work.

5. Results

To verify the hypotheses describing the relationship between individual components of types of environmental innovations and organizational outcomes, statistical analyzes were carried out. As a first step, a correlation analysis was conducted using Pearson's coefficient. The results are presented in Tables 2.

Table 2.
Correlations

		Environmental product innovation	**Environmental process innovation**	**Environmental organizational innovation**	**Environmental marketing innovation**
Economic out-comes	Pearson correlation	,627**	,612**	,538**	,647**
	Relevance (bilateral)	0,000	0,000	0,000	0,000
	N	293	293	293	293
Environmenta l out-comes	Pearson correlation	,608**	,614**	,533**	,602**
	Relevance (bilateral)	0,000	0,000	0,000	0,000
	N	293	293	293	293
Social out-comes	Pearson correlation	,553**	,567**	,508**	,602**
	Relevance (bilateral)	0,000	0,000	0,000	0,000
	N	293	293	293	293

** Correlation significant at the 0.01 level (two-sided).

Source: own work.

The correlation analysis shows significant relations between all types of environmental innovations and the levels of results in Poland. As a result, it should be stated that there are no grounds to reject the hypothesis.

Since the analysis of pairwise correlations revealed strong associations, it was decided to perform stepwise regressions. Three regression models were obtained - for different organizational outcomes (presented in Table 3).

Table 3.
Fitting regression models

	Poland
Economic outcomes	$F(4,288) = 64,965$; $p < 0,001$; $r^2 = 0,467$
Environmental outcomes	$F(4,288) = 56,154$; $p < 0,01$; $r^2 = 0,430$
Social outcomes	$F(4,288) = 47,907$; $p < 0,001$; $r^2 = 0,391$

Source: own work.

Those models seem to fit the data well. When it comes to economic outcomes R2 explains 47% of the variance in the dependent variable. In case of environmental outcomes - the percentage of explained variance is 43%. However, in the case of social outcomes - it is 39%. The regression equations can be written as follows (the equation for three models are presented in table 4):

Yorganizational outcomes = b0 + b1 x X1 + b2 x X2 + b3 x X3 + b4 x X4

where:

X1 - Environmental product innovations,

X2 - Environmental process innovations,

X3 - Environmental organizational innovations,

X4 - Environmental marketing innovations.

Table 4.
The regression equations

	Poland
Economic out-comes (ECL OUT*)	YECL_OUT = 1.501 + 0,219 x X_1 + 0,157 x X_2 +0,331 x X_4
Environmental out-comes (ENV_OUT*)	YENV_OUT = 1,427 + 0,197 x X_1 + 0,246 x X_2 + 0,249 x X_4
Social out-comes (SOC_OUT*)	YSOC_OUT = 1,407 + 0,220 x X_2 + 0,388 x X_4

Source: own work.

6. Discussion and conclusions

Empirical research confirmed that different types of environmental innovations are essential factors for sustainable outcomes and, as a result, their growth. Research also revealed differences and similarities between companies operating in Poland.

We can note that the relationship between product innovation and economic outcomes is not statistically significant, and process and organizational innovations matter, but marketing innovations do not, for the out-comes (presented on Fig. 2).

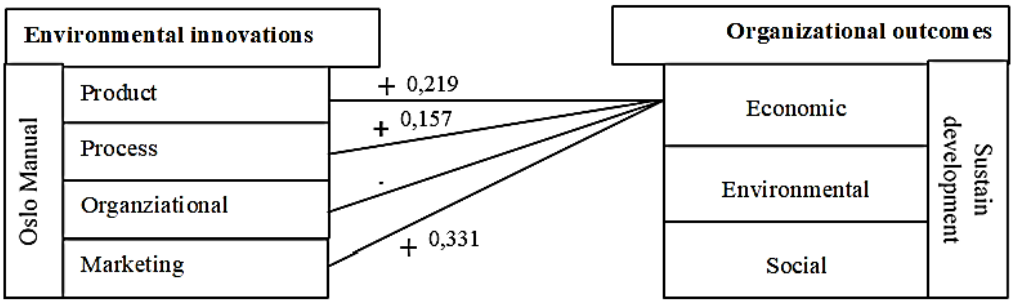

Figure 2. Relationship between environmental innovations and economic outcomes in Poland.
Source: own work.

The relationship between all types of innovation and environmental performance proved statistically significant (presented in Fig. 3). What can result from consistency in setting environmental goals and pursuing them in order to achieve not only the goal resulting from the implementation of the innovation itself, but also the measurement of the assumed environmental effects.

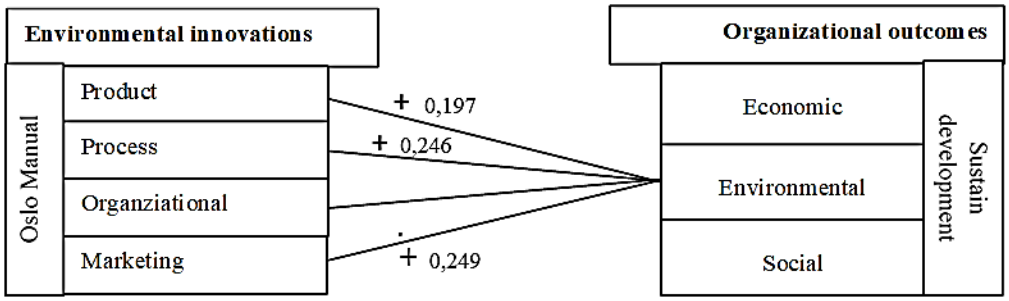

Figure 3. Relationship between environmental innovations and environmental outcomes in Poland.
Source: own work.

In terms of social outcomes the relationship between process and organizational innovations was revealed to be statistically significant, although the relationship with marketing innovations is significant only for companies operating in Poland (presented on Fig. 4).

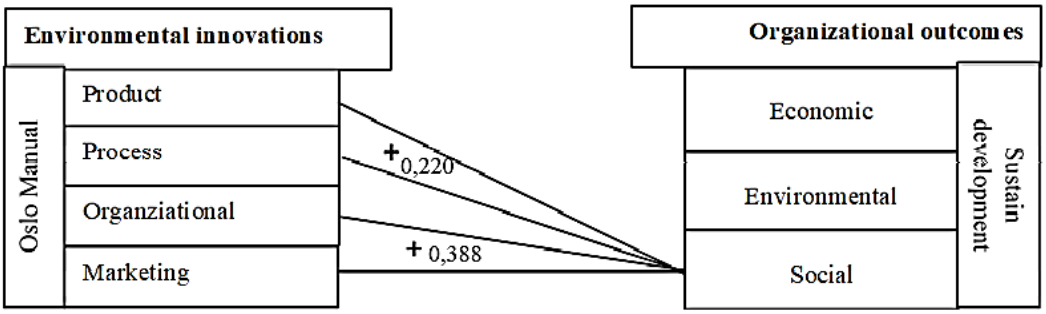

Figure 4. Relationship between environmental innovations and social outcomes in Poland.
Source: own work.

Undoubtedly, the challenges of sustainable development are an important motivator for business innovation while allowing the creation of competitive advantages (Hansen et al., 2009). Coupled with increasing concern for sustainability and sustainable development issues, environmental innovations have been of increasing interest among both scholars and practitioners (Hizarci-Payne et al., 2021). Furthermore, the relationship between environmental management practices and company performance has been an ongoing focus of academic research (Tsai et al., 2020). However, reports in the literature on the impact of environmental innovations on business performance are inconclusive (Tang et al., 2018). Studies presented in the related literature focus mainly on the technological aspect, less on the social (Cheng et al., 2014) and organizational aspects.

This study adds to the literature on the relationship between the types of innovation identified in the Oslo Manual and the dimensions of sustainable performance. The research presented in the article shows that distinguished types of innovation support sustainable performance of companies, but differences can be observed between companies operating in Poland. The observed differences may be due to culturally different contexts and longer practice in sustainability-oriented activities. Furthermore, this study analyzes different types of innovations, indicating that there is no significant relationship between them and the dimensions of sustainable performance (presented in Table 5).

Table 5.
Summary of the research

Outcomes	Product	Process	Organizational	Marketing
Economic	+	+		+
Environmental	+	+		+
Social		+		+

Source: own work.

The research revealed a surprising lack of a relationship between environmental product innovation with social performance. However, in the case of environmental performance, this research confirmed some of the results presented in (Ch'ng et al., 2021) on the relationship with innovation in process. At the same time, a different result for organizational innovation was noted, which in the article in (Ch'ng et al., 2021) – lack of relationships, while this research also indicates a link with all sustainable outcomes and lack of relationship between product innovations and social outcomes. Moreover, marketing innovation in Poland supports economic, environmental and social outcomes. This seems to be an interesting conclusion - perhaps again, it is related to cultural conditions, perhaps the goals set for the activities (their priorities) related to the dimensions of sustainable development.

In this sense, the main contribution of this study is a broad and holistic view, which made it possible to use the four types of environmental innovations and link them in the model to organizational performance and clarify the relationship between them. It seems crucial to take a systemic view of what innovations collectively build the model and to note that organizational innovation appears as an element present in each of the models obtained. Thus, it is

an indication that organizational activities should support process, marketing, or product innovations to lead to sustainable results of environmental innovation implementation.

Research limitations

This study has several limitations that should be taken into account in the interpretation and implications of its results. First, although outcomes were measured using subjective indicators consisting of a limited number of items. Using objective indicators or collecting data through in-depth interviews would have provided more detailed data. Likewise, increasing the size of the research sample and expanding the research to include companies operating in other countries (replication of research) would allow for generalization of the results, as the results obtained may be specific to companies operating in Poland.

Future research directions

Future research could address the relationship between environmental innovation and sustainable organizational outcomes with exogenous contextual factors, eg, dimensions of national cultures and macroeconomic indicators. Likewise, the link with exogenous factors, e.g. age and size of the organization, culture, core values, leadership, management style, or organizational structure. It is also ambiguous whether radical or incremental innovation, or some combination of the two, contributes more to higher sustainable performance. Therefore, it would seem interesting to consider the distinction between radical and incremental innovations and verify whether other dimensions of sustainable outcomes will be influenced. For it cannot be assumed that the assumption should be made that radical innovations promote sustainability more than incremental ones. Similarly, an analysis of all types of innovation - social, environmental, economic, and sustainable outcomes - would also be valuable.

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References

1. Aguilera-Caracuel, J., Ortiz-de-Mandojana, N. (2013). Green Innovation and Financial Performance: An Institutional Approach. *Organization and Environment*, *26*(4). https://doi.org/10.1177/1086026613507931.
2. Aldieri, L., Makkonen, T., Paolo Vinci, C. (2020). Environmental knowledge spillovers and productivity: A patent analysis for large international firms in the energy, water and land resources fields. *Resources Policy*, *69*. https://doi.org/10.1016/j.resourpol.2020.101877.
3. Aschehoug, S.H., Boks, C., Storen, S. (2012). Environmental information from stakeholders supporting product development. *Journal of Cleaner Production*, *31*. https://doi.org/10.1016/j.jclepro.2012.02.031.
4. Berry, M.A., Rondinelli, D.A. (1998). Proactive corporate environmental management: A new industrial revolution. *Academy of Management Executive*, *12*(2). https://doi.org/10.5465/ame.1998.650515.
5. Boons, F., Montalvo, C., Quist, J., Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production*, *45*. https://doi.org/10.1016/j.jclepro.2012.08.013.
6. Cai, W., Li, G. (2018). The drivers of eco-innovation and its impact on performance: Evidence from China. *Journal of Cleaner Production*, *176*. https://doi.org/10.1016/j.jclepro.2017.12.109.
7. Ch'ng, P.C., Cheah, J., Amran, A. (2021). Eco-innovation practices and sustainable business performance: The moderating effect of market turbulence in the Malaysian technology industry. *Journal of Cleaner Production*, *283*, 124556. https://doi.org/10.1016/J.JCLEPRO.2020.124556.
8. Chan, H.K., Yee, R.W.Y., Dai, J., Lim, M.K. (2016). The moderating effect of environmental dynamism on green product innovation and performance. *International Journal of Production Economics*, *181*. https://doi.org/10.1016/j.ijpe.2015.12.006.
9. Chen, Y.S., Lai, S.B., Wen, C.T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67*(4). https://doi.org/10.1007/s10551-006-9025-5.
10. Cheng, C.C.J., Yang, C.L., Sheu, C. (2014). The link between eco-innovation and business performance: A Taiwanese industry context. *Journal of Cleaner Production*, *64*. https://doi.org/10.1016/j.jclepro.2013.09.050.
11. da Silva Rabêlo, O., de Azevedo Melo, A.S.S. (2019). Drivers of multidimensional eco-innovation: empirical evidence from the Brazilian industry. *Environmental Technology (United Kingdom)*, *40*(19). https://doi.org/10.1080/09593330.2018.1447022.
12. Dogaru, L. (2020). Eco-innovation and the contribution of companies to the sustainable development. *Procedia Manufacturing*, *46*. https://doi.org/10.1016/j.promfg.2020.03.043.

13. Dögl, C., Holtbrügge, D. (2014). Corporate environmental responsibility, employer reputation and employee commitment: An empirical study in developed and emerging economies. *International Journal of Human Resource Management*, *25*(12). https://doi.org/10.1080/09585192.2013.859164.
14. Doh, J.P., Howton, S.D., Howton, S.W., Siegel, D.S. (2010). Does the market respond to an endorsement of social responsibility? The role of institutions, information, and legitimacy. *Journal of Management*, *36*(6). https://doi.org/10.1177/0149206309337896.
15. Driessen, P.H., Hillebrand, B., Kok, R.A.W., Verhallen, T.M.M. (2013). Green new product development: The pivotal role of product greenness. *IEEE Transactions on Engineering Management*, *60*(2). https://doi.org/10.1109/TEM.2013.2246792.
16. Faber, N., Jorna, R., van Engelen, J. (2009). The sustainability of "sustainability" — A study into the conceptual foundations of the notion of "sustainability". In: *Tools, Techniques and Approaches for Sustainability: Collected Writings in Environmental Assessment Policy and Management*. https://doi.org/10.1142/9789814289696_0016.
17. Fernando, Y., Chiappetta Jabbour, C.J., Wah, W.X. (2019). Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: Does service capability matter? *Resources, Conservation and Recycling*, *141*, 8-20. https://doi.org/10.1016/J.RESCONREC.2018.09.031.
18. Garcia, R., Wigger, K., Hermann, R.R. (2019). Challenges of creating and capturing value in open eco-innovation: Evidence from the maritime industry in Denmark. *Journal of Cleaner Production*, *220*. https://doi.org/10.1016/j.jclepro.2019.02.027.
19. Hahn, T., Figge, F., Pinkse, J., Preuss, L. (2010). Editorial Trade-Offs in Corporate Sustainability: You Can't Have Your Cake and Eat It. In: *Business Strategy and the Environment, Vol. 19, Iss. 4*. https://doi.org/10.1002/bse.674.
20. Hanelt, A., Busse, S., Kolbe, L.M. (2017). Driving business transformation toward sustainability: exploring the impact of supporting IS on the performance contribution of eco-innovations. *Information Systems Journal*, *27*(4). https://doi.org/10.1111/isj.12130.
21. Hansen, E.G., Grosse-Dunker, F., Reichwald, R. (2009). Sustainability innovation cube - A framework to evaluate sustainability-oriented innovations. *International Journal of Innovation Management*, *13*(4). https://doi.org/10.1142/S1363919609002479.
22. Hizarci-Payne, A.K., İpek, İ., Kurt Gümüş, G. (2021). How environmental innovation influences firm performance: A meta-analytic review. *Business Strategy and the Environment*, *30*(2). https://doi.org/10.1002/bse.2678.
23. Horbach, J. (2008). Determinants of environmental innovation-New evidence from German panel data sources. *Research Policy*, *37*(1). https://doi.org/10.1016/j.respol.2007.08.006.
24. Jaggi, B., Freedman, M. (1992). An examination of the impact of pollution performance on economic and market performance: pulp and paper firms. *Journal of Business Finance & Accounting*, *19*(5). https://doi.org/10.1111/j.1468-5957.1992.tb00652.x.

25. Kok, L., Wurpel, G., ten Wolde, A. (2013). Unleashing the Power of the Circular Economy. Report by IMSA Amsterdam for Circle Economy. *The Circul Economy*.
26. Kumar, V., Rahman, Z., Kazmi, A.A. (2013). Sustainability Marketing Strategy: An Analysis of Recent Literature. *Global Business Review*, *14*(4). https://doi.org/10.1177/0972150913501598.
27. Lampikoski, T., Westerlund, M., Rajala, R., Möller, K. (2014). Green innovation games: Value-creation strategies for corporate sustainability. *California Management Review*, *57*(1). https://doi.org/10.1525/cmr.2014.57.1.88.
28. Larbi-Siaw, O., Xuhua, H., Owusu, E., Owusu-Agyeman, A., Fulgence, B.E., Frimpong, S.A. (2022). Eco-innovation, sustainable business performance and market turbulence moderation in emerging economies. *Technology in Society*, *68*, 101899. https://doi.org/10.1016/J.TECHSOC.2022.101899.
29. Liao, Z. (2018). Corporate culture, environmental innovation and financial performance. *Business Strategy and the Environment*, *27*(8). https://doi.org/10.1002/bse.2186.
30. Lin, B.C., Zheng, S. (2016). A new direction in environmental economics. *Journal of Economic Surveys*, *30*(3). https://doi.org/10.1111/joes.12166.
31. Liu, X., Dai, H., Cheng, P. (2011). Drivers of integrated environmental innovation and impact on company competitiveness: Evidence from 18 Chinese firms. *International Journal of Technology and Globalisation*, *5*(3-4). https://doi.org/10.1504/IJTG.2011.039767.
32. Medrano, N., Cornejo-Cañamares, M., Olarte-Pascual, C. (2020). The impact of marketing innovation on companies' environmental orientation. *Journal of Business and Industrial Marketing*, *35*(1). https://doi.org/10.1108/JBIM-10-2018-0319.
33. Melece, L. (2015). Eco-innovation and its development in Baltic states. *Management Theory and Studies for Rural Business and Infrastructure Development*, *37*(3). https://doi.org/10.15544/mts.2015.36.
34. Nishitani, K., Jannah, N., Kaneko, S., Hardinsyah. (2017). Does corporate environmental performance enhance financial performance? An empirical study of Indonesian firms. *Environmental Development*, *23*. https://doi.org/10.1016/j.envdev.2017.06.003.
35. OECD (2009). Sustainable Manufacturing and Eco-Innovation: Framework, Practices and Measurement. In: *Oecd*.
36. OECD (2011). Better Policies to Support Eco-Innovation. In: *OECD Studies on Environmental Innovation*.
37. OECD/Eurostat (2018). Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation. The Measurement of Scientific, Technological and Innovation Activities. *Handbook of Innovation Indicators and Measurement*.
38. Orlitzky, M., Schmidt, F.L., Rynes, S.L. (2003). Corporate social and financial performance: A meta-analysis. *Organization Studies*, *24*(3). https://doi.org/10.1177/0170840603024003910.

39. Porter, M.E. (1991). America's green strategy. *Scientific American*, *264*(4).
40. Przychodzen, J., Przychodzen, W. (2013). Corporate sustainability and shareholder wealth. *Journal of Environmental Planning and Management*, *56*(4). https://doi.org/10.1080/09640568.2012.685927.
41. Rabadán, A., González-Moreno, Á., Sáez-Martínez, F.J. (2019). Improving firms' performance and sustainability: The case of eco-innovation in the agri-food industry. *Sustainability (Switzerland)*, *11*(20). https://doi.org/10.3390/su11205590.
42. Redman, A. (2018). Harnessing the Sustainable Development Goals for businesses: A progressive framework for action. *Business Strategy and Development*, *1*(4). https://doi.org/10.1002/bsd2.33.
43. Rennings, K., Ziegler, A., Ankele, K., Hoffmann, E. (2006). The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance. *Ecological Economics*, *57*(1). https://doi.org/10.1016/j.ecolecon.2005.03.013.
44. Rezende, L. de A., Bansi, A.C., Alves, M.F.R., Galina, S.V.R. (2019). Take your time: Examining when green innovation affects financial performance in multinationals. *Journal of Cleaner Production*, *233*. https://doi.org/10.1016/j.jclepro.2019.06.135.
45. Roper, S., Tapinos, E. (2016). Taking risks in the face of uncertainty: An exploratory analysis of green innovation. *Technological Forecasting and Social Change*, *112*. https://doi.org/10.1016/j.techfore.2016.07.037.
46. Santos, D.F.L., Lima, M.M. de, Basso, L.F.C., Kimura, H., Sobreiro, V.A. (2017). Eco-innovation and financial performance at companies established in Brazil. *International Journal of Business and Emerging Markets*, *9*(1). https://doi.org/10.1504/ijbem.2017.080783.
47. Savitz, A.W., Weber, K. (2006). The Triple Bottom Line How Today's Best-Run Companies Are Achieving Economic, Social, and Environmental Success— and How You Can Too. *Trusteeship, Vol. 16, Iss. 5.*
48. Song, H., Zhao, C., Zeng, J. (2017). Can environmental management improve financial performance: An empirical study of A-shares listed companies in China. *Journal of Cleaner Production*, *141*. https://doi.org/10.1016/j.jclepro.2016.09.105.
49. Tang, M., Walsh, G., Lerner, D., Fitza, M.A., Li, Q. (2018). Green Innovation, Managerial Concern and Firm Performance: An Empirical Study. *Business Strategy and the Environment*, *27*(1). https://doi.org/10.1002/bse.1981.
50. Tsai, K.H., Huang, C.T., Chen, Z.H. (2020). Understanding variation in the relationship between environmental management practices and firm performance across studies: A meta-analytic review. *Business Strategy and the Environment*, *29*(2). https://doi.org/10.1002/bse.2386.

51. Tseng, M.L., Wang, R., Chiu, A.S.F., Geng, Y., Lin, Y.H. (2013). Improving performance of green innovation practices under uncertainty. *Journal of Cleaner Production*, *40*. https://doi.org/10.1016/j.jclepro.2011.10.009.
52. Tumelero, C., Sbragia, R., Evans, S. (2019). Cooperation in R & D and eco-innovations: The role in companies' socioeconomic performance. *Journal of Cleaner Production*, *207*. https://doi.org/10.1016/j.jclepro.2018.09.146.
53. UN (2017). A/RES/71/313. Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development. *General Assembly*, *July*.
54. Vargas-Vargas, M., Meseguer-Santamaría, M.L., Mondéjar-Jiménez, J., Mondéjar-Jiménez, J.A. (2010). Environmental protection expenditure for companies: A spanish regional analysis. *International Journal of Environmental Research*, *4*(3).
55. Vasileiou, E., Georgantzis, N., Attanasi, G., Llerena, P. (2022). Green innovation and financial performance: A study on Italian firms. *Research Policy*, *51*(6), 104530. https://doi.org/10.1016/J.RESPOL.2022.104530.
56. Wagner, M., Llerena, P. (2011). Eco-Innovation Through Integration, Regulation and Cooperation: Comparative Insights from Case Studies in Three Manufacturing Sectors. *Industry and Innovation*, *18*(8), 747-764. https://doi.org/10.1080/13662716.2011.621744.
57. Walecka-Jankowska, K., Zgrzywa-Ziemak, A., Zimmer, J. (2017). Innowacje zorientowane na zrównoważony rozwój z perspektywy różnych koncepcji zrównoważenia przedsiębiorstwa. In: P. Kubiński (Ed.), *Innowacje w biznesie: nowe modele i nowe praktyk* (pp. 63-81). Exante.
58. Yurdakul, M., Kazan, H. (2020). Effects of eco-innovation on economic and environmental performance: Evidence from Turkey's manufacturing companies. *Sustainability (Switzerland)*, *12*(8). https://doi.org/10.3390/SU12083167.
59. Zhang, Y., Sun, J., Yang, Z., Wang, Y. (2020). Critical success factors of green innovation: Technology, organization and environment readiness. *Journal of Cleaner Production*, *264*. https://doi.org/10.1016/j.jclepro.2020.121701.

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SHAPING SUSTAINABLE DEVELOPMENT COMPETENCIES THROUGH STUDENT INTERNSHIPS

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Purpose: One of the most important challenges of civilization in the contemporary world is obtaining the goals of sustainable development. This challenge is addressed to present and future generations who have to possess or acquire various sustainable development competencies. Shaping them is particularly essential in the case of generation Z, thus it should take place both in the process of academic education, as well as in cooperation with university stakeholders. The aim of the paper is to answer the question of whether the implementation of students' internships enables shaping sustainable development competencies.
Design/methodology/approach: The survey was conducted in Poland in 2022 among 367 full-time students in the management field of study. The CAWI method was used. The paper presents a quantitative analysis of the obtained data. In the theoretical part of the article, the author explained the essence and goals of sustainable development, described sustainable development competencies, and the role of higher education and stakeholders in shaping the SD competencies of Generation Z.
Findings: Generation Z has a positive attitude towards the implementation of the concept of sustainable development and almost all of the studied sustainable development goals are of great importance to the respondents. The obtained results confirmed that the implementation of internships in a real work environment affects the shape of many SD competencies of students. The greatest opportunities for the development of SD competencies were provided to interns by business organisations and administration, while less importance was assigned to such stakeholders as NGOs. Students expect the cooperation of the university and its stakeholders in shaping their SD competencies.
Research limitations/implications: The size of the surveyed group does not allow for the formulation of general conclusions. However, the obtained results may be the basis for further in-depth studies on the problem. Similar research could be conducted to establish the opinion of employers and university representatives with a broader consideration of other variables.
Practical implications: The conclusions of the study will provide universities and various stakeholders with valuable information on the possibility of using student internships to develop SD competencies of representatives of Generation Z.
Originality/value: The obtained results allow one to fill the research gap concerning the assessment of whether the realization of student internships in a real work environment enables shaping students' competencies in the field of sustainable development.

Keywords: sustainable development, sustainable competencies, green competencies, education for sustainable development, internships, stakeholders, business students, Generation Z.

Category of the paper: Research paper.

Introduction

In 2015, in New York, the leaders of UN member countries signed the document called "Transforming Our World: the 2030 Agenda for Sustainable Development". In this way, they made an ambitious commitment to initiate to take steps to reduce poverty in all its forms, ensure access to education, food and clean water, take action for equal opportunities, promote human rights, peace and stability in the world, protect the environment, mitigate climate change, provide access to sustainable energy sources (UNa).

The 2030 Agenda defines 17 sustainable development goals (SDGs) and 169 actions related to them, which have to be achieved by governments, international organisations, non-governmental organisations, the science and business sector, as well as by citizens (UNc). They focus on 5 areas: people, planet, prosperity, peace, and partnership. They indicate what actions should be taken and what their results should be. A graphical presentation of the 17 SDGs is shown in Figure 1.

Figure 1. The Sustainable Development Goals (SDGs).

Source: (UNb).

The UN's 17 Sustainable Development Goals aim to guide countries towards a sustainable future and a more peaceful and inclusive society (Gupta, Vegelin, 2016; Lim et al., 2018). Achieving these goals is possible by including sustainable development (SD) in education at all levels, in particular training teachers and trainers in sustainability issues, and how to integrate them into their daily practice, ensuring that updated and new curricula take economic, social, and environmental dimensions of sustainable development, and making education for SD an integral part of the training of leaders in business, industry, trade union, non-profit and voluntary organisations, and the public service (UNESCO, 2013).

Representatives of Generation Z will play a key role in achieving SD goals. In the literature, it is assumed that Generation Z is the cohort group born after 1995 (Lut, 2020). Generation Z is currently at the stage of completing education as students and beginning professional careers becoming of interest to the employment market (Goh, Lee, 2018).

The academic education of this generation is currently often based on curricula including the subject of sustainable development, but the implementation of these programs is mainly theoretical. It is important to look for opportunities to develop SD competencies not only in the formal education system but also in a practical way, as real-world learning (Brundiers et al., 2010), for example through students' participation in internships organized by universities (Rios et al., 2018; Lopes et al., 2019). Undertaking cooperation between various stakeholders (UN, 2020; Cavicchi, 2021), including especially collaboration between universities and employers, can significantly support the development of a range of SD competencies of generation Z representatives (Oonk et al., 2022).

On the basis of the review of the literature on the subject, it can be stated that numerous studies are being conducted concerning education in the field of sustainable development. Many authors focus on education programs (Trencher et al., 2018; Obrecht et al., 2022; Pubule et al., 2019; Wiek et al., 2016) or the necessity to adapt them to the requirements published in various official documents, e.g. UNESCO, UN, Agenda 2030, etc. (Leal et al., 2019; Owens, 2017; Annan-Diab, Molinari, 2017).

Other studies refer to the analysis of competencies acquired during the formal education process in educational institutions (Scharenberg et al., 2021), in particular in higher education institutions (Remington-Doucette, Musgrove, 2015; Hay, Eagle, 2020; Alm et al., 2022), and also concern learning methods (Figueiro et al. 2022) and assessment of the effects of education concerning sustainability competencies (Cebrián et al., 2019; Sandri et al., 2018). The results of research discussing SD competencies are also interesting from the teachers' point of view (Cebrián , Junyent, 2015; Rieckmann, Barth, 2022; Scherak, Rieckmann, 2020; Corres et al., 2020; Poza-Vilches et al., 2019).

Some authors present research results that take into account the characteristics of respondents, such as age (Remington-Doucette, Musgrove, 2015; Orobia et al., 2020), gender (Remington-Doucette, Musgrove, 2015; Finnveden et al., 2019), job position (Cavicchi, 2021), field of study (Remington-Doucette, Musgrove, 2015; Hay, Eagle, 2020). However,

the literature on shaping sustainable competencies within the field of management and business education is not very extensive. Interesting results were obtained by Ziegler and Porto-de-Oliveira (2022), who described a backcasting approach to education for sustainable development in management based on group-based, service-learning. A bibliometric review of current trends and research needs in the area of educating business students about sustainability was developed by Cullen (2017). Research concerning the education of students in SD in the field of management was also conducted by Corazza et al. (2022), and Figueiro et al. (2022). However, this research was more concerned with the education of students in a formalized way within academic education. On the other hand, the issue of developing students' competencies in the field of SD in a real work environment is relatively rarely analysed (Brundiers et al., 2010), in cooperation with various stakeholders (Cavicchi, 2021).

A research gap has been identified in this area, indicating the lack of sufficient research on the opinions of management students on the development of their SD competencies in a real work environment, as a result of the involvement of employers as stakeholders of higher education institutions who enable students to carry out their internships.

The aim of the article is to assess the possibility of using student internships to shape students' competencies in the field of sustainable development. Bridging the identified research gap made it possible to formulate the following research question: does the implementation of student internships in a real work environment enable shaping of students' competencies in the field of sustainable development?

In this article, the author first concentrates on the literature review concerning three main areas: the essence and goals of sustainable development, sustainable development competencies, and the role of higher education and stakeholders in shaping the SD competencies of Generation Z. Then, the description of the methodology, and the description of the research sample are given. Afterwards, the data are analysed, and the results are discussed. Finally, the conclusions and limitations of this study are provided.

The essence and goals of sustainable development

Technological, structural, and demographic changes in an increasingly interconnected world mean that the nature of work is also changing. In accordance with the EU model of social well-being, no person or place should be left behind in the transition to a sustainable economy. Social investment must remain an overriding priority, including in such areas as education, training, lifelong learning, and working conditions. These are the key factors enabling changes towards a sustainable Europe by 2030 (European Commission).

One of the first and most frequently quoted definitions of sustainable development was published in 1987 by the Bruntland Commission in the report called Our Common Future, in which sustainable development means “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN, 1987, p. 43). Over the years, this definition is still used (UNb), although various authors include additional aspects in it. For example, Aleixo et al. (2018) define sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs, through transdisciplinary practices and the development of key competencies in education promoted by new ICTs to create collaborative business models".

SD has become the overriding priority of all strategic activities for many countries. Incorporating this concept into the mission and vision has been recognized as a key issue for economic development. Currently, sustainable development is perceived as making efforts to balance the environment, social and economic system based on the assumption that organisations exist in an ecosystem, not in isolation (Orobia et al., 2020). In 2015, these three areas became the foundation for the UN 2030 Agenda for Sustainable Development strategy to achieve the Sustainable Development Goals.

As mentioned, the 2030 Agenda contains 17 SDGs which form the basis of all SDG – related activities and research, and their full wording makes it possible to clarify their meaning and significance (UNd).

Goal 1. End poverty in all its forms everywhere.

Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

Goal 3. Ensure healthy lives and promote well-being for all at all ages.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 5. Achieve gender equality and empower all women and girls.

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable, and modern energy for all.

Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Goal 10. Reduce inequality within and among countries.

Goal 11. Make cities and human settlements inclusive, safe, resilient, and sustainable.

Goal 12. Ensure sustainable consumption and production patterns.

Goal 13. Take urgent action to combat climate change and its impacts;

Goal 14. Conserve and sustainably use the oceans, sea, and marine resources for sustainable development.

Goal 15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Achieving these goals is only possible by reducing poverty, hunger, the gender gap, and inequalities and increasing the sustainable management of resources and awareness about climate change (Reckien et al., 2017).

The Agenda 2030 is addressed not only to governments and parliaments, international institutions, local authorities, and residents but also to businesses and the private sector (Stiglitz, 2019). The provisions of the Agenda refer directly to businesses: "We acknowledge the role of the diverse private sector, ranging from micro- enterprises to cooperatives to multinationals. We call upon all businesses to apply their creativity and innovation to solving sustainable development challenges" (point 67 of the Agenda) (Pizzi et al., 2020).

Sustainable development goals are therefore becoming important in the activities of modern enterprises. As a result, they incorporate universal values and principles relating to human rights, labour, the environment, and anti-corruption into their strategies and activities. Business is a force that can do good in social life. Advocating sustainable development, businesses in the era of Industry 4.0 can and should take responsibility for their actions and their impact on the environment and society, and also contribute to building a better world (Imran et al., 2019).

In order to ensure the sustainable development of enterprises, managers must be aware of the potential consequences of their decisions to use their resources and make wise choices in implementing business strategies and activities that help the organisation achieve better results (Karkoulian et al., 2016). What is more, sustainable development must include the ability of the company to stay in business for a long time while achieving excellent financial performance and administrative systems that increase employee productivity and company profits (Orobia et al., 2020). However, the sustainable development of a company is not possible without the development of SD competencies of employees.

Sustainable development competencies

Wiek et al. define sustainability competencies as "a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem-solving with respect to real-world sustainability problems, challenges, and opportunities" (Wiek et al., 2011, p. 204). According to Cebrián and Junyent (2015), the term sustainability competencies

is the combination of cognitive skills, practical abilities, and ethical values and attitudes mobilised in a real situation or context related to sustainability.

Reviewing the literature on the subject shows that there are many definitions and classifications of competencies related to sustainable development. Over the last few years, there has been a rapid increase in the number of publications regarding the assessment of sustainability competencies (Cebrián et al., 2019). An extensive analysis of the types of competencies and their classification was made by Corres et al. (2020). One of the most often discussed classifications was presented in a document developed by UNESCO (2017) and contains the following 8 key competencies: systems thinking competency, anticipatory competency, normative competency, strategic competency, collaboration competency, critical thinking competency, self-awareness competency, integrated problem-solving competency (UNESCO 2017). A detailed description of their meaning is presented in Table 1.

Table 1.
Sustainability competencies

Competencies	Description
Systems thinking competency	The abilities to recognize and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.
Anticipatory competency	The abilities to understand and evaluate multiple futures – possible, probable, and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.
Normative competency	The abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
Strategic competency	The ability to collectively develop and implement innovative actions that further sustainability at the local level and further afield.
Collaboration competency	The abilities to learn from others; to understand and respect the needs, perspectives, and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem-solving.
Critical thinking competency	The abilities to question norms, practices, and opinions; to reflect on one's own values, perceptions, and actions; and to take a position in the sustainability discourse.
Self-awareness competency	The abilities to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.
Integrated problem-solving competency	The overarching abilities to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive, and equitable solution options that promote sustainable development, integrating the abovementioned competencies.

Source: (UNESCO, 2017, p. 10).

This classification became the starting point for many authors dealing with the subject of SD competencies. For example, Rios et al. (2018) adapted these competencies for practical application at the University of Calgary. The authors studied such competencies as anticipatory thinking and long-term foresightedness; empathy and understanding of different worldviews and relationships; capacities for stakeholder engagement and group collaboration; action-oriented leadership skills and change agency skills; critical thinking and decision-making capacity within complexity; and systems thinking and an understanding of connectedness.

Based on their extensive literature survey and analysis of competencies, Lozano et al. (2017) identified the following set of 12 SD competencies: system thinking, interdisciplinary work, anticipatory thinking, justice, responsibility and ethics, critical thinking and analysis, interpersonal relations and collaboration, empathy and a change of perspective, communication and use of media, strategic action, personal involvement, assessment and evaluation, and tolerance of ambiguity and uncertainty.

One of the oldest classifications of competencies in the range of SD, which is very often described in the scientific literature and used in empirical research, was developed by de Haan (2010). The author distinguishes 12 competencies which have been divided into 3 groups:

1. Interactive use of media and methods:
   - Competence to take on new perspectives: the ability to build up knowledge with an open mind and new attitudes.
   - Competence in anticipation: the ability to analyse and assess developments with foresight.
   - Competence in interdisciplinary knowledge acquisition: gaining knowledge and being able to act at an interdisciplinary level.
   - Competence in dealing with incomplete and overly complex information: recognising and weighing up risks, dangers, and uncertainties.
2. Interaction in heterogeneous groups:
   - Competence in cooperation: the ability to plan and work together with others.
   - Competence to cope with difficult individual decisions: the ability to consider conflicting goals when reflecting on strategies for action.
   - Competence in participation: the ability to participate in collective decision-making and development processes.
   - Competence in motivation: the ability to motivate oneself and others to become active.
3. Acting autonomously:
   - Competence to reflect on models: the ability to reflect on one's own models and those of others.
   - Competence in moral action: the ability to use ideas of justice as a basis for decision-making and action.
   - Competence to act independently: the ability to plan and act independently.
   - Competence to support others: the ability to show empathy for others.

Cebrián and Junyent (2015) developed a theoretical framework of the professional SD competencies and elaborated 8 key components:

- Future/alternative scenarios visioning: understanding the different scenarios, possible futures, promoting work with different visions and scenarios for alternative and future changes.

- Contextualizing: taking into account the different dimensions of a problem or action, the spatial dimension (local-global) and the temporal dimension (past, present, and future).
- Work and live with complexity: the ability to identify and connect the ecological, economic, and social dimensions of problems. Generate the conditions for systems thinking in the school environment.
- Think critically: creating the conditions for critical thinking to question assumptions and to recognize and respect different trends and views in different situations.
- Decision-making, participation and acting for change: moving from awareness to action; sharing responsibilities and engaging in joint action.
- Clarify values: values clarification and strengthening behaviour towards sustainability thinking, mutual respect, and understanding of other values.
- Establish a dialogue between disciplines: developing teaching and learning approaches based on innovation and interdisciplinarity.
- Manage emotions and concerns: promoting reflection on one's own emotions and as a means to reach a deeper understanding of problems and situations.

The above examples present general classifications of SD competencies, while other divisions, specific to particular situations, can also be found in the literature. For example, Cavicchi (2021), based on the literature (Salgado et al., 2018), formulated six work experiences to assess the development of SD competencies during student internships:

- part in interdisciplinary projects requiring the integration of different approaches derived from the natural and social sciences,
- develop an awareness of the different perspectives of the stakeholders involved in SD projects,
- identify problems related to the management of SD issues,
- propose solutions to SD problems, owing to their development of networking abilities with institutional and entrepreneurial organisations,
- improve their understanding of SD policies promoted at the institutional level, as well as of the possible impact of these policies and the scenarios they generate in the local context,
- combine their personal and professional development with active citizenship favoring SD.

When discussing the subject of SD competencies, the issue of green competencies cannot be omitted (Bianchi et al., 2022). In recent years, there was considerable interest in green competencies, as reflected in the surge of articles published in this field. According to Cabral and Dhar (2021), green competencies are a multidimensional construct comprised of green knowledge, green skills, green abilities, green attitudes, green behaviours, and green awareness.

According to Zhao et al. (2014), environmental knowledge, attitudes and values of individuals are major factors that influence shaping green competencies. Green competencies are the green knowledge and skills that an individual has accumulated through previous experiences on environmental issues that lead to an individual's strong conviction and feeling towards acting in an environmentally friendly manner (Subramanian et al., 2015).

Green competencies are a set of sustainability competencies to feed into education programmes to help learners develop knowledge, skills, and attitudes that promote ways to think, plan and act with empathy, responsibility, and care for our planet and public health. Green competencies comprises four interrelated competence areas: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability. Each area comprises three competencies that are interlinked and equally important (Bianchi et al., 2022).

A slightly different approach to SD competencies was presented by Akkerman and Bakker (2011). According to the authors, one of the important principles of taking action in the context of sustainable development is developing competencies in the field of crossing borders. This means the necessity of having the ability to seek, recognize, appreciate, and use different boundaries to learn, co-create and introduce innovations together through practices. The first learning mechanism, i.e. identification, involves questioning one's own and others' core identities and exploring the mutual complementarity of different practices. Identification leads to insights into what the diverse practices concern but does not necessarily lead to actual collaboration. The second learning mechanism, i.e. coordination, expresses what people can learn from seeking communicative connections between diverse practices or perspectives, for example, by contacting each other to exchange relevant information or by using languages from different practices. The third mechanism, i.e. reflection, includes making and taking perspectives. People come "to realize and explicate differences between practices and thus to learn something new about their own and others' practices. The fourth learning mechanism, i.e. transformation, involves joint work at the boundaries between practices, combining ingredients from different practices into a new (i.e. hybrid) practice. According to Akkerman and Bakker (2011), boundary crossing learning is supposed to develop when these four learning mechanisms are adopted while learning across practices.

Summarizing the above considerations, it should be emphasized that there are many different classifications of SD competencies. However, a more important issue is how these competencies will be developed by current and future employees, in what circumstances they will be acquired and shaped, and who will be responsible for this process. A major role in the transition to a sustainable knowledge society should play higher education institutions (HEIs) (O'Riordan et al., 2020).

The role of higher education in shaping the SD competencies of generation Z

With the release of the 17 Sustainable Development Goals (SDGs, Resolution 2015), the role of education has been strengthened. SDG number 4 is about education, and its target 4.7 is designed explicitly to promote education for sustainable development.

After the establishment of the 17 SDGs, the UN launched a special appeal to higher education institutions to actively promote the SDGs in education and research (Annan-Diab, Molinari, 2017; Utama et al., 2018). Higher education institutions hold key responsibility for education including sustainable development (Mora et al., 2020). They should take a leadership role in implementing this transformation, preparing students to play an active role to support the transition process towards a sustainable society (Lambrechts, Hindson, 2016). Education for sustainable development is an integral part of quality education, where all educational institutions, and in non-formal and informal education, can and should foster the development of sustainability competencies (Cebrián et al., 2021).

Education can catalyze and/or accelerate social changes towards sustainable development. Educational institutions should offer curricula that support sustainable development attainments in knowledge, skills and attitudes, and ensure partnerships with stakeholders in business and community (UNESCO, 2014). Academic curricula should enable the development of key competencies in the field of sustainable development, including problem-solving skills and effective cooperation with experts and stakeholders (Brundiers et al., 2010).

A holistic vision of sustainable development establishes links between students, higher education institutions, and society (Aleixo et al., 2018). Universities are expected to act as "agents of change" (Korfgen et al., 2018), promoting the ideals of the SDGs through problem-oriented research and coherent educational programs. Universities must support a change in behaviour related to SD goals among students, scientists, researchers, and external stakeholders by undertaking various activities (Caeiro et al., 2020; Findler et al., 2019; Finnveden et al., 2019; Leal et al., 2019).

In recent years, SDGs have impacted HEIs' traditional curricula (Sanchez-Carracedo et al., 2021). According to the contents of the UNESCO report from 2014, changing the curricula requires the cooperation of various groups and institutions (UNESCO, 2014). The following actions are therefore necessary:

- taking collaboration across government, business communities, and educational institutions to identify the required skills and competencies,
- building stronger linkages between business and education systems, and the identification opportunities for apprenticeships and internships,
- collaboration across government and industry to work together on new standards and to work with education institutions to determine the skills needed to meet those standards,
- collaboration across the industry with institutions and learners in applied projects, internships, and other means for skills transfer and development.

Sustainable development requires a paradigm shift in education, which should be characterized by interactive learning in participatory environments (Holgaard et al., 2016). The competency development of SD should be conducted in such a way as to provide students with a learning environment from many different stakeholders (Oonk et al., 2022). This is especially important in the case of higher education because graduates will be working with many stakeholders in the future during their work on complex challenges within sustainable development (Schopp et al., 2020).

It should be noted that stakeholders' collaboration with universities in the field of education rarely regards activities in the real work environment. Most often it is only an exchange of information, e.g. consulting study programs or organizing seminars for students and teachers in the field of SD (Sisto et al., 2020). Academic education should bridge the gaps between theory and practice, thereby promoting more practical activities and projects in the sustainability curricula through greater dialogue with stakeholders. The possibility to involve different stakeholders can be an occasion to see what they really do in practice and show their experiences in terms of sustainability (Cavicchi, 2021). The activities of various stakeholders may influence the growth of SD competencies of representatives of generation Z. This is particularly important because representatives of this generation are currently students and will soon take up professional activity (Yamane, Kaneko, 2021).

Orobia et al. (2020) conducted research on engagement in sustainable development among youth, analysing the following aspects: economic (strategy, finance, marketing, and innovation), social (people and skills, social responsibility and stakeholders), and environmental (ecosystem, production and resource management). The authors identified a gap existing in the education system, pointing to the need for more practical education in the field of sustainable development. Also, students think it is necessary to learn by doing as a way of approaching sustainability in practical terms (Dziubaniuk, Nyholm, 2020).

Generation Z members are aware of various environmental, social, and economic challenges emerging in the modern world and feel co-responsible for solving them (Turner, 2015). Generation Z is sometimes referred to as the "green generation" because they have a high environmental awareness and try to consider the good of the environment in their consumption (Wawer et al., 2022). The most important environmental issues for them concern climate change (global warming), renewable energy (reducing oil dependency), stopping pollution (reducing emissions, eliminating pesticides), recycling and reducing waste, protecting wildlife, and optimising the use of resources (Wang et al., 2022). They are also ready to take part in the responsibility for the planet's condition themselves because they believe in intergenerational justice. They want to provide future generations with the earth in a state at least no worse than it is now (Oliveira, 2018). Developing an environmentally friendly approach in society is one of the main goals of sustainable development- oriented education (Tariq, 2020).

The role of stakeholders in the shaping of SD competencies through student internships

According to Freeman, the stakeholder means "any group or individual who can affect or is affected by the achievement of the organisation's objectives" (Freeman, 1984, p. 46). The main stakeholders include non-governmental organisations, local authorities, workers and trade unions, businesses and industry, the scientific and technological community, and farmers. Other relevant stakeholders are also invited to participate in UN processes related to sustainable development. These are for example local communities, educational and academic entities, foundations, and private philanthropic organisations (UN, 2020).

The stakeholders may be sustainability professionals from different organisations with different areas of expertise. They may also be professionals from different sectors, politicians in national or local government, activists, and users of environmental services as businesses or members of the public (Salgado et al. 2018).

First of all, higher education institutions are involved in the education of students, however, shaping attitudes and behaviours in the field of SD should take place not only in the formal education system, but also in the informal one, i.e. in everyday activities such as work, home, and leisure; and various types of training (UNESCO, 2014). Succeeding in education for SD means therefore the need to take into account two key areas, i.e. the world of life (Personal) and the world of work (Professional) (UNESCO, 2013). The key aspects of the links between these two areas are presented in Figure 2.

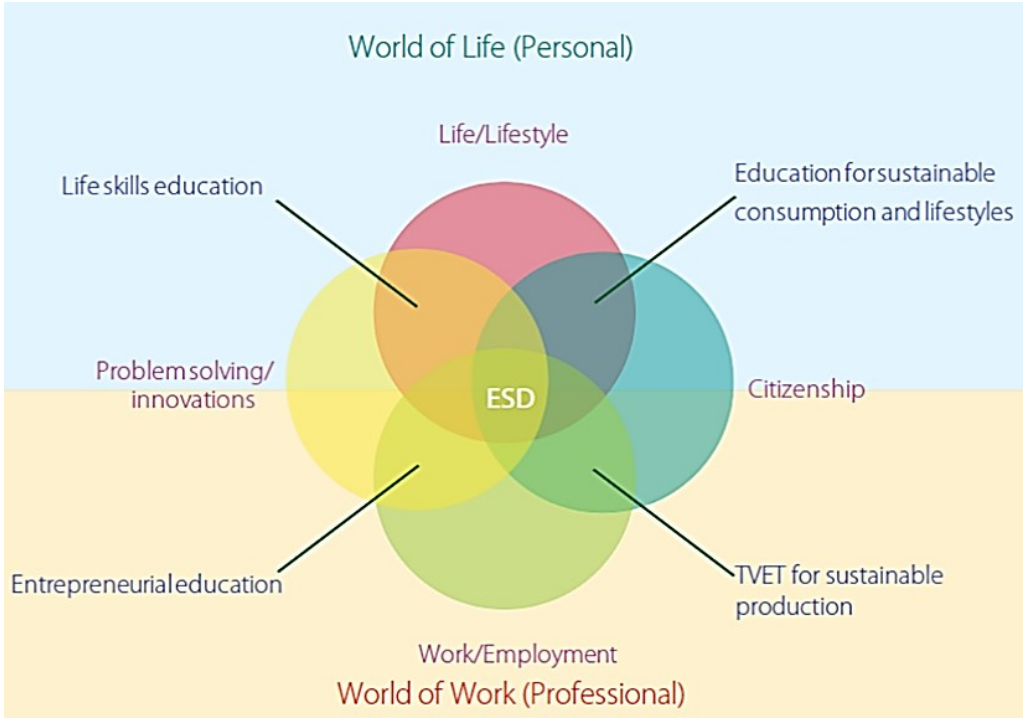

Figure 2. Key aspect of successful education for sustainable development.

Source: (UNESCO, 2013).

In SD education in the world of work, it is important to enable students to acquire skills appropriate to work for a desired employer or demonstrate entrepreneurial competence to start and run their own company in accordance with SD principles (Hermann, Bossle, 2020). It is these competencies that have a positive and significant impact on the owners and managers undertaking innovative activities in the field of sustainable development of small and medium enterprises (Denac et al., 2018; Ismail, 2022). This is possible, among others, thanks to real-world learning, which allows one to gain practical experience in combining knowledge with activities for sustainable development (Pretorius et al., 2021). Real-world learning opportunities allow students to recognize and engage in different forms of collaboration at different degrees of intensity. Linking knowledge to action requires students and their collaborating partners to ask critical questions – what works, what does not, why, and give constructive feedback – how could it work and why (Brundiers et al., 2010).

Being part of a stakeholder professional environment allows students to become familiar with different values and processes of reasoning and decision-making. Students begin to understand various institutional contexts within which a sustainability problem exists and how far this context influences which solution strategies are proposed and pursued by experts or stakeholders. According to Brundiers et al., (2010) dominant real-world learning models are project- and problem-based learning, service learning, and internships in communities, businesses, and governments. An overview of key differences between project-based learning, service learning, and internship has been presented in Table 2.

Table 2.
Overview of key differences among three dominant models of real-world learning formats

Area of comparison	Project-based learning	Service learning	Internship
Outcomes: what students learn/ benefit	Collaborative problem-solving capacity	Education and teaching capacity	Professional working experience; career development
Practices: what students do	Collaborating with partners to develop a solution approach	Educating people	Assisting or working on a professional project
Interaction with stakeholder	Two-way knowledge generation (co-production)	One-way knowledge transfer (students to community)	One-way knowledge transfer (employer to student and student to employer)
Integration of theory and practice	Explicit, supervised by faculty and stakeholder	Implicit, not supervised by faculty	Implicit, not supervised by faculty
Impacts on world	Systemic innovation	Support of social innovation and change	Modular innovation

Source: (Brundiers et al., 2010).

One of the valuable forms of practical learning is a student internship. Three basic benefits resulting from using internships in the process of educating students are as follows (Lopes et al., 2019):

- internships allow students to apply the theoretical knowledge they explored during classes in real working contexts,
- internships allow students to develop a range of personal, performative and organisational skills that go beyond the more traditional academic, theoretical knowledge and skills,
- internship experiences may reduce the emotional shock reported by many students when facing the job market for the first time since they have the opportunity to establish early contact with employers and co-workers.

The places where internships are carried out are various organisations - both business and non-profit ones. It is real-world learning implemented through internships in a real work environment, e.g. in enterprises, government, non-governmental organisations (NGOs), and research institutions, that can contribute to the greatest extent to the development of students' competencies in the field of SD (López López et al., 2019). Small- and medium-sized enterprises and non-profit organisations play a special role in the development of these competencies through internships (Rios et al., 2018). Thanks to internships, students are better prepared for professional activity (Gault et al., 2010), and their chances of finding employment faster increase (Clemente et al., 2020).

Research carried out by Oonk et al. (2019) indicates, however, that students during internships do not engage in sufficient cooperation with stakeholders and are not particularly willing to build relationships with them. Moreover, the students did neither show more competencies development as a result of working in this real and multi-stakeholder environment. Conducting considerations regarding the development of competencies in the field of SD is especially important in the case of representatives of the Z generation, who will soon take up professional activity and will decide on the implementation of SD goals in enterprises.

Concluding the above theoretical considerations, it should be emphasized that shaping competencies in the field of SD through practical education in the form of an internship is particularly important for students studying business courses – future managers, leaders, and business owners. It is them who will manage companies and human teams in the future and should do it in a sustainable and socially responsible manner (Cullen, 2017; Hay, Eagle, 2020). The future of the next generations may depend on their approach to the implementation of the SD goals set out in the 2030 Agenda.

Methodology

The aim of the conducted empirical research was to assess the use of student internships as a form of practical education of generation Z to shape competencies in the field of sustainable development. The main research question is as follows: does the implementation of the internship in a real work environment enable shaping students' competencies in the field of sustainable development?

Two detailed research questions have been formulated in the study:

Q1. What knowledge in the field of sustainable development do management students have and how important are the SD goals listed in Agenda 2030 according to them?

Q2. Does the implementation of internships in a real work environment enable shaping students' competencies in the area of sustainable development?

To achieve the research goal, the author developed a questionnaire consisting of 7 closed-ended questions. Three of them concerned question Q1, next four ones – question Q2. The author designed the questionnaire based on the literature analysis mentioned above, in particular UN d; UNESCO, 2017; Oliveira, 2018; Wiek et al., 2011; Cavicchi, 2021; Salgado et al., 2018.

The 5-point Likert scale has been applied to the questionnaire. Answers have been given on the scale: definitely yes, somewhat yes, neither yes nor no, somewhat no, definitely no, and also: very good, good, average, low, none (or: very important, important, moderately important, not important, not at all important), and also: very often, often, sometimes, rarely, never. The section with detailed information about respondents contained questions about the level of study, gender, and type of organisation, in which the internship was carried out.

From October to November 2022, emails with a link to the online questionnaire were sent to students of universities located in Poland. The data were collected using Computer-Assisted Web Interviewing (CAWI). For analysis, 367 questionnaires have been accepted. The survey was conducted among students of bachelor's (63%) and master's studies (27%), only in one field of study, i.e. management (100%). 62% of them were women and 38% were men. Respondents completed internships in the private sector (business) (59%), public administrations (23%), and non-governmental organisations (18%).

Results

The purpose of the first question of the questionnaire was to obtain information if they had gained knowledge about SD during university studies. *Definitely yes* answered 57% of people, *rather yes* 27%, and the rest of the respondents had no opinion. This result indicates that the

vast majority of management students acquired knowledge about SD during formal academic education. Such a result allows one to state not only that universities implement educational goals in the area of SD well in this group of students, but also that students possess SD knowledge and can competently answer the next questions included in the questionnaire.

The second question concerned the scope of the level of knowledge held by respondents in five areas related to SD, i.e. 17 SD Goals, Agenda 2030, carbon footprint, circular economy, and green competencies. The results are presented in Table 3.

Table 3.
The level of knowledge concerning SD (%)

Issue	Very good	Good	Average	Low	None
17 SD Goals	7	32	42	14	5
Agenda 2030	8	11	46	26	9
Carbon footprint	6	39	33	16	6
Circular economy	12	19	44	16	9
Green competencies	10	42	31	13	4

Source: Own elaboration.

The obtained results indicate that the largest number of students have a *very good* and *good* level of knowledge of green competencies (52%), carbon footprint (45%) and 17 SDGs (39%), while the smallest group of people (19%) knows the 2030 Agenda.

The third question in this block of the questionnaire was crucial for obtaining an answer to the first research question and concerned the assessment of the importance of 17 SDGs for the respondents. The detailed distribution of responses is presented in Figure 3.

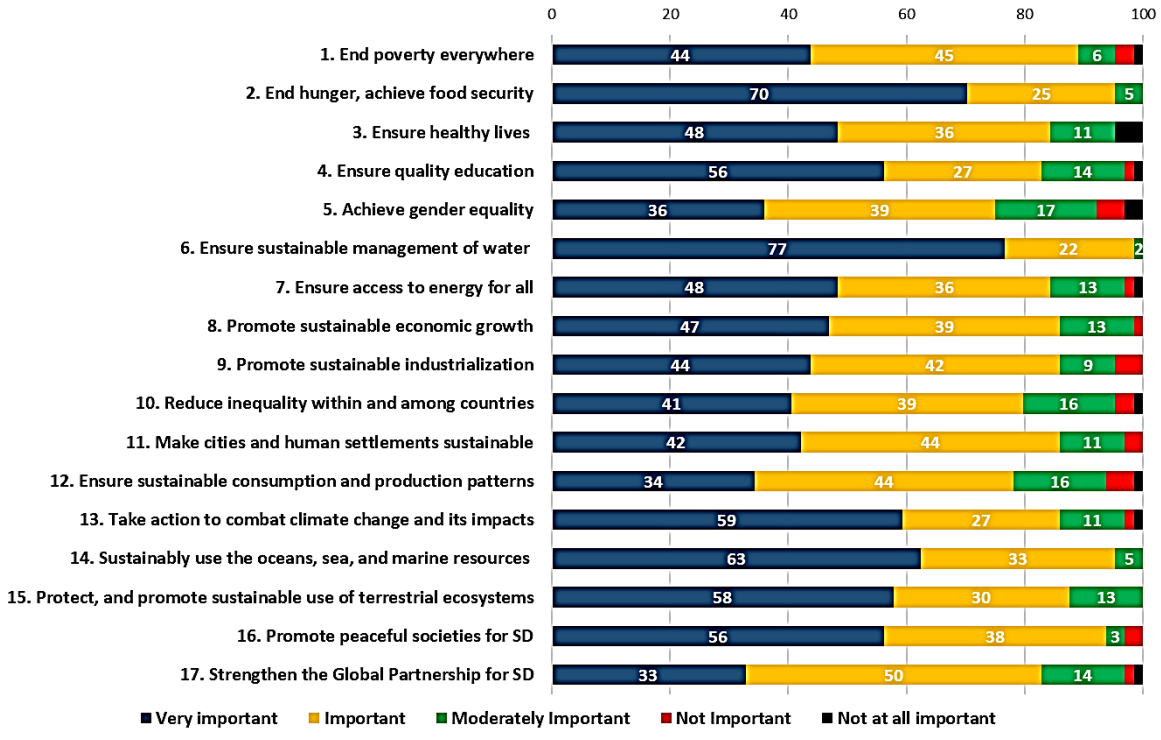

Figure 3. The assessment of the importance of 17 SDGs in the respondents' opinion (%).
Source: Own elaboration.

The analysis of the obtained results shows that the most important SD goals, according to the largest group of respondents, are: sustainable management of water (77%), ending hunger, achieving food security (70%), sustainably using the oceans, sea, and marine resources (63%), take action to combat climate change and its impacts (59%), protect, and promote sustainable use of terrestrial ecosystems (58%), promote peaceful societies for SD (56%), and ensure quality education (56%). It is worth noting that most of these goals concern environmental protection, which may indicate that Generation Z is aware of environmental threats in the world and is rightly referred to as the "green generation". Among the goals which, in the respondents' opinion, are not so important were: achieving gender equality (36%), ensuring sustainable consumption and production patterns (34%), and strengthening the global partnership for SD (33%).

It should be emphasized that almost all of the mentioned SDGs are of great importance to the respondents (when analysing both *very important* and *important* answers). This fact confirms their positive attitude towards the implementation of the concept of sustainable development.

The preparation of second part of the questionnaire was aimed at finding an answer to the question of whether the implementation of internships in a real work environment enables shaping students' competencies in the area of sustainable development, and if so, to what extent.

The first question in this block concerned the assessment of the approach of people representing the organisation (superiors, mentors, employees) to the development of SD competencies of interns. The analysis of their involvement in this area regarded the frequency of conversations with interns about the essence and goals of SD. The distribution of the responses received is presented in Table 4.

Table 4.
Conducting conversations about SD by persons representing the organisation (%)

	Very often	Often	Sometimes	Rarely	Never
Conversations between a superior or mentor with the interns	3	33	39	13	12
Conversations between employees and the interns	5	34	40	11	9

Source: Own elaboration.

The above results indicate that 36% of respondents confirm that they talked about the subject of SD *very often* or *often* with their supervisor or mentor, as well as with other employees (39%). However, in both cases, more than 60% of people in total marked the answers as *sometimes, rarely, and never*. This is a very unsatisfactory result and is an important area requiring the introduction of changes in the implementation of internships in organisations in the future.

Another important question in the questionnaire concerned the assessment of whether significant activities related to SD were carried out by students during the internship in the organisation. The distribution of answers is presented in Figure 4.

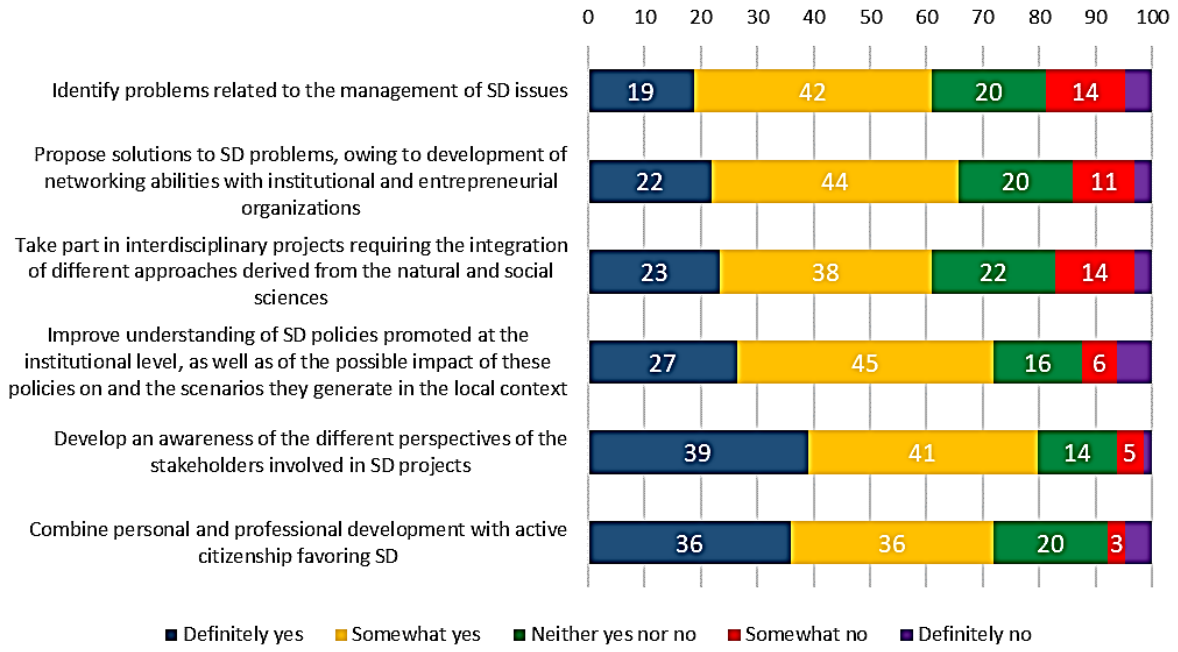

Figure 4. Activities related to SD undertaken by respondents during their internship (%).
Source: Own elaboration.

The analysis of the distribution of answers allows us to state that during the internship the respondents had the greatest opportunity to develop an awareness of the different perspectives of the stakeholders involved in SD projects (80%), and to combine personal and professional development with active citizenship favoring SD (72%). However, the following skills were developed to the least degree: identifying problems related to the management of SD issues (61%), proposing solutions to SD problems, owing to the development of networking abilities with institutional and entrepreneurial organisations (66%), and taking part in interdisciplinary projects requiring the integration of different approaches (61%).

In order to deepen the analysis of the obtained results, the answers given by the respondents were compared, taking into account the type of organisation in which the internship was carried out, i.e. business, administration, and NGO. It was important to obtain information on whether the type of organisation, as a type of stakeholder, is related to the assessment of the level of development of interns' SD competencies. Figure 5 presents the calculated average response values on the scale of 1-5, where 1 means *definitely no* and 5 means *definitely yes*.

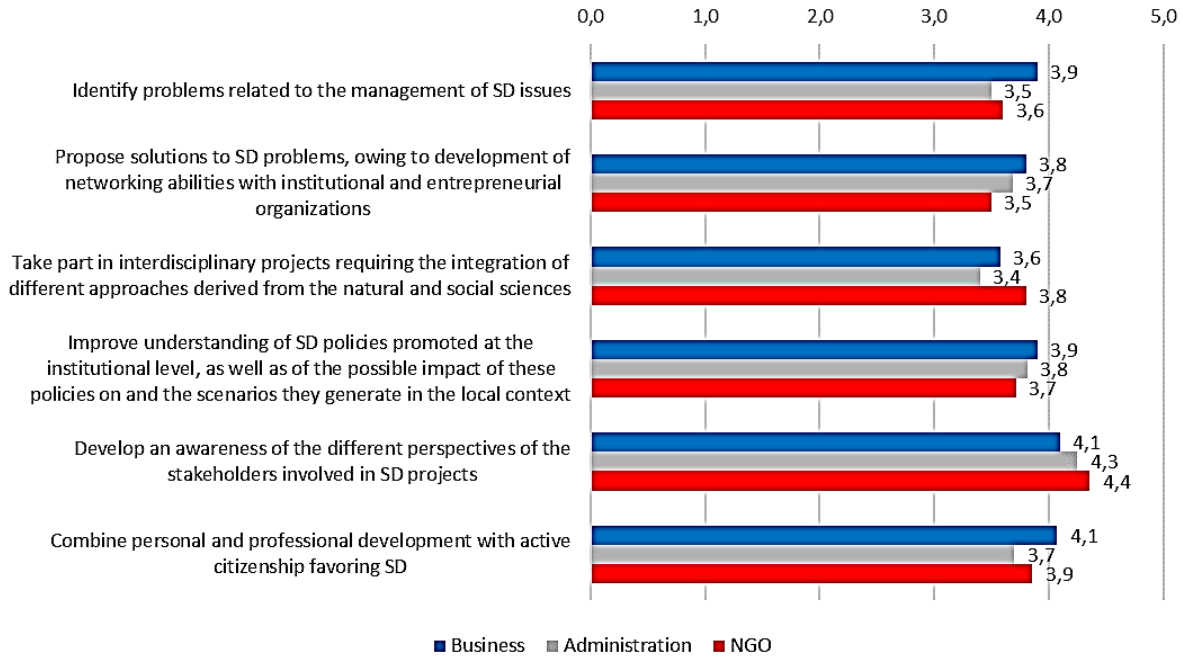

Figure 5. Activities related to SD competencies, undertaken by respondents during internship according to the type of stakeholder (average values on the scale of 1-5).

Source: Own elaboration.

The obtained results show that the greatest opportunities for the development of SD competencies were provided by business organisations to interns (general average value is 3.9). Slightly worse results in this aspect were achieved by non-governmental organisations (general average value is 3.8). Students completing internships in administration received the least benefit (3.7), however, all of these results are on a very similar level.

The next question in the questionnaire concerned the assessment of shaping eight key SD competencies through the internship. They were described in UNESCO (2017) documents and many scientific papers. These are the following ones: systems thinking competency, anticipatory competency, normative competency, strategic competency, collaboration competency, critical thinking competency, self-awareness competency, and integrated problem-solving competency. The distribution of respondents' answers is presented in Figure 6.

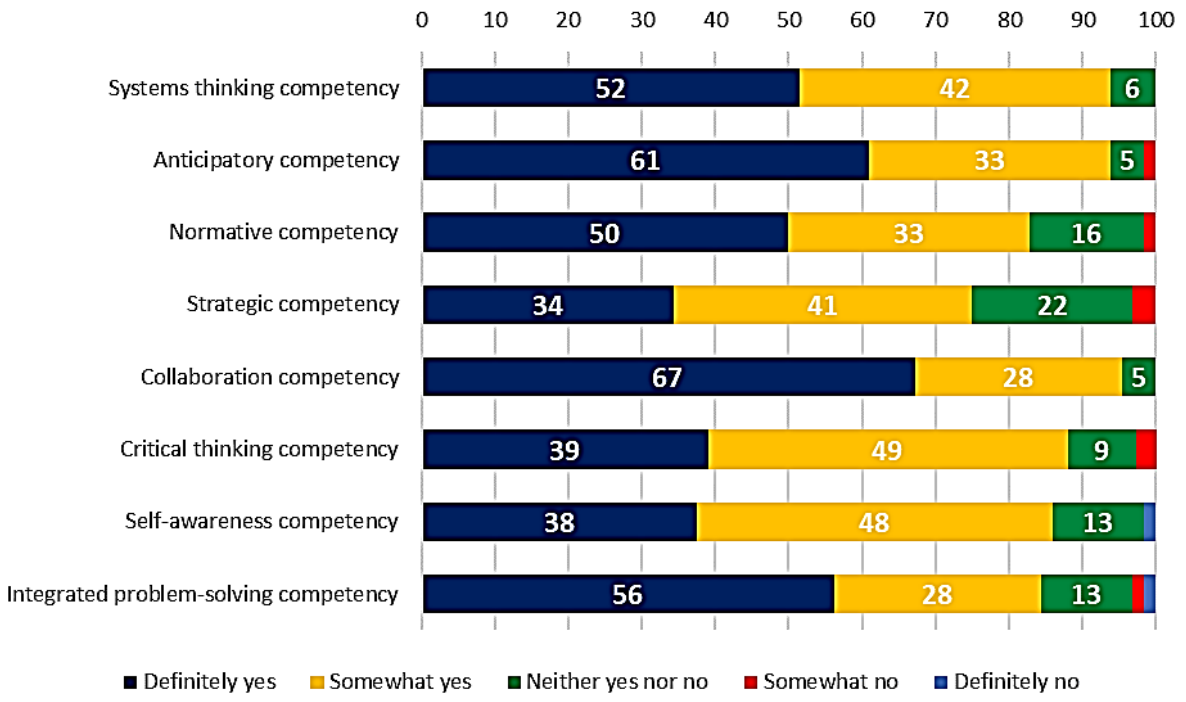

Figure 6. Shaping key SD competencies as the result of an internship (%).

Source: Own elaboration.

The analysis of the distribution of answers shows that during the internship, management students developed the most SD competencies such as collaboration competency (67%), anticipatory competency (61%), integrated problem-solving competency (56%), systems thinking competency (52%), and normative competency (50%). The development of strategic competency, thanks to internship, was confirmed by the smallest number of people (34%). In addition, less than 40% of the respondents indicated critical thinking competency (39%) and self-awareness competency (38%). However, when analysing the *definitely yes* and *somewhat yes* answers together, it can be noticed that almost all of the examined competencies were developed as a result of the internship.

As in the case of the in-depth analysis in Figure 5, also in this question, the average values of the received answers were calculated (on the analogous scale of 1-5). The results are presented in Figure 7.

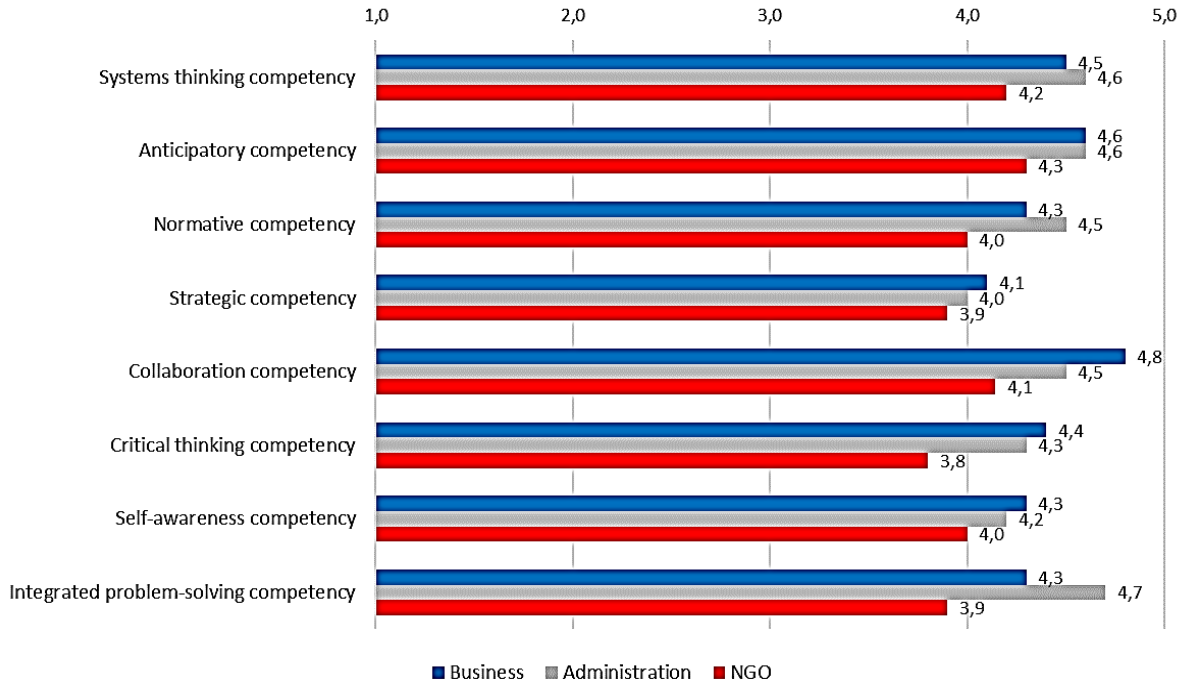

Figure 7. Shaping key SD competencies as a result of internship according to the type of stakeholder (average values on the scale of 1-5).

Source: Own elaboration.

On the basis of the presented results, it can be stated that the competencies examined in this question were shaped to the greatest extent in business companies and administration (general average value is 4.4 in both cases). A visible disproportion was shown in the case of the third type of stakeholder, i.e. NGOs, whose ratings are definitely the lowest (average 4.0). At the same time, it is worth noting that the scores for all the competencies analysed in this question are in the range of 3.8 – 4.8 and are higher than in the case of SD competencies presented in Figure 5.

The final question in the questionnaire was summarizing. The respondents expressed their opinion of whether the implementation of the internship in the organisation in cooperation with various university stakeholders should be a form of shaping SD competencies. *Definitely yes* answer was given by 24% of people, *rather yes* by 54%, 17% had no opinion, and 5% said *rather no*. Such a distribution of answers means that the vast majority (78% in total) of students expect that shaping SD competencies will be performed not only in the process of their formal education but also thanks to employers – through internships in the real work environment and cooperation with various stakeholders.

Discussion

The analysis of the respondents' answers to the first question of the questionnaire shows that the vast majority of management students confirm that during their studies they acquired knowledge regarding SD. It means that the curricula in this field of study are in line with the UNESCO (2014) guidelines, which draw attention to the key role of higher education in the SD range. At the same time, the analysis of the literature on the subject allows one to state that various higher education institutions are very interested in highly effective education in the field of SD (O'Riordan et al., 2020).

Another aspect of the research was focused on the assessment of students' competence regarding knowledge in 5 SD areas, i.e. 17 SD Goals, Agenda 2030, carbon footprint, circular economy, and green competencies. The obtained results indicate that the possessed competencies relate to the greatest extent to those issues which refer to pro-environmental activities and ecological knowledge. This conclusion is confirmed by numerous studies presenting the Z generation as the green generation, whose representatives attach great importance to activities in accordance with the SD concept (Hay, Eagle, 2020; Dabija et al., 2019; Wawer et al., 2022). However, in this context, the knowledge of the 2030 Agenda as a formal document is not so high (PŁ, 2021). Such a conclusion should become the basis for the analysis of the content of education programs and the consistent expansion of students' theoretical knowledge in the area of SD.

The last issue related to the first research question is the opinion concerning the importance of the 17 SDGs. As in the previous question, also in this case, according to the respondents, the most important are those goals that relate to environmental protection and the elimination of ecological threats in the world. For members of generation Z, typical ecological values are essential, i.e., the company's reduction of greenhouse gas emissions and energy and water consumption, responsible waste and wastewater management (Rzemieniak, Wawer, 2021). This confirms that the development of green competencies of students in various forms of formal and informal education, both during university education and through internships, is an activity not only beneficial for economic and social reasons but also desirable by young people entering the labour market (Yamane, Kaneko, 2021). However, the results of the research suggest that the assessment of the importance of achieving particular goals is rated much higher by students than the possibility of having a personal impact on these goals (PŁ, 2021).

The next four questions were aimed at finding answers to whether the implementation of internships in a real work environment enables students to shape SD competencies.

At the beginning of the analysis of the obtained results, it should be stated that over 60% of people representing the organisation, i.e. superiors, mentors, or employees, did not talk about SD to the interns, either generally or in connection with the rules of work in a given

organisation. This may mean that they either do not have such knowledge themselves or did not consider the topic important to discuss with interns. This is an unfavorable situation and it requires a change in this sort of approach in the process of implementing internships. They are indeed an excellent opportunity to develop students' SD competencies as future employees in a real work environment (Brundiers et al., 2010). Subramanian et al. (2015) highlight the importance of how managers in general and HR managers, in particular, must take an active role in promoting green practices. As leaders, managers should offer clear and unambiguous green performance indicators and expectations for evaluating green performance to their employees.

The next question was especially important because it concerned the skills that students developed thanks to the activities carried out during the internship. On the basis of the study, it can be stated that during work they had the greatest opportunity to: develop an awareness of the different perspectives of the stakeholders involved in SD projects, combine personal and professional development with active citizenship favoring, improve understanding of SD policies promoted at the institutional level, as well as of the possible impact of these policies and the scenarios they generate in the local context.

In the research conducted by Cavicchi (2021), the above-mentioned competencies were also indicated by respondents, but they were slightly less important than others, such as: developing new SD competencies through networking and teamwork activities and proposing solutions to the complex problems of the SD project. Students perceived that the internships presented an opportunity to create learning communities, promoted on behalf of the organisation that hosted the internship (Cavicchi, 2021). It should be emphasized that regardless of the outcome of the ranking of the above-mentioned competencies in various studies, they were all indicated as those, which students had the opportunity to develop during their internships.

A review of the literature on the subject made it possible to identify a different classification of SD competencies, which was used in the next question of the questionnaire. The obtained results indicate that the surveyed students of management developed to the greatest extent such competencies as collaboration, anticipation, integrated problem-solving, systems thinking, and normative. Research conducted by Ziegler and Porto-de-Oliveira (2022) confirms that they are very important for students. According to Rios et al. (2018), interpersonal skills are essential for achieving sustainability objectives.

The last question in the questionnaire concerned the issue of cooperation between universities and various stakeholders in the implementation of students' internships. Almost 80% of students express the opinion that shaping SD competencies should be fulfilled not only in the process of their formal education but also thanks to employers – as a result of internships carried out in a real work environment. This viewpoint is often confirmed by various studies (Rios et al., 2018). Partnerships between higher education institutions and firms mediated by students' internships allow increased mutual benefits in the form of the exchange of knowledge and innovation (Franco et al., 2019). According to Cavicchi (2021), regarding practical

SD activities, internships were perceived as opportunities to network with stakeholders and develop problem-solving abilities.

Summing up the above discussion, it should be emphasized that the obtained research results are based on the subjective opinion of the respondents. More attention should be devoted to assessing and developing measures of the core competencies concepts in terms of their construct validity and multi-dimensionality (Rios et al., 2018).

Conclusion and limitations

The analysis of the literature on the subject allowed the author to identify the key areas related to the article: the essence and goals of SD, SD competencies, the role of higher education institutions and various stakeholders in shaping the SD competencies of Generation Z, as well as the possibility of using student internships to develop these competencies.

The conducted research made it possible to find answers to two research questions. The first one is: What knowledge in the field of sustainable development do students of management have and what do they think about the importance of SD goals listed in Agenda 2030?

The results of the conducted studies indicate that management students have extensive knowledge of selected SD areas. However, higher education institutions should make a detailed analysis of the content of curricula and the extent of theoretical knowledge required of students in these areas. There is a need for further education of generation Z regarding the 17 SDGs and related documents, including Agenda 2030. The most important for students were those SD goals which concerned environmental protection and elimination of ecological threats in the world. This confirms the conclusion that for the representatives of Generation Z, the most important are the goals with which they identify themselves and the achievement of which they can have influence. On the other hand, they gave significantly less importance to goals on which they had no direct influence, e.g. achieving gender equality and strengthening the global partnership for SD.

In today's world, sustainability takes on particular importance. Awareness of this problem should be significant, especially among young people, who in the future will decide, as employees and employers, to take pro-environmental actions and will be a driving force towards achieving sustainable development goals (Yamane, Kaneko, 2021).

The second research question was aimed at finding the answer to whether the implementation of internships in a real work environment enables students to shape SD competencies. The obtained research results confirm that the answer to this question is affirmative. Although key people employed in the organisation often do not conduct formal conversations with interns about SD, the development of these competencies is carried out in

practice while performing everyday duties and undertaking various activities in the work environment. Therefore, this is a very favorable situation, as the growth of SD of competencies is based on empirical actions. The results of the research also allow one to conclude that not all the examined competencies of management students were shaped to the same extent during the internship. This suggests the need to assign interns to perform more diverse tasks and solve non-standard problems to enable them to fully use their potential and expand the range of SD competencies they have acquired.

Summing up the above considerations, the obtained results allow one to fill the research gap concerning management students' opinions on shaping their competencies in the field of SD in the real work environment, thanks to the involvement of employers as stakeholders of higher education institutions, who enable students to pursue internships.

The results obtained can be recommended to higher education institutions to improve the quality of teaching processes in terms of the transfer of theoretical knowledge, as well as various stakeholders (business, public administration, non-governmental institutions) who should take action to practically form students' competencies through internships. The greatest opportunities for the development of SD competencies were provided to interns by business organisations and administration, while less importance was assigned to such stakeholders as NGOs.

The results of this study should be read in light of certain limitations. The author is aware that the cardinality of the surveyed group does not allow for the formulation of general conclusions.

Although quite numerous, the study sample cannot be considered fully representative of the entire population of Generation Z. Additionally, the research was conducted solely among management students. Although it was a conscious selection of the research sample, the conclusions cannot be applied to students of other faculties and courses. Research shows that attitudes to sustainable development are equally or even more favorable among business students than in higher education more generally (Bask et al. 2020). The respondents' attitudes to the examined issues could also be different due to the different levels of knowledge and awareness of the issues in areas related to the SDGs. Additionally, the duration of the internship ranged from 120 to 180 hours. This is quite a short period and perhaps not all aspects of SD and connected problems, covered by the questions in the questionnaire, could be observed by the interns.

In the future, it would be worthwhile to conduct similar studies to establish the opinion of students with a broader consideration of other variables, such as different fields of study of the respondents, previous professional experience, gender, or duration of the internship. The in-depth results of the analysis of interns' opinions in terms of the type of organisation and the number of employees may also be particularly interesting. Therefore, the obtained results can be the basis for further in-depth research on these problems.

References

1. Akkerman, S.F., Bakker, A. (2011). Boundary Crossing and Boundary Objects. *Review of Educational Research*, *81(2),* pp. 132-169. doi: 10.3102/0034654311404435.
2. Aleixo, A.M., Leal, S., Azeiteiro, U.M. (2018). Conceptualization of sustainable higher education institutions, roles, barriers, and challenges for sustainability: An exploratory study in Portugal. *Journal of Cleaner Production*, *172*, pp. 1664-1673. doi: 10.1016/j.jclepro.2016.11.010.
3. Alm, K., Beery, T.H., Eiblmeier, D., Fahmy, T. (2022). Students' learning sustainability - implicit, explicit or non-existent: a case study approach on students' key competencies addressing the SDGs in HEI program. *International Journal of Sustainability in Higher Education*, *23(8),* pp. 60-84. doi 10.1108/IJSHE-12-2020-0484.
4. Annan-Diab, F., Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *International Journal of Management Education*, *15(2),* pp. 73-83. https://doi.org/ 10.1016/j.ijme. 2017.03.006.
5. Bask, A., Halme, M., Kallio, M., Kuula, M. (2020). Business students' value priorities and attitudes towards sustainable development. *Journal of Cleaner Production*, *264, 9.* 121711. https://doi.org/10.1016/j.jclepro.2020.121711.
6. Bianchi, G., Pisiotis, U., Cabrera Giraldez, M. (2022). Gr*eenComp. The European sustainability competence framework.* Punie, Y., Bacigalupo, M. (eds), *EUR 30955 EN*. Luxembourg: Publications Office of the European Union.
7. Brundiers, K., Wiek, A., Redman, C.L. (2010). Real-world learning opportunities in sustainability: from classroom into the real world. *International Journal of Sustainability in Higher Education*, *11(4),* pp. 308-324. https://doi.org/10.1108/14676371011077540.
8. Cabral, C., Dhar, R.L. (2021). Green competencies: insights and recommendations from a systematic literature review. *Benchmarking-an International Journal*, *28(1),* pp. 66-105. https://doi.org/10.1108/14676371011077540.
9. Caeiro, S., Hamon, L.A.S., Martins, R., Aldaz, C.E.B. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions-A Critical Reflection. *Sustainability*, *12(2),* 543. https://doi.org/10.3390/su12020543.
10. Cavicchi, C. (2021). Higher Education and the Sustainable Knowledge Society: Investigating Students' Perceptions of the Acquisition of Sustainable Development Competences. *Frontiers in Sustainable Cities*, *3, 16.* https://doi.org/10.3389/frsc.2021. 664505.
11. Cebrián , G., Junyent, M. (2015). Competencies in Education for Sustainable Development: Exploring the Student Teachers' Views. *Sustainability*, *7(3),* pp. 2768-2786. https://doi.org/10.3390/su7032768.

12. Cebrián , G., Junyent, M., Mula, I. (2021). Current Practices and Future Pathways towards Competencies in Education for Sustainable Development. *Sustainability*, *13(16), 9.* doi:10.3390/su13168733.
13. Cebrián , G., Segalàs, J., Hernández, À. (2019). Assessment of sustainability competencies: a literature review and future pathways for ESD research and practice. *Central European Review of Economics and Management*, *3(3),* pp. 19-44. doi:10.29015/cerem.664.
14. Clemente, I.M., Giner, G.R., Velez, G.S. (2020). Towards Sustainability in University Education. Improving University Graduates Chances of Employability by Participation in a High Achievement Academic Program. *Sustainability*, *12 680*. doi:10.3390/su12020680.
15. Corazza, L., Cottafava, D., Torchia, D. (2022). Education for sustainable development: a critical reflexive discourse on a transformative learning activity for business students. *Environment Development and Sustainability*. https://doi.org/10.1007/s10668-022-02335-1.
16. Corres, A., Rieckmann, M., Espasa, A., Ruiz-Mallén, I. (2020). Educator Competences in Sustainability Education: A Systematic Review of Frameworks. *Sustainability*, *12(23),* 9858. https://doi.org/10.3390/su12239858.
17. Cullen, J.G. (2017). Educating Business Students About Sustainability: A Bibliometric Review of Current Trends and Research Needs. *Journal of Business Ethics*, *145(2),* pp. 429-439. doi: 10.1007/s10551-015-2838-3.
18. Dabija, D.C., Bejan, B.M., Dinu, V. (2019). How Sustainability Oriented Is Generation Z In Retail? A Literature Review. *Transformations in Business & Economics*, *18(2),* pp. 140-155.
19. de Haan, G. (2010). The development of ESD-related competencies in supportive institutional frameworks. *International Review of Education*, *56(2-3),* pp. 315-328. doi: 10.1007/s11159-010-9157-9.
20. Denac, M., Obrecht, M., Radonjic, G. (2018). Current and potential ecodesign integration in small and medium enterprises: Construction and related industries. *Business Strategy and the Environment*, *27(7),* pp. 825-837. https://doi.org/10.1002/bse.2034.
21. Dziubaniuk, O., Nyholm, M. (2020). Constructivist approach in teaching sustainability and business ethics: a case study. *International Journal of Sustainability in Higher Education*, *22(1),* pp. 177-197. doi: 10.1108/IJSHE-02-2020-0081.
22. European Commision, *A Sustainable Europe by 2030, Reflection paper: Towards a Sustainable Europe by 2030*. Retrieved from: https://commission.europa.eu/publications/sustainable-europe-2030_en, 12.12.2022.
23. Figueiro, P.S., Neutzling, D.M., Lessa, B. (2022). Education for sustainability in higher education institutions: A multi-perspective proposal with a focus on management education. *Journal of Cleaner Production*, *339, 14*. https://doi.org/10.1016/j.jclepro.2022.130539.

24. Findler, F., Schonherr, N., Lozano, R., Reider, D., Martinuzzi, A. (2019). The impacts of higher education institutions on sustainable development A review and conceptualization. *International Journal of Sustainability in Higher Education*, *20(1),* pp. 23-38.
25. Finnveden, G., Newman, J., Verhoef, L.A. (2019). Sustainable Development and Higher Education: Acting with a Purpose. *Sustainability*, *11(14),* 4. https://doi.org/10.3390/su11143831.
26. Franco, M., Silva, R., Rodrigues, M. (2019). Partnerships between higher education institutions and firms: The role of students' curricular internships. *Industry and Higher Education*, *33(3),* pp. 172-185. https://doi.org/10.1177/0950422218819638.
27. Freeman, R. (1984). *Strategic management - a stakeholder approach*. Cambridge: Cambridge University Press.
28. Gault, J., Leach, E., Duey, M. (2010). Effects of business internships on job marketability: the employers' perspective. *Education and Training*, *52(1),* pp. 76-88. doi:10.1108/00400911011017690.
29. Goh, E., Lee, C. (2018). A workforce to be reckoned with: The emerging pivotal Generation Z hospitality workforce. *International Journal of Hospitality Management*, *73*, pp. 20-28. doi: 10.1016/j.ijhm.2018.01.016.
30. Gupta, J., Vegelin, C. (2016). Sustainable development goals and inclusive development. *International Environmental Agreements: Politics, Law and Economics*, *16(3),* pp. 433-448. https://doi.org/10.1007/s10784-016-9323-z.
31. Hay, R., Eagle, L. (2020). Impact of integrated sustainability content into undergraduate business education. *International Journal of Sustainability in Higher Education*, *21(1),* pp. 131-143. doi: 10.1108/IJSHE-05-2019-0174.
32. Hermann, R.R., Bossle, M.B. (2020). Bringing an entrepreneurial focus to sustainability education: A teaching framework based on content analysis. *Journal of Cleaner Production*, *246(3),* 19. https://doi.org/10.1016/j.jclepro.2019.119038.
33. Holgaard, J., Hadgraft, R., Kolmos, A., Guerra, A. (2016). Strategies for Education for Sustainable Development – Danish and Australian perspectives. *Journal of Cleaner Production*, *112(4),* pp. 3479-3491. doi: 10.1016/j.jclepro.2015.09.063.
34. Imran, M., Salisu, I., Aslam, H.D., Iqbal, J., Hameed, I. (2019). Resource and Information Access for SME Sustainability in the Era of IR 4.0: The Mediating and Moderating Roles of Innovation Capability and Management Commitment. *Processes*, *7(4),* 211. https://doi.org/10.3390/pr7040211.
35. Ismail, I.J. (2022). Entrepreneurs' competencies and sustainability of small and medium enterprises in Tanzania. A mediating effect of entrepreneurial innovations. *Cogent Business & Management*, *9(1),* 2111036, https://doi.org/10.1080/23311975.2022.2111036.
36. Karkoulian, S., Assaker, G., Hallak, R. (2016). An empirical study of 360-degree feedback, organizational justice, and firm sustainability. *Journal of Business Research*, *69(5),* pp. 1862-1867. https://doi.org/10.1016/j.jbusres.2015.10.070.

37. Korfgen, A., Forster, K., Glatz, I., Maier, S., Becsi, B., Meyer, A., Kromp-Kolb, H., Stotter, J. (2018). It's a Hit! Mapping Austrian Research Contributions to the Sustainable Development Goals. *Sustainability*, *10(9),* 3295. doi: 10.3390/su10093295.
38. Lambrechts, W., Hindson, J. (2016). *Research and Innovation in Education for Sustainable Development*. Viena, Austria.
39. Leal, W., Shiel, C., Paco, A., Mifsud, M., Avila, L.V., Brandli, L.L., Molthan-Hill, P., Pace, P., Azeiteiro, U.M., Vargas, V.R., Caeiro, S. (2019). Sustainable Development Goals and sustainability teaching at universities: Falling behind or getting ahead of the pack? *Journal of Cleaner Production*, *232*, pp. 285-294. https://doi.org/10.1016/j. jclepro.2019.05.309.
40. Lim, M.M.L., Jorgensen, P.S., Wyborn, C.A. (2018). Reframing the sustainable development goals to achieve sustainable development in the Anthropocene-a systems approach. *Ecology and Society*, *23(3),* 19. https://doi.org/10.5751/ES-10182- 23032.
41. Lopes, B., Silva, P., Melo, A., Brito, E., Dias, G.P., Costa, M. (2019). The 'Lunar Side' of the Story: Exploring the Sustainability of Curricular Internships in Higher Education. *Sustainability*, *11(21),* 5879. doi:10.3390/su11215879.
42. Lozano, R., Merrill, M.Y., Sammalisto, K., Ceulemans, K., Lozano, F.J. (2017). Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal. *Sustainability*, *9(10),* 15. doi: 10.3390/su9101889.
43. Lut, D. (2020). *Constructive Organizational Culture - Ideal Work Environment For Generation Z.* Conference: Tourism and Sustainable Development 2020. Timisoara, Romania, 9–10 July 2020. Retrieved from: https://www.researchgate.net/publication /341266779_constructive_organizational_culture_-ideal_work_environment_for_ generation_z, 10.12.2022.
44. López López, I., Bote, M., Rives, L.M., Bañón, A.R. (2019). Higher Education Institutions as a Transformation Platform under the Sustainable Development Goals Framework. *European Journal of Sustainable Development*, *8(3),* 306-312. https://doi.org/10.14207/ ejsd.2019.v8n3p306.
45. Mora, H., Pujol-Lopez, F.A., Mendoza-Tello, J.C., Morales-Morales, M.R. (2020). An education-based approach for enabling the sustainable development gear. *Computers in Human Behavior*, *107*, 11. doi: https://doi.org/10.1016/j.chb.2018.11.004.
46. O'Riordan, T., Jacobs, G., Ramanathan, J., Bina, O. (2020). Investigating the Future Role of Higher Education in Creating Sustainability Transitions. *Environment*, *62(4),* pp. 4-15. doi: 10.1080/00139157.2020.1764278.
47. Obrecht, M., Feodorova, Z., Rosi, M. (2022). Assessment of environmental sustainability integration into higher education for future experts and leaders. *Journal of Environmental Management*, *316*, 9. 115223 doi: 10.1016/j.jenvman.2022.115223.

48. Oliveira, R.V. (2018). Back to the Future: The Potential of Intergenerational Justice for the Achievement of the Sustainable Development Goals. *Sustainability*, *10(2),* 16. doi:10.3390/su10020427.
49. Oonk, C., Gulikers, J., den Brok, P., Mulder, M. (2022). Stimulating boundary crossing learning in a multi-stakeholder learning environment for sustainable development. *International Journal of Sustainability in Higher Education*, *23(8),* pp. 21-40. doi: 10.1108/IJSHE-04-2021-0156.
50. Oonk, C., Gulikers, J., Mulder, M. (2019). Educating boundary crossing planners: evidence for student learning in the multi stakeholder regional learning environment, *Journal of Planning Education and Research*, *39(3),* pp. 360-373. doi: 10.1177/0739456X17737598.
51. Orobia, L.A., Tusiime, I., Mwesigwa, R., Ssekiziyivu, B. (2020). Entrepreneurial framework conditions and business sustainability among the youth and women entrepreneurs. *Asia Pacific Journal of Innovation and Entrepreneurship*, *14(1),* pp. 60-75. https://doi.org/10. 1108/APJIE-07-2019-0059.
52. Owens, T.L. (2017). Higher education in the sustainable development goals framework. *European Journal of Education*, *52(4),* pp. 414-420. https://doi.org/10.1111/ejed.12237.
53. Pizzi, S., Rosati, F., Venturelli, A. (2020). The determinants of business contribution to the 2030 Agenda: Introducing the SDG Reporting Score. *Business Strategy and the Environment*, *30(1),* pp. 404-421. doi: 10.1002/bse.2628.
54. Zespół ds. Zrównoważonego Rozwoju PŁ (2021). *Politechnika Łódzka w drodze do zrównoważonego rozwoju. Wyniki badania przeprowadzonego wśród studentów i pracowników*. Łódź: Politechnika Łódzka.
55. Poza-Vilches, F., López-Alcarria, A., Mazuecos-Ciarra, N. (2019). A Professional Competences' Diagnosis in Education for Sustainability: A Case Study from the Standpoint of the Education Guidance Service (EGS). in the Spanish Context. *Sustainability*, *11(6),* 1568. https://doi.org/10.3390/su11061568.
56. Pretorius, R.W., Carow, S., Wilson, G., Schmitz, P. (2021). Using real-world engagements for sustainability learning in ODeL in the Global South: challenges and opportunities. *International Journal of Sustainability in Higher Education*, *22(6),* pp. 1316-1335. https://doi.org/10.1108/IJSHE-08-2020-0287.
57. Pubule, J., Kalnbalkite, A., Teirumnieka, E., Blumberga, D. (2019). Evaluation of the Environmental Engineering Study Programme at University. *Environmental and Climate Technologies*, *23(2),* pp. 310-324. doi:10.2478/rtuect-2019-0070.
58. Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-Restrepo, M., McEvoy, D., Satterthwaite, D. (2017). Climate change, equity and the Sustainable Development Goals: an urban perspective. *Environment and Urbanization*, *29(1),* pp. 159-182. https://doi.org/ 10.1177/0956247816677778.
59. Remington-Doucette, S., Musgrove, S. (2015). Variation in sustainability competency development according to age, gender, and disciplinary affiliation Implications for teaching

practice and overall program structure. *International Journal of Sustainability in Higher Education*, *16(4),* pp. 537-575. doi:10.1108/IJSHE-01-2013-0005.

60. Rieckmann, M., Barth, M. (2022). Educators' Competence Frameworks in Education for Sustainable Development. In: P. Vare, N. Lausselet, M. Rieckmann (eds.), *Competences in Education for Sustainable Development. Critical Perspectives* (pp. 19-26). Springer International Publishing. https://doi.org/10.1007/978-3-030-91055-6_3.
61. Rios, M.M.M., Herremans, I.M., Wallace, J.E., Althouse, N., Lansdale, D., Preusser, M. (2018). Strengthening sustainability leadership competencies through university internships. *International Journal of Sustainability in Higher Education*, *19(4),* pp. 739-755. https://doi.org/10.1108/IJSHE-06-2017-0097.
62. Rzemieniak, M., Wawer, M. (2021). Employer Branding in the Context of the Company's Sustainable Development Strategy from the Perspective of Gender Diversity of Generation Z. *Sustainability*, *13(2),* 828. https://doi.org/10.3390/su13020828.
63. Salgado, F.P., Abbott, D., Wilson, G. (2018). Dimensions of professional competences for interventions towards sustainability. *Sustainability Science*, *13(1),* pp. 163-177. doi: 10.1007/s11625-017-0439-z.
64. Sanchez-Carracedo, F., Ruiz-Morales, J., Valderrama-Hernandez, R., Munoz-Rodriguez, J. M., Gomera, A. (2021). Analysis of the presence of sustainability in Higher Education Degrees of the Spanish university system. *Studies in Higher Education*, *46(2),* pp. 300-317. https://doi.org/10.1080/03075079.2019.1630811.
65. Sandri, O., Holdsworth, S., Thomas, I. (2018). Vignette question design for the assessment of graduate sustainability learning outcomes. *Environmental Education Research*, *24(3),* pp. 406-426. doi: 10.1080/13504622.2016.1263280.
66. Scharenberg, K., Waltner, E.-M., Mischo, C., Rieß, W. (2021). Development of Students' Sustainability Competencies: Do Teachers Make a Difference? *Sustainability*, *13(22),* 12594. https://doi.org/10.3390/su132212594.
67. Scherak, L., Rieckmann, M. (2020). Developing ESD Competences in Higher Education Institutions-Staff Training at the University of Vechta. *Sustainability*, *12(24),* 10336. doi:10.3390/su122410336.
68. Schopp, K., Bornemann, M., Potthast, T. (2020). The Whole-Institution Approach at the University of Tubingen: Sustainable Development Set in Practice. *Sustainability*, *12(3),* 24. https://doi.org/10.3390/su12030861.
69. Sisto, R., Sica, E., Cappelletti, G.M. (2020). Drafting the Strategy for Sustainability in Universities: A Backcasting Approach. *Sustainability*, *12(10),* 4288. doi:10.3390/ su12104288.
70. Stiglitz, J.E. (2019). An Agenda for Reforming Economic Theory. *Frontiers of Economics in China*, *14(2),* pp. 149-167. doi:10.3868/s060-008-019-0009-3.

71. Subramanian, N., Abdulrahman, M.D., Wu, L., Nath, P. (2015). Green competence framework: evidence from China. *International Journal of Human Resource Management*, *27(2),* pp. 151-172. doi: 10.1080/09585192.2015.1047394.
72. Tariq, M., Yasir, M., Majid, A. (2020). Promoting employees' environmental performance in hospitality industry through environmental attitude and ecological behavior: Moderating role of managers' environmental commitment. *Corporate Social Responsibility and Environmental Management, 27(6),* pp. 3006-3017. https://doi.org/10.1002/csr.2019.
73. Trencher, G., Vincent, S., Bahr, K., Kudo, S., Markham, K., Yamanaka, Y. (2018). Evaluating core competencies development in sustainability and environmental master's programs: An empirical analysis. *Journal of Cleaner Production*, *181*, pp. 829-841. doi: 10.1016/j.jclepro.2018.01.164.
74. Turner, A. (2015). Generation Z: Technology and Social Interest. *The Journal of Individual Psychology*, *71(2),* pp. 103-113. https://doi.org/10.1353/jip.2015.0021.
75. UNESCO (2013). *ESD+TVET: Promoting Skills for Sustainable Development*. Paris, UNESCO, Retrieved from: https://unesdoc.unesco.org/ark:/48223/pf0000216269, 17.12.2022.
76. UNESCO (2014). *Shaping the future we want: UN Decade of Education for Sustainable Development (2005-2014) final report*. Retrieved from: www.bibb.de/dokumente/pdf/ a33_un_decade_final_report_2014_230171e.pdf, 17.12.2022.
77. UNESCO (2017). *Education for Sustainable Development Goals: Learning Objectives*. Retrieved from: http://unesdoc.unesco.org/images/0024/002474/247444e.pdf, 17.12.2022.
78. United Nations General Assembly (1987). *Our Common Future*. Oslo, Norway: United Nations General Assembly, Development and International Co-operation: Environment.
79. United Nations (UNa). *Transforming our world: the 2030 Agenda for Sustainable Development,* Department of Economic and Social Affairs, Sustainable Development. Retrieved from: https://sdgs.un.org/2030agenda, 11.11.2022.
80. United Nations (UNb). *Sustainable Development Goals.* Retrieved from: https://www.un.org/sustainabledevelopment/news/communications-material/, 11.11.2022.
81. United Nations (UNc), *The Sustainable Development Agenda.* Retrieved from: https://www.un.org/sustainabledevelopment/development-agenda/ 12.12.2022.
82. United Nations (UNd). *Sustainability Development Goals*. Department of Economic and Social Affairs, Sustainable Development. Retrieved from: https://sdgs.un.org/goals, 11.11.2022.
83. United Nations (2020). Strengthening stakeholder engagement for the implementation and review of the 2030 Agenda*, Stakeholder Engagement and the 2030 Agenda - A practical guide*. Retrieved from: https://sdgs.un.org/publications/stakeholder-engagement-and-2030-agenda-practical-guide-24556, 12.12.2022.
84. Utama, Y.J., Ambariyanto, A., Zainuri, M., Darsono, D., Setyono, B., Widowati, Putro, S. P. (2018). Sustainable development goals as the basis of university management towards

global competitiveness, *IOP Conf. Series: Journal of Physics: Conf. Series, 1025,* 012094. https://doi.org/10.1088/1742-6596/1025/1/012094.

85. Wang, W.S., Mo, T.T., Wang, Y.C. (2022). Better self and better us: Exploring the individual and collective motivations for China's Generation Z consumers to reduce plastic pollution. *Resources Conservation and Recycling*, *179*, 1. 106111. doi: 10.1016/ j.resconrec.2021.106111.
86. Wawer, M., Grzesiuk, K., Jegorow, D. (2022). Smart Mobility in a Smart City in the Context of Generation Z Sustainability, Use of ICT, and Participation. *Energies*, *15(13),* 4651. https://doi.org/10.3390/en15134651.
87. Wiek, A., Bernstein, M., Foley, R., Cohen, M., Forrest, N., Kuzdas, C., Kay, B., Keeler, L. (2016). Operationalising Competencies in Higher Education for Sustainable Development. In: M. Barth, G. Michelsen, M. Rieckmann, I. Thomas (Eds.), *Routledge Handbook of Higher Education for Sustainable Development* (pp. 241-260). London-New York: Routledge.
88. Wiek, A., Withycombe, L., Redman, C.L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science*, *6(2),* pp. 203-218. doi: 10.1007/s11625-011-0132-6.
89. Yamane, T., Kaneko, S. (2021). Is the younger generation a driving force toward achieving the sustainable development goals? Survey experiments. *Journal of Cleaner Production*, *292*, 125932. doi: 10.1016/j.jclepro.2021.125932.
90. Zhao, H.H., Gao, Q., Wu, Y.P., Wang, Y., Zhu, X.D. (2014). What affects green consumer behavior in China? A case study from Qingdao. *Journal of Cleaner Production*, *63*, pp. 143-151. doi: 10.1016/j.jclepro.2013.05.021.
91. Ziegler, R., Porto-de-Oliveira, L.C. (2022). Backcasting for sustainability - An approach to education for sustainable development in management. *International Journal of Management Education*, *20(3),* 10. doi: https://doi.org/10.1016/j.ijme.2022.100701.

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EVALUATION OF DESIGN MATURITY MODELS FOR USABILITY IN THE IT INDUSTRY

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Purpose: The ability of an enterprise to execute projects, using the tools appropriate to do so, is called project maturity. On the other hand, at a higher level of detail, it is seen as the appropriate selection of a portfolio of projects, in such a way that the implementation of given projects is directed to support the goals and strategies of the enterprise, as well as the ability to apply appropriate project management tools and techniques. Accelerating changes in the company's environment, cause them to be forced to implement project management, in order to increase flexibility and standardization, so that activities become more professional. In sum, this translates into better financial health of the enterprise, a better position among competitors and, what is related to this, gaining new markets for their products and services. Project maturity models provide a starting point for conducting an analysis of the current state of the enterprise and indicate the direction or directions in which the enterprise should develop. The purpose of this article is to present the results of a usability analysis of project maturity models for an IT enterprise. The following models are presented in it: PMMM (The Kerzner Project Management Maturity Model) - developed by H. Kerzner; P3M3 (Portfolio, Program and Project Management Maturity Model) - developed by the Office of Government Commerce; OPM3 (Organizational Project Management Maturity Model) - developed by the Project Management Institute; P2MM (PRINCE2 Maturity Model) - developed by the Office of Government Commerce. The essence of project maturity, the project approach and its operation and improvement in management systems is also discussed.
Design/methodology/approach: The article is exploratory in nature, and the primary research was conducted using the expert interview method.
Research limitations/implications: Future research should focus on further analysis of both design and process maturity models.
Practical implications: The research discussed in this article can contribute to further empirical research, including, among other things, the initiation of work on the development of a project maturity model aimed at the IT industry.
Social implications: The practical implications of the research involve the possibility of using IT to improve existing maturity models and practical implementation in IT companies.
Originality/value: The main value of the article is the analysis of models past IT practitioners, and the overview presented is based on existing and used maturity models.

Keywords: project management, project maturity, project maturity models, enterprise maturity.

Category of the paper: General review, Research paper.

1. Introduction

Business processes and, above all, the way in which they are carried out, are today considered critical resources that determine an organization's market value (Seethamraju, 2012). For this reason, companies are looking for opportunities to change and thus enable it to enter a higher level of organizational development. Projects were for a very long time the domain of only the IT and construction industries, but today the project approach dominates many other industries. Companies taking their first steps in project management often do not know where to start, what to invest in, which techniques to use. Ultimately, some of the solutions purchased are not used in practice or are not compatible with other tools (Chrisis, Konrad, Shrum, 2003). There is a risk of discouraging employees from the whole idea of project management, and projects continue to exceed original budgets, are not completed on time or do not meet certain quality requirements (Crawford, Bryce, 2003). When implementing the project approach, often companies focus on the approach itself and not on the product and its quality. Nowadays, on the other hand, in many industries, including IT, the quality of the delivered product and service under individual customer requirements, created right in the organization's manufacturing process, is becoming increasingly important (Wojciechowska, Strojny, 2022). Project management aims to make changes and implement new organizational, technological and market solutions that destabilize the organization in order for it to enter a higher level of organizational development (Duraj, 2004). For this reason, one of the most important elements of improving an enterprise is improving the management system (Bielawa, 2011). Recent economic crises and functioning in a turbulent environment have forced organizations to seek modern management concepts. In such a dynamic and innovative environment, the philosophy of project management, i.e. how to meet customer requirements on time without exceeding the budget, may become not only a fad, but also a necessity (Wittek, 2011). However, this poses many implementation problems. For this reason, the purpose of this article is to present the results of a usability analysis of project maturity models for an IT enterprise. In addition, the benefits that the enterprise can achieve by using the models in question to improve the quality management system will be indicated, as well as the most significant criteria and obstacles. The purpose of this article is to present the results of the usability analysis of project maturity models for an IT enterprise. The realization of the above goal requires an explanation of the essence of the project approach and its functioning and improvement in management systems (Gębczynska, Bujak, 2011). The main value of the article is the analysis of models past IT practitioners, and the overview presented is based on existing and used maturity models. The project approach is becoming more and more widely used in Polish and global enterprises, as it leads to high quality project products and repetition and elimination of bottlenecks in subsequent projects Maylor, 1999). This is because of the need to organize and track tasks within a project to complete the project within the required time, scope and budget (the project

triangle). However, this is one of the formal elements, because in the IT industry often two of the three elements of the project triangle change, while the most important is the fact that the project approach serves to improve the organization, to identify elements that need improvement or change, and to implement good practices tailored to the company in the implementation of projects. This, in turn, causes the impact of project management on other operational activities and affects activities related to organizational structure, processes or motivational systems (Kusyk, 2010). This article focuses on project management issues, is of an overview nature and refers to several project maturity models in relation to IT companies.

2. Characteristics of the IT industry

The IT (information technology) sector is engaged in carrying out tasks related to the acquisition, collection, processing and distribution of information, using electronic equipment such as telephones, computers and television (Collin, Glowinski, 1999). The IT sector is divided into three basic segments: hardware, software and IT services. Thus, it includes the production of hardware and software, consulting on its use, sales and service of hardware and software, data processing and database development, as well as education in information technology and telecommunications activities (Kępka, 2010). The sector is internally diversified, with the majority of companies being small businesses, while the most important enterprises are subsidiaries of multinational corporations, which most often set trends in organizations. The last several years in the global economy, there has been a continuous and dynamic growth in demand for information technology products and services. As a result of the changes associated with the development of the IT industry, every enterprise faces new challenges, some of which become threats (e.g. loss of market, bankruptcy of the enterprise, lack of competitiveness of the offer, high operating costs, etc.) and others become opportunities for development (e.g. new product, gaining new customers for products and services) (Strojny, Szmigiel, 2016). The processes of digitization and informatization, including the dynamic development of the IT industry, have led to the creation of thousands of projects around the world (Liebert, 2017). Leading to the dynamic development of the industry and the creation of advanced IT solutions, thereby causing management problems (Kozarkiewicz, Wojcik, 2015). The IT industry is one that influences almost every element of the economy by assessment, encroaching on virtually every area of life, be it banking, e-commerce, manufacturing systems. For this reason, on the one hand, the sector is susceptible to economic factors that have a significant impact on shaping the market for IT services, both in the group of suppliers and in the group of customers (Juchniewicz, 2012). So its operation depends on the general economic situation. On the other hand, however, there is a constant demand for modernization of

IT facilities in enterprises, thus, despite the dynamics of the market, the IT industry has become an integral part of change and has become less susceptible to market changes, compared to the rest of the economy. It has the ability to create solutions and products, even in a moment of economic crisis, it is worth noting that the IT sector has introduced various types of IT services, such as Internet services (Winiarski, 2008).

IT companies, despite their role and importance in the economy, face many challenges and threats such as product development, acquisition of new market segments, loss of customers, and excessive operating costs of the company (Strojny, Szmigiel, 2016). Difficulties associated with IT industry projects, can be solved by spreading project management knowledge and clarifying the project maturity of the enterprise. As noted by J. Kacala, the biggest problem for organizations that need to manage projects is acquiring and maintaining the knowledge flowing from completed projects. This is due to the specificity and originality of each project (Strategist, 1999). In practice, the final outcome is determined by a number of factors that can positively and negatively affect the project and its implementation (Pritchardt, 2001), for example, it can be related to the very nature of the organization, which requires too detailed distribution of tasks, power and information (Spalek, 2004) Evidence of the aforementioned management difficulties in companies is the research conducted by Stadnish Group in 2017, showing that only one out of three projects is successful (www.productive24.com).

Every project should end in success as understood by both the creator and the recipient of the product or service. Success may involve new financial revenues, but also the acquisition of new markets. On the other hand, as a consequence of the fact that IT projects are atypical ventures and rely mainly on the search for new solutions (Spalek, 2014) and the possibility of their implementation, they have an innovative character (Mierzwińska, 2013), but also a high degree of risk (Lasek, Adamus, 2014). However, it has been noted that in the IT industry, the use of methodology alone is not enough to offset these risks, since the most important part of IT projects in particular is the people (Spolsky, 2005). For this reason, regardless of the methodology used, project management is closely related to people management and thus to the project maturity of an organization. Therefore, it is necessary to provide companies with ways to manage both projects and processes (Koszlajda, 2010). Today, projects are an integral part of any growing company with classified and structured processes in the IT industry. (Verband der Automobilindustrie, 2010).

3. Methodological assumptions

The author's work on the article consists of several stages, the first of which is a literature review, followed by the selection of models and characterization of the most popular ones, as well as the conduct of interviews and presentation of research results. The first stage is to

conduct a literature survey, which is an important part of research projects (Silverman, 2009), providing an objective and reliable summary of a given theoretical area. It allows referring to the existing state of knowledge (Anderson et al., 2008), presenting the existing theoretical and research approaches contributing to the expansion and development of a specific research field (Levy, 2006).

The critical literature review process consists of (Czakon, 2011):

1. Identification of published and unpublished works on the topic of interest to the researcher, i.e. the process of data collection.
2. Evaluation of the identified works in terms of the problem addressed and its solution.
3. The research report, i.e. documenting the research done.

The purpose of the article is to present the results of the usability analysis of project maturity models for IT companies. In pursuit of this goal, a critical review of the literature was carried out, followed by the identification of project maturity models and, as a final step, their analysis. The main criterion for the selection of project maturity models, was their potential analogy to the needs that IT enterprises have. Taking into account the purpose of the work presented above, the main research problem was also defined, which is as follows: What project maturity models can be a key element of the management system in IT enterprises? The main research problem posed was clarified by posing specific research questions:

1. Which project maturity models are best suited to IT enterprises?
2. What elements of the structure of project maturity models are best used in the IT industry?
3. What limitations exist in the use of project maturity models in the IT industry?

The research problem proposed in the article set the direction of the research work. During the work, a qualitative approach to research was applied, based on expert assessments conducted using a structured individual interview technique.

4. The issue of the project maturity

The term "maturity" in colloquial terms is defined as "a state of reaching full development" or "a state of readiness for certain tasks" (Szymczak, 1978). In such terms, the concept refers to living organisms and psychological and social phenomena resulting from human activities. This means that the very process of reaching maturity is closely related to the improvement of skills in several dimensions: economic, social or biological (Juchniewicz, 2009).

On the other hand, in the scientific context, the meaning of the term "project maturity of the organization" is constantly changing, despite the growing interest in the field of project management, both by practitioners and theoreticians, this definition has not been clearly defined (Lichtarski, 2015). Project maturity of an organization in the most general and simplest

definition is defined as the ability of an organization to develop by mastering the skills of strategic and operational project management (Strojny, habilitation).In broader terms, it can be stated that project maturity is "the ability, readiness of an organization to effectively select a portfolio of projects - supporting the strategy and goals of the organization, and the use of professional techniques and tools, project management methodologies to bring a project to a successful conclusion and translate this success into subsequent projects" (Juchniewicz, 2012). This issue is addressed by leading project management standards like IPMA, PMI and PRINCE2. According to the PMI organization, project maturity should be understood as an enterprise's ability to achieve strategic business goals, which can only be achieved through appropriate project selection and management. This definition focuses attention on linking project management to the achievement of organizational goals, and companies that actually adopt a project approach are likely to achieve competitive advantage (Weidemann, 2017).

One of the fundamental assumptions associated with the level of project maturity is that as maturity increases, the effectiveness of project management increases, which translates into the achievement of strategic goals (Litke, 2005). The organization should grow to memento until it has reached the appropriate level of maturity, moreover, with regard to the systems and processes that support project management, the organization realizes two additional benefits (Korzner, 2005):

- work is performed with minimal changes in scope,
- implemented processes minimally disrupt ongoing operations.

Nowadays, the importance of projects in organizations is so significant that it requires an appropriate adjustment of the internal environment in which the project is implemented. In such a situation, one can speak of adopting a project orientation. Increasing those elements that increase the agility of the enterprise (Jack's habilitation). Enterprises that have introduced a systemic approach to project management have created conditions conducive to project implementation (Brookes, Clark, 2009).

It should be noted that important from the point of view of project maturity is to ensure a balance between its elements, i.e.: processes, structure, people and systems, because only then the result will be measurable benefits in project management (Wiedmann, 2017). Indication of the optimal level of project maturity is extremely difficult, the pursuit of a higher level is associated with costs, barriers of the current staff, technological capabilities and process constraints, so the organization must evaluate the possibilities so that the pursuit of a higher level is profitable (Sońta-Drączkowska, 2012).

Assessing an organization's level of project maturity requires the use of appropriate tools, namely project maturity models. Currently, there are many such models, developed by experts and organizations. In fact, every reputable organization involved in setting project management standards has created its own project maturity model. They define in detail the elements that go into the concept of project management, most of the models measure on the basis of the degree of proficiency in (Halachkiewicz, 2007):

- communication of project team participants,
- maintenance of relationships with stakeholders,
- motivation of team members, integration,
- synchronization and coordination of activities, identification of risks,
- determining the focus, quality, budget and timing of projects.

5. The analysis of selected project maturity models

Due to the interest in maturity issues in project management, a number of studies and models have been developed in this area, and they are built according to the philosophy of achieving successive levels of maturity (Kwak, Ibbs, 2000; Turner, Müller, 2003; Andersen, Jessen, 2003; Lianying et al., 2012). It is worth noting that it was first put into the form of a widely available standard by the Software Engineering Institute in the Capability Maturity Model (CMM), or process maturity models (Paulk, 1993). In 2006, K.P. Grant and S. Pennypacker had already identified 30 maturity models relating to the CMM or its individual components. Kosieradzka A. and Smagowicz J. made an analysis of maturity models, where project maturity models were distinguished (Kosieradzka, Smagowicz, 2016):

- PMMM (The Kerzner Project Management Maturity Model) - developed by H. Kerzner.
- P3M3 (Portfolio, Program and Project Management Maturity Model) - developed by the Office of Government Commerce.
- OPM3 (Organizational Project Management Maturity Model) - developed by the Project Management Institute..
- P2MM (PRINCE2 Maturity Model) - developed by the Office of Government Commerce

Most of the models identify dimensions where the manifestations of mature project management can be observed. However, the PMMM model, takes an evolutionary approach it presents the phases of development of an organization or community from a low level of maturity to a high level.

5.1. The Kerzner Project Management Maturity Model (PMMM)

Over the past few decades, it has been noted, the aforementioned very dynamic development of the area of project management, both in business and public organizations. The first maturity model created was the Kerzner Project Management Maturity Modelm, or PMMM for short. The many years of experience of the model's author, Harold Kerzner, made it possible to detail the five levels of maturity an organization can be at, as well as information regarding the actions to be taken in order to reach higher levels. H. Kerzner distinguished five levels of maturity in his model (Kerzner, 2001):

1. Common language - the organization's participants know the importance of projects, the organization has some knowledge of projects, uses the same terms and can distinguish them from day-to-day operations.Wspólne procesy – organizacja rozumie i rozpoznaje procesy w obrębie zarządzania projektami oraz rozumie jak ważne jest ich zdefiniowanie i zmodyfikowanie. Dodatkowo posiada umiejętność powtórzenia tych procesów przy kolejnych projektach.
2. Common processes - the organization understands and recognizes the processes within project management and understands the importance of defining and modifying them. Additionally, it has the ability to repeat these processes on subsequent projects.
3. Unified methodology - the organization understands that the use of synergy in the combination of methodologies is critical and uses a unified methodology for project management. Synergy makes it easier for the organization to control.
4. Benchmarking - the organization understands that improvement is necessary to maintain a competitive advantage, improves the adopted project management methodology and decides what it should learn and from whom.
5. Continuous improvement - the organization constantly evaluates the information obtained from level 4 and decides which information is useful for improvement, the organization provides a model for other organizations to learn from its experience and provides a model in the area of self-improvement.

The PMMM model is a publicly available and free tool, so regardless of the size of the organization, it can be used.

5.2. Portfolio, Programme and Project Management Maturity Model (P3M3)

One of the models mentioned is the Portfolio, Program and Project Management Maturity Model (abbreviated P3M3). It is a model of an organization's maturity in managing not only projects, but also programs and portfolios (Juchniewicz, 2009; The Office of Government 2010), allowing to diagnose how well an organization manages not only its projects, but focuses on higher levels, namely portfolio, program and risk management in the context of corporate governance principles. The model was developed by the PRINCE2 organization. The maturity model is an evolved version of the PMMM, or Project Management Maturity Model, based on the principles of CMM (developed by the Softwere Engineering Institute), later transformed into the model now known as CMMI, combining elements of both a continuous and an oil-based model (The Office of Government Commerce, 2010). The P3M3 model is based on three tools (Sorychta-Wojszczyk, 2018):

1. Project Management Maturity Model – PjMMM.
2. Programme Management Maturity Model – PgMMM.
3. Portfolio Management Maturity Model – PfMMM.

Common knowledge domains have been defined for the above-mentioned tools (Juchniewicz, 2016):

- management control defines the degree of control over the organization's day-to-day operations,
- benefit management determines the extent to which the organization's productivity is defined, monitored and ensured,
- financial management determines the degree of investment management and control by the organization,
- stakeholder management describes the extent to which the organization identifies and communicates with project stakeholders to minimize risks and negative impacts,
- strategic management in the organization describes the extent to which the organization controls the correlation of projects with strategy,
- risk management describes the extent to which the organization is aware of negative risks and identifies preventive measures, as well as positive risks and actions that can multiply potential benefits,
- resource management describes the level at which the organization uses its position in the value chain and minimizes the impact of shortages.

In turn, the basis of the model are the maturity levels, according to the PMMM, which are defined for the project, program and portfolio at which the organization may be (Pirannejad, Ingrams, 2022):

- level 1: awareness of processes (awareness of process) - chaotic processes,
- level 2: repeatable processes (repeatable process) - processes used by isolated groups,
- level 3: defined processes (defi ned process) - processes defined, standardized and implemented,
- level 4: managed processes (managed process) - processes are managed and measured,
- level 5: optimized processes (optimized process) - processes are thoughtfully optimized.

These levels, are the structural elements of the P3M3 model, which can be used in a number of ways in an organization, for example: to identify key practices, to identify practices, or by audit teams during audits. The levels described in the model represent successive states of maturity during their development. An enterprise that is at the lowest level can also implement projects successfully, but managers work in such an organization in a problem-solving mode when problems arise. Schedules and budgets, on the other hand, are most often exceeded or meeting them results in the delivery of much lower quality products (Reiners, 2012). The model allows you to see what stage the organization is at and what steps it needs to take to get to a higher level of maturity, it is an extremely useful model because it not only gives you information on how to change the organization, but also gives you a benchmark.

5.3. Organization Project Management Maturity Model (OPM3)

Model The OPM3 model was developed by Project Management Institute (PMI) organizations in 2003. OPM3 is defined as "the consistent, logical application of knowledge, skills, tools and techniques to organizational and project activities to achieve organizational goals through projects" (Kruszewski, 2003). OPM3 is developed on the basis of so-called best practices. It distinguishes 586 best practices, where each practice is assigned to OPM3 dimensions. These dimensions are based on the 4 phases of process management:

- standardization,
- measurement,
- control,
- continuous improvement

and 3 areas of project management:

- projects,
- programs,
- portfolios.

The combination of these two areas makes it possible to formulate 12 OPM3 dimensions related to, among other things, standardization of project management processes or measurement of program management processes. Project maturity assessment with OPM3 is carried out using a special computer program.

The OPM3 model is described in detail, with as many as 586 best practices on the basis of which an organization can assess its activities and the conduct of projects in accordance with the methodology. The broad scope will allow verification of maturity in almost any organization.

5.4. PRINCE2 Maturity Model (P2MM)

In 2004, the Office of Government Commerce published a working version of the P2MM maturity model, while the first official version appeared in 2006. It was built on the Project Management Maturity Model (PMMM) developed by OGC, as well as the official PRINCE2 methodology manual "PRINCE2 Effective Project Management" published by OGC.

It is a project management maturity model designed specifically to measure the progress of PRINCE2 project processes in organizations. It is designed for organizations that have adopted and are using the PRINCE2 methodology, as this is the basis on which maturity is measured. Its purpose is to determine to what extent the PRINCE2 methodology is used in an organization to manage projects (Juchniewicz, 2010). However, the model can also be used as an independent component of the more general PMMM model. The P2MM model is based on the first three levels of the PMMM model, having three maturity dimensions (Labuda, 2009):

- level 1 - initial, the organization begins to implement the PRINCE2 methodology,
- level 2 - iterative, the PRINCE2 methodology is used to manage projects, but its use is inconsistent,
- level 3 - defined, the organization's current standard for project implementation is PRINCE2.

The maturity assessment is conducted by an enterprise representative or an accredited Programme and Project Management Registered Consultant in the first stage, while the second stage is conducted only by an accredited consultant based on a structured interview with selected people from the enterprise. This model shows the exact steps on how to verify the introduction of PRINCE2 methodology, it will be extremely useful for an organization that wants to verify its effectiveness.

If we want an organization to be successful in implementing a project management philosophy, the impact of project management on the rest of operations must be defined and communicated, it must be reflected in the organizational structure, processes and incentive systems. The project approach must be anchored in the culture of the entire organization as exemplified by the organization's project maturity models (Kuzyk, 2010).

It is worth noting that it is the IT industry that creates many programs to improve project management in companies. Since it is the forerunner of tools to improve project management in companies, and thus support the development of maturity, it should also be able to manage and create a project management model so that the tool is best suited to existing needs. Verifying and identifying the ideal elements of a project maturity model for an IT company requires analyzing existing models in the literature and comparing their elements with the needs of IT companies (Wojciechowska, Strojny, 2021).

6. Evaluation of selected project maturity models based on key criteria proposed for IT companies

The analysis of project maturity models has made it possible to select those that are the most frequently analyzed by researchers and used by practitioners. However, the most important element is to relate the models to an enterprise operating in the IT industry, since they are general models designed for any industry. All the analyzed models have their own specifics, many areas or elements. Each of the maturity models has tools and a description of how exactly it should be applied and information on what exactly we are analyzing, while not every element, let alone the entire model can be applied 1:1 in the IT industry. Each industry has its own peculiarities of implemented projects, in the IT industry the most important elements are variability and dynamics, and the fact that success is not always the product or service assumed at the start of the project. For this reason, when evaluating models, it is worth focusing on a few

key criteria that will be relevant to any company operating in the IT industry. The evaluation of the models was based on three criteria:

1. The ability to implement the entire project maturity model in an IT company.

The key criterion is from the point of view of the dynamics of change in enterprises and its needs, it was selected for evaluation because the IT industry is one of the fastest growing industries in the global market and enterprises and the organization need a solution to the problem at the time of its occurrence. When a business gap or bottleneck occurs, the IT enterprise should solve the problem relatively quickly. There are many models and approaches to project maturity in the literature and practice, many companies by trial and error method to achieve results, so it is important to verify whether any of the analyzed models can be implemented 1:1 in the IT industry. Meanwhile, importantly, it is not the implementation itself that is key, but also the correct functioning and bringing efficiency.

2. The model includes an IT industry component.

This criterion was chosen because, as its name suggests, it will verify whether the models in question have an area or component dedicated to the IT industry. A component or an entire model designed for the IT industry would be invaluable because it would allow one to understand the fit of a given model or its components for the IT enterprise, without the need for matching. This is so important because many IT companies lack people associated with maturity studies and people who understand the need for change. Such a model would bring the maturity of the enterprise to a higher level with less effort. It is characteristic of the IT industry to deliver working products to customers in a short period of time, i.e. to act agilely. So it is essential to also introduce change dynamically and agilely.

3. Ease of understanding the model for a technical person (a non-managerial person).

The third criterion is to verify that the model is understandable to a person who is not a management person on a daily basis, but an executive employee, in the case of the IT industry this is, for example, a programmer or a business analyst. This criterion centers around the transparency and ease of understanding of the model for any interested person in the organization. The IT industry, in addition to agility and dynamism, is distinguished by the additional language of the industry, most often English words are mixed with Polish and do not always have the same meaning as in a literal translation, the criterion will determine whether a person who usually uses the industry language and has a specific way of communication will also understand the specifics of the project maturity model. Most often, the people who are professionally involved in management, improving project management and increasing the maturity of enterprises are specialists in fields such as finance, economics, psychology or management. For this reason, it is so important that the project maturity model be understood by all internal stakeholders, e.g. the HR and payroll department, the development department, the analytical department, or the sales department. Yes, the model can be implemented by a specialist and such an implementation can be considered 100% done, while the most important thing is what the company's employees will do with this implementation. If the company's

employees do not understand its purpose and benefits, both for the company but also for themselves, the whole implementation will fail.

The models were evaluated using an expert method, otherwise known as a heuristic. They are characterized by the fact that the research is based on a purposive selection of people taking part in the study, and each respondent is selected consciously by the person who conducts the survey. These people are supposed to be experts in their field, related to the research problem at hand. The experts are supposed to answer the questions that are included in the questionnaires that contain the problem under discussion, and they should be people who are highly qualified, experienced and knowledgeable, and those who think independently, perhaps suggesting a new approach to the problem (Sudol, 2016). Three specialists were selected for the study:

1. Project manager in the IT industry (E1).

Gracjan Walczak – Project Manager working at CCC Group. In the IT industry for four and a half years, having started his work from managing projects in a software house to the largest companies in Poland such as Warta, Xplus or the aforementioned CCC.

2. Project manager in the IT industry (E2).

Marcin Drozd – Project Manager with over 3 years of IT experience, implementing projects for both corporate and institutional clients throughout Europe.

3. Project manager i university lecturer (E3).

Krzysztof Witkowski – Project Manager with over 20 years of experience, interim manager. Co-author of project management implementations in IT, mining, engineering industry and local and central public administration, among others. IPMA certifications lev. B, PRINCE2 Practitioner. Academic lecturer at, among others, Rzeszow University of Technology, Silesian University of Technology, Ks. J. Tischner European University.

All specialists referred to each of the three criteria in the given design maturity model. The proposed criteria, along with the assessment relating to them, are presented in Table 1.

Table 1.
Evaluation of project maturity models against IT industry criteria

Kryteria oceny	PMMM	P3M3	OPM3	P2MM
Możliwość implementacji projektowej w firmie z branży IT	(E1): Tak (E2): Tak (E3): Tak	(E1): Tak (E2): Tak (E3): Tak	(E1): Tak (E2): Tak (E3): Tak	(E1): Nie (E2): Nie (E3): Nie
Model zawiera komponent dotyczący branży IT i zdolności technologicznych IT	(E1): Tak (E2): Tak (E3): -	(E1): Tak (E2): Nie (E3): -	(E1): Tak (E2): Tak (E3): -	(E1): Tak (E2): Tak (E3): -
Łatwość zrozumienia modelu dojrzałości projektowej dla osoby technicznej?	(E1): Tak (E2): Tak (E3): Tak	(E1): Tak (E2): Nie (E3): Nie	(E1): Tak (E2): Tak (E3): Tak	(E1): Tak (E2): Tak (E3): Nie

Source: Own study.

The above table compacts the evaluation of the criteria by specialists, shows the general approach about the evaluation criteria from the perspective of the experience of a particular expert. However, in addition, each of the specialists also referred by elaborating on their

statements about each criterion to detail their answers. All specialists believe that the models: PMMM, P3M3 and P2MM are possible to implement in their entirety in an IT company, while the exception is the P2MM model, because Marcin Drozd believes, as with the other models, that it can be implemented in its entirety, while the exception is the response of Gracjan Walczak and Krzysztof Witkowski, who believe that it is not possible to implement the P2MM model 1:1 in the IT industry. Marcin Drozd stressed that P2MM in the form of "pure PRINCE2" is not the best approach for the IT industry, but with large-scale projects of low complexity it is possible to implement it effectively in the IT industry as well. It is also worth noting that Gracjan Walczak pointed out the practical use of models from his own experience of PMMM, P2M3 and OPM3, among others, in software house companies. Marcin Drozd, on the other hand, decried that P3Me is possible to implement, of course, but seems to focus on higher levels of the organization, so it may not be the most effective option for a smaller IT company, but for corporations like SII or Asseco it would be ideal.

The second criterion, the inclusion of an IT component in the model, showed the greatest divergence in the experts' responses. Gracjan Walczak is of the opinion that every model contains a component aimed strictly at the IT industry. Marcin Drozd, on the other hand, agrees with the first expert on 3 models, namely: PMMM, OPM3 and P2MM. On the other hand, he believes that the P3M3 model is focused on the already mentioned higher levels of the organization, and there are no specified things aimed at IT companies. Meanwhile, Expert 3, i.e. Krzysztof Witkowski, believes that criterion No. 2 should not be evaluated, because the specifics of IT are no different from other creative industries, so it is impossible to assess whether it contains a component aimed strictly at one particular IT industry.

Marcin Drozd points out that the P3M3 model is not aimed at a technical person. Krzysztof Witkowski, on the other hand, believes that the P2MM model is not aimed at a technical person, but added a model not included in the IPMA Delta study that would be understood by a technical person. As for the other criteria and answers, the experts agree that they are understandable to a technical person, Gracjan Walczak believes that any model is possible to be understood by a technical person, Marcin Drozd believes that PMMM, OPM3 and P2MM are understandable, and Krzysztof Witkowski believes that PMMM, P3M3 and OPM3 are easy to understand by a technical person.

7. Evaluation of selected project maturity models based on key criteria proposed for IT companies

The purpose of the article is to present the results of a usability analysis of project maturity models for an IT enterprise. The first part of the work on the article was to perform a critical review of the literature, which was done by analyzing the project maturity models and selecting

from among them, those that are most often analyzed by practitioners and researchers in relation to the IT industry, and then the presented models were evaluated. The project maturity models presented in the article are part of the available models in the literature, while they are the most representative in the area of the IT industry. The literature deals with issues related to the general functioning of businesses or topics of too detailed business management. However, insufficient attempts are made to formulate concepts and models for the management of organizations of a certain type, including organizations in the IT industry. A critical review of the literature made it possible, to identify the existing models, to identify the most popular and widely used ones in the IT industry, while it identified a certain number of them rejecting other less popular concepts.

The main research problem of the article is as follows: What project maturity models can be a key element of the management system in IT companies? The main research problem posed was clarified by posing specific research questions, which are included in the following table along with the answers.

Table 2
Answers to research questions

Research questions	Answers
Which project maturity models are best suited to IT enterprises?	The most fitting models are: PMMM, P3M3, OPM3.
What elements of the design maturity model structure are best used in the IT industry?	Elements dedicated to the IT industry, taking into account the volatility and dynamics of the industry and the specifics of projects implemented flexibly.
What limitations exist in the use of design maturity models in the IT industry?	1. Lack of understanding of the model 2. Partial implementation of the model. 3. Application of the model in an inappropriate manner, not in accordance with the guidelines. 4. Application of a model designed for a different size of enterprise.

Source: own study.

Further research should focus on analyzing process maturity models aimed at the IT industry, then formulating a holistic concept combining both processes and projects to develop a model designed for an IT company pursuing both.

As the market develops, design maturity models are used and developed, interest in them has existed for several decades. Despite the continued interest in and use of them, there is still scientific and practical research flowing from many industries. This situation is due to market demand and dynamics. In the future, it is expected that the interest in design maturity models will not pass away, because they bring tangible benefits to enterprises. On the other hand, it is becoming increasingly necessary to develop project maturity models to help determine the level of maturity of an enterprise in a given industry. It will be equally necessary to develop implementation methods with respect to the specifics of the industry and the constraints of a given enterprise. Future research should focus primarily on areas of a specific industry, as it will be extremely difficult and labor-intensive to match the specifics, size and culture of an organization. For this reason, it is necessary to create industry-specific models, flexible and with a carefully

described implementation process, so that a manager can fit such a model to his or her industry and company or organization without great difficulty. This would allow, to focus only on the details of the enterprise, separate elements, and the main features of the model would be implemented automatically. This would probably result, a greater willingness to implement such models and interest in them itself, which would be another element for deeper research and realization of more and more detailed models.

References

1. Anderson, S., Allen, P., Peckham, S., Goodwin, N. (2008). Asking the Right Questions: Scoping Studies in the Commissioning of Research on the Organisation and Delivery of Health Services. *Health Research Policy and Systems, vol. 6, no. 1*. DOI: 10.1186/1478–4505–6–7.
2. Chrisis, M.B., Konrad, M., Shrum, S. (2003). *CMMI Guidelnes for Process Integration and Product Improvement*. USA: Addison-Wesley.
3. Collin, S.M.H., Głowiński, C. (1999). *Słownik komputerów i internet.* Warszawa: WILGA.
4. Crawford, P., Bryce, P. (2003). Project Monitoring and Evaluation: a Method for Enhancing the Efficiency and Effectiveness of Aid Project Implementation. *International Journal of Project Management, vol. 21*.
5. Czakon, W. (2011). Metodyka systematycznego przeglądu literatury. *Przegląd Organizacji, 3.*
6. Gębczyńska, A., Bujak, A. (2011). Wykorzystanie modelu dojrzałości procesowej w doskonaleniu systemów zarządzania jakością. *Zeszyty Naukowe Wyższej Szkoły Bankowej we Wrocławiu, Nr 20*.
7. Juchniewicz, M. (2009). Dojrzałość projektowa organizacji i jej zastosowanie w zarządzaniu. *Przegląd Organizacji, nr 7-8*.
8. Juchniewicz, M. (2010). Dojrzałość projektowa organizacji jako narzędzie doskonalenia procesów zarządzania projektami. In: S. Lachiewicz, M. Matejun (eds.), *Współczesne koncepcje zarządzania produkcją, jakością i logistyką.*
9. Juchniewicz, M. (2012). Prognozy zmian na rynku pracy a programy kształcenia na poziomie wyższym. In: Polityka edukacyjna wobec rynku pracy. *Zeszyty Naukowe Wydziałowe Uniwersytetu Ekonomicznego w Katowicach.* Katowice.
10. Juchniewicz, M. (2016). Osiąganie doskonałości w realizacji projektów przy wykorzystaniu modeli dojrzałości projektowej. In: M. Trocki, E. Bukłaha (eds.), *Zarządzanie projektami – wyzwania i wyniki badań.* Warszawa: Oficyna Wydawnicza SGH.
11. Kępka, B. (2010). *Strategia rozwoju branży informatycznej – plan działania. Dla województwa zachodniopomorskiego, raport*.

12. Kerzner, H. (2005). *Advanced Project Management*. Gliwice: Helion.
13. Kosieradzka, A., Smagowicz, J. (2016). Analiza porównawcza modeli dojrzałości organizacji. In: M. Ćwiklicki, M. Jabłoński, S. Mazur (eds.), *Współczesne koncepcje zarządzania publicznego. Wyzwania modernizacyjne sektora publicznego*. Fundacja Gospodarki i Administracji Publicznej.
14. Koszlajda, A. (2010). *Zarządzanie projektami IT. Przewodnik po metodykach.* Warszawa: Helion.
15. Kozarkiewicz, A., Wójcik, P. (2015). Czynniki sukcesu i bariery współpracy międzyorganizacyjnej w realizacji projektów wytwarzania oprogramowania. *Zeszyty Naukowe, nr 225.* Uniwersytet Ekonomiczny.
16. Kruszewski, L.M. (2003). *Organizational Project Management Maturity Model*. Pittsburgh: Project Management Institute Inc.
17. Kusyk, M. (2010). *Badanie dojrzałości projektowej firm z północnej Polski.* Gdańsk: PMI GB.
18. Łabuda, W. (2009). Koncepcja wdrożenia PMO w przedsiębiorstwie. *Zeszyty Naukowe.* Warszawska Wyższa Szkoła Informatyki.
19. Lasek, M., Adamus, A. (2014). Kiedy warto stosować metodyki zwinne (Agile Methodologies) w zarządzaniu projektami wytwarzania oprogramowania? *Informatyka Ekonomiczna, nr 1(31),* Uniwersytet Ekonomiczny we Wrocławiu.
20. Levy, Y., Ellis, T.J. (2006). A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research. *Informing Science Journal, Vol. 9*.
21. Liebert, F. (2017). Zarządzanie projektami w przedsiębiorstwach branży IT – studium literaturowe. *Zeszyty Naukowe Politechniki Śląskiej, Organizacja i Zarządzanie.* Gliwice.
22. Litke, H.-D. (2005). *Projektmanagement Methoden, Handbuch für die Praxis*. Munchen-Wien: Hanser Verlag.
23. Maylor, H. (1999). *Project Management*. Harlow: Prentice Hall.
24. Mierzwińska, L. (2013). Personalne aspekty sukcesu projektu informatycznego realizowanego z zastosowaniem metodyk zwinnych, cz. 1. *Zarządzanie i Finanse, nr 4.*
25. Paulk, M.C. et al. (1993). *Capability Maturity Model for Software (Version 1.1) (CMU/SEI-93-TR-024).* Pittsburgh, Pennsylvania: Software Engineering Institute.
26. Pirannejad, A., Ingrams, A. (2022). Open Government Maturity Models: A Global Comparison. *Social Science Computer Review, 08944393211063107*.
27. Pritchardt, C.L. (2001). *Zarządzanie ryzykiem w projektach*. Warszawa: WIG-Press.
28. Productive.com. Retrived from: http://www.productive.com, 22.02.2023.
29. Reiners, G.M. (2012). Understanding the differences between Husserl's (descriptive) and Heidegger's (interpretive) phenomenological research. *Journal of Nursing & Care, 1(5).*
30. Seethamraju, R. (2012). Business Process Management – A Missing Link in Business Education. *Business Process Management Journal, vol. 18, no. 3*.
31. Silverman, D. (2009). *Prowadzenie badań jakościowych*. Warszawa: PWN.

32. Sońta-Drączkowska, E. (2012). *Zarządzanie wieloma projektami*. Warszawa: PWE.
33. Sorychta-Wojsczyk, B. (2018). Analiza dojrzałości projektowej w jednostkach samorządu terytorialnego – studium literaturowe. *Zeszyty Naukowe. Organizacja i Zarządzanie*. Politechnika Śląska.
34. Spałek, S. (2004). *Krytyczne czynniki sukcesu w zarządzaniu projektami*. Gliwice: Wyd. Politechniki Śląskiej.
35. Spałek, S. (2014). Assessing Project Management Maturity in the area of knowledge management in select companies. *International Journal of Economics, Finance and Management Sciences, vol. 2, no. 2.*
36. Spolsky, J. (2005). *Zarządzanie projektami informatycznymi. Subiektywne spojrzenie programisty*. Gliwice: Helion.
37. Strategor (1999). *Zarządzanie formą. Strategie, struktury, decyzje, tożsamość*. Warszawa: PWE.
38. Strojny, J. (2019). *Orientacja procesowo-projektowa organizacji samorządu lokalnego: wymiary, poziomy dojrzałości, determinanty oraz efekty w zakresie rozwoju lokalnego*.
39. Strojny, J., Szmigiel, K. (2015). Analiza porównawcza podejść w zakresie zarządzania projektami. *Modern Management Reviev – vol. XX, 22(3).*
40. Sudoł, S. (2016). Delficka metoda badawcza. In: *Zarządzanie. Teoria i praktyka*.
41. Szymczak, M. (ed.) (1978). *Słownik języka polskiego.* Warszawa: PWN.
42. The Office of Government Commerce (2010). *The Portfolio, Programme, and Project Management Maturity Model (P3M3®) Version 2.1.* London.
43. Verband der Automobilindustrie (2010). *Zapewnienie jakości na mapie procesów - Podstawy, analizy ryzyka, metody, modele procesów, tom IV*. Heinrich Druck + Medien.
44. Wiedmann, D. (2017). Poziom dojrzałości projektowej a narzędzia IT wspomagające zarządzanie projektami. *Handel Wewnętrzny, 3(368), tom II*. Uniwersytet Ekonomiczny w Poznaniu, pp. 136-145.
45. Winiarski, J. (2008). *Analiza możliwości zastosowania metody AHP do oceny ryzyka w projektach z branży IT*. Gdańsk: Uniwersystet Gdański.
46. Wittek, Ż. (2018). Dojrzałość projektowa organizacji jako potencjał rozwojowy przedsiębiorstw. *Prace Naukowe Uniwersytetu Ekonimicznego we Wrocławiu, nr 2018*, ISSN 1899-3192.
47. Wojciechowska, A., Strojny, J. (2022). *Ocena modeli dojrzałości procesowej pod kątem użyteczności dla branży IT*. Kraków.

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DESIGN THINKING AND ITS USE TO BOAST INNOVATIVENESS

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Purpose: The aim of the paper is to analyze the innovations in design thinking.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: It could be pointed out that exist the relationship between design thinking and the organizational innovativeness. Design Thinking began it's important role especially when start-ups were start to increase in the global market. Nowadays this method plays important role as a part of dynamic, agile action on the world stage and in various sectors of business from teaching to building IT systems. Because of that method can be used as a boast in innovative activities in many sectors. The publication describes main relations between design thinking and innovations and give an overview of the tools used in design thinking to boast innovativeness.
Originality/value: Detailed analysis of all subjects related to the problems connected with the innovations and design thinking.

Keywords: Industry 4.0; innovation, industrial enterprise, design thinking, innovativeness.

Category of the paper: literature review.

1. Introduction

Design can be defined as both noon and a verb in the context of any creative activity. As a verb, design is the process of originating and developing a plan for an aesthetic and functional product or service, which usually requires considerable amount of research, thought, modelling, iterative adjustment and re-designing. As a noon it is both for the final plan of action or the result of following plan of action. The industrial design process and methods are in part based around innovation and creativity and guides projects through a fuzzy and chaotic reality while keeping a close touch with the end user (Gullberg et al., 2021). Those concepts can be used in Industry 4.0 condition in industrial enterprise to boast it's innovativeness (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł,

Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Steculа, Wolniak, 2022; Olkiewicz et al., 2021).

The aim of the paper is to analyze the design thinking from innovativeness point of view.

2. The basic rules of design thinking

Design thinking is an activity that is implicit in the process of design. As a concept Design Thinking emerged in the latter part of twentieth century. The discourse on design and design thinking is grounded in traditional disciplines such as industrial and graphic design as well as engineering and architecture. We can define design as the principal mark that distinguishes the profession from science (Brzoska, 2016). Design thinking refers to creative strategies that designers utilize during the process of designing (Visser, 2006). Design thinking is also an approach which can be used to consider issues and resolve problems more broadly than within professional design practice and has been applied in business and to social issues (Dorst, 2011, abek, Wolniak, 2013, 2016; Hys, Wolniak, 2018). Design thinking in business uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity (Dorst, 2012). The qualities of design thinking are affected by variables such as fixation, creativity, process strategy, and generation of alternatives. A significant part of the problem-solving process in design thinking involves the ability to synthesize knowledge from a variety of sources (Cross, 2007; Pink, 2006). For this reason, design thinking has a multidisciplinary character. Attempts have been also made to distinguish design thinking as a form of abductive thought which has the capacity to generate novel ideas (Dorst, 2012).

Also design and design thinking is an integral part to the production of things or artifacts. Indeed, design thinking is implicated in all aspects of the manmade world from physical artifacts to symbolic and conceptual objects. Design thinking should involve all form of cognitive activities including remembering, understanding, applying, analyzing, evaluating and creating (Anderson, Shattuck, 2012). Design thinking is mainly about building innovators who can use the design thinking paradigm to transform ideas into reality, to transform organization, and to transform all aspects of life (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021). There are four rules of design thinking to be fulfilled in the process. The rules are described in the Table 1.

Table 1.
Rules of design thinking

Rules	Explanation
Human rule	All innovator activity is ultimately social in nature. Human rule is based on individuals, but teamwork is also necessary to invent new and challenging innovations. The team should be diverse and agile to do the process of creating innovations best. People are the most valued asset in the design process.
Ambiguity rule	Innovators must preserve ambiguity. (Never go home with just one idea.) Innovation demands experimentation at the limits of knowledge, at the limits of the ability to control events and with the freedom to see things differently. The innovation must always be in a rebuilding mode. The process of creating innovation can be long and the ambiguity may be frustrating, but it is necessary to create alternative futures.
Redesign rule	All innovation is re-innovation. When looking to the future, it is always helpful to look to the past. Try to understand previous solution of the problem and learn from them. Because technology and social circumstances change constantly, it is imperative to understand how needs have been addressed in the past and by whom. Then we can more easily apply the foresight method to estimate basic social and technical conditions that we could encounter 5, 10 or more years from now.
Tangible rule	Make innovation tangible. Being tangible is essential because we need to learn rapidly in order to produce well. Conceptual prototyping has been a central activity in design thinking in all cases.

Source: On basis: (Plattner et al., 2015; Carleton, Cockayne, 2013).

3. Stages of design thinking

Design Thinking consists of five successive stages. All stages are indispensable and should be done sequentially without leaving out any of them. We can distinguish five stages of Design Thinking as follows (Figure 1, Table 2):

- empathize,
- define,
- ideate,
- prototype, and
- test.

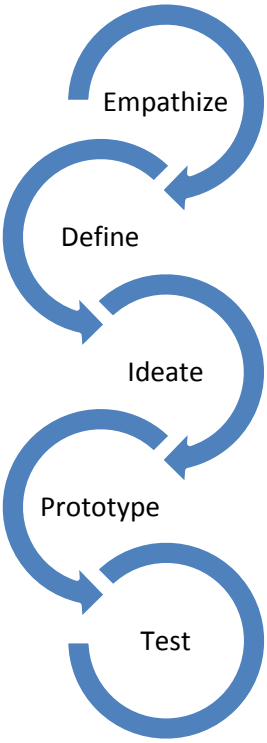

Figure 1. Five steps of Design Thinking.

Source: Wolniak, 2017.

Design thinking process realisation in the company should take into account following steps (Hobcraft, 2020):

- Design Thinking starts with empathy, a deep human focus to gain insights which may reveal new and unexplored ways of seeing, and courses of action to follow in bringing about preferred situations for business and society.
- It involves reframing the perceived problem or challenge at hand, and gaining perspectives, which allow a more holistic look at the path towards these preferred situations.
- It encourages collaborative, multi-disciplinary teamwork to leverage the skills, personalities and thinking styles of many in order to solve multifaceted problems.
- It initially employs divergent styles of thinking to explore as many possibilities, deferring judgment and creating an open ideation space to allow for the maximum number of ideas and points of view to surface.
- It later employs convergent styles of thinking to isolate potential solution streams, combining and refining insights and more mature ideas, which pave a path forward.
- It engages in early exploration of selected ideas, rapidly modelling potential solutions to encourage learning while doing, and allow for gaining additional insights into the viability of solutions before too much time or money has been spent

- It tests the prototypes which survive the processes further to remove any potential issues.
- It iterates through the various stages, revisiting empathetic frames of mind and then redefining the challenge as new knowledge and insight is gained along the way.
- It starts off chaotic and cloudy steamrolling towards points of clarity until a desirable, feasible and viable solution emerges.

Table 2.
Five stages of Design Thinking

Stage	Characteristic
Empathize	Stage is used to determine the characteristics of the audience for which the product is designed through detailed observations, interviews or surveys. This way you can find detailed information about the product users and their needs. Innovation always starts with a thorough diagnosis of the needs and expectations of users and potential users of the product while also understanding the technical conditions and markets conditions of the product.
Define	In this step the team should specify the user needs. The interdisciplinary team should carry out a synthesis of the information which was collected during the previous phase of the process to determine the extent of the problem. A design brief should present the client's requirements for a job. These may be verbal or written, simple or complex. A brief should contain a specific goal to be met by the design. During the analysis standard frame of mind and habits should be rejected, in order to design the most creative and customer-oriented solutions. This stage is relatively difficult, because people naturally will work on specific solutions, which are known to them, and do not move in the uncertainty of many possible directions. Note, however, that too rapid concretization of solutions can lead to a situation in which a solution will not sufficiently satisfy the needs of the customer. Example questions: • Do you understand what the client is asking for? • Does the client understand what they are asking for? • Do you agree on the definition of terms? • Does the brief have any flaws? • Can you manage client expectations?
Ideate	At this stage, using tools such as brainstorming, we should generate as many creative ideas as possible. Please note that, in accordance with the rules of brainstorming even the most improbable ideas and solutions should be considered. Generating good ideas requires not only technical knowledge on the topic, but also ingenuity, courage and creativity. In order to facilitate this process everyone should refrain from criticism of ideas generated by other team members. This phase should be completed by evaluating and selecting the best idea. Then a prototype of the solution should be created. At this stage, a design team might also choose to harness one of the multitudes of art and design movements as a paradigm. As the ideate stage progresses, it will become clear whether there are any misunderstandings or shortcomings in the definition stage and whether enough research was done. Feedback can be sought through the design process to clarify points with the client and to address aspects which were ill-defined during the definition stage. Example questions: • Do you understand the brief? • Do you have enough research information? • Which methods will be used for idea generation?

Cont. table 2.

Prototype	In this step, it is necessary to build one (or in some cases several solutions), assembly and test the prototype(s) prior to the presentation. During the building phase the prototype is created as a physical representation of a solution to the problem. The basic function of the prototype is the ability to present visual solutions for users and fast feedback on its operation. This way you can check whether the project complies with the requirements set by the customer or are changes to made. A prototype gives the design team and client the ability to visualize and handle a design concept, to get an idea of its physical presence and tactile qualities. You can never be entirely sure that the final product will be a success, even if you have previously conducted tests using prototype solutions, Frequent building, improvement and testing of prototypes may be necessary. This approach ensures that the client's expectations have been fulfilled and the risk of potential failure has been minimized. The aim of prototype is to test various aspects of a design solution. To do this all aspects of the design solution should be effectively evaluated. To convey the idea of what the design solution might look like, a prototype does not need to be made with the final materials. Example questions: • Do all potential solutions require prototyping? • What elements will the prototype test? • What functionality will the prototype have?
Test	In the last stage the prototype should be presented as a solution to the original client in order to obtain their opinion on the generated product. In this way, you can test its functioning. At this stage, the aim is to check the functioning of the designed solution in a real environment in which the product will be used. Specify the necessary parameters and their values, so you can clearly determine the results of the test. In this step you should involve many people in the testing process. Omission of this step in the design process can lead to a situation that the proposed solution does not quite meets the required assumptions and expectations of customers. Example questions: • Has the client signed off on the design(s)? • Have printers or other production professionals been booked? • Has the artwork been delivered to production professionals? • Has the job been proofed against the design? • Has the finished job been delivered?

Source: On base: Ambrose, Harris, 2010; Tschimmel, 2012.

Sometimes authors distinguish seven steps of design thinking, such as define, research, ideate, prototyping, selection, implementation and learning as shown in Table 3 (Hobcraft, 2020).

Table 3.
Seven stages of Design Thinking

Stage	Characteristic
Define	A precise understanding of the problem and its constraints which allow a more exact solution to be developed.
Research	The stage reviews information, such as the history of the design problem, end-user research and opinion-led interviews. In this stage we can identify potential obstacles.
Ideate	In this stage end-user motivations and needs are identified and ideas are generated to meet these, for example through brainstorming.
Prototyping	In this stage we should to resolve ideas, which are presented for user-group and stakeholder review, prior to being presented to client.
Selection	In this stage the proposed solution is reviewed against the design brief objective. Some solutions might be practical but may not be the best ones.
Implementation	In this stage we should finalize the design for the purpose of delivery to the client.
Learning	The stage helps the designer(s) to improve their performance and, for this reason, designers should seek client and target audience feedback and determine if the solution met the goals of the brief. This may identify improvements that can be made in the future.

Source: On basis: Ambrose, Harris, 2010.

4. Design Thinking and inovativeness

The method of design thinking can be used to resolve many problems connected with innovativeness (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). For example following issues can be resolved using described method (Hobcraft, 2020; Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023):

- redefining value,
- human-centred innovation,
- quality of life,
- problems affecting diverse groups of people,
- involving multiple systems,
- shifting markets and behaviours,
- coping with rapid social or market changes,
- issues relating to corporate culture,
- issues relating to new technology,
- re-inventing business models,
- addressing rapid changes in society,
- complex unsolved societal challenges,
- scenarios involving multidisciplinary teams,
- entrepreneurial initiatives,
- educational advances,
- medical breakthroughs,
- inspiration is needed,
- problems that data can't solve.

Design thinking is an approach to collaboration, learning, problem solving and innovation. In practice the whole design process is a structured framework for identifying challenges, gathering information's, generating potential innovations, refining ideas and testing new solutions. The main reason why companies strive for innovation is to be more flexible and adaptable to the new and dynamic business environment on the market. In this situation new adaptive instruments are needed to initiate this new ideas. This opportunity is provided by the design thinking method because it can be a strategic and a key tool facilitating the combination of internal processes in an organization and take them to a new level by focusing on the customer and its needs. Practice in many organizations shows that when managers perceive the framework of design thinking ad an approach in their every activity and such of their companies (new products, new services and experiences, marketing, human resources, innovation, etc.)

the result is reaching desirable market solutions with an added value for the user and also secure realization and profit for the organization (Ivanova, Koleva, 2020).

According the type of analysis we can achieve various effects using design thinking methods. In the table 5 we distinguished some typical varieties of Design thinking. Each of them can have various impacts on the innovations. There are also many typical common Design thinking tools. We describe them in the table 5.

Table 4.
Types of Design thinking

Type	Characteristic
Design Thinking	Also known as Meta Design Thinking, Strategic Design Thinking, and Transformation by Design. Method starts upstream with no outcome assumptions, and results in diverse outcomes.
Product Design Thinking	Starts downstream with product creation assumptions and results in product outcomes.
Service Design Thinking	Starts downstream with service creation assumptions and results in service outcomes.
Experience Design Thinking	Starts downstream with experience creation assumptions and results in experience outcomes.

Source: On base: Hobcraft, 2020.

Table 5.
Design thinking tools

Tool	Characteristic
Visualization	Tools involves the use of imagery, either visual or narrative. In addition to traditional charts and graphs, it can take the form of storytelling and the use of metaphor and analogies, or capturing individual ideas on post-it notes and whiteboards so they can be shared and developed jointly.
Ethnography	It encompasses a variety of qualitative research methods that focus on developing a deep understanding of users by observing and interacting with them in their native habitat. Techniques here would include participant observation, interviewing, journey mapping, and job-to-be-done analysis.
Structured collaborative sense-making techniques	Tools like mind mapping facilitate team-based processes for drawing insights from ethnographic data and create a "common mind" across team members. Collaborative ideation, using brainstorming and concept development techniques, assists in generating hypotheses about potential opportunities. These tools leverage difference by encouraging a set of behaviors around withholding judgment, avoiding debates, and paying particular attention to the tensions difference creates in the process of seeking higher-order thinking and creating more innovative solutions.
Assumption surfacing	Tool focuses on identifying assumptions around value creation, execution, scalability, and defensibility that underlie the attractiveness of a new idea.
Prototyping	Its techniques facilitate making abstract ideas tangible. These include approaches such as storyboarding, user scenarios, metaphor, experience journeys, and business concept illustrations. Prototypes aim to enhance the accuracy of feedback conversations by providing a mechanism to allow decision-makers to create more vivid manifestations of the future.
Cocreation	Toll incorporates techniques that engage users in generating, developing, and testing new ideas.
Field experiments	Tolls are designed to test the key underlying and value-generating assumptions of a hypothesis in the field. Conducting these experiments involves field testing the identified assumptions using prototypes with external stakeholders, with attention to disconfirming data.

Source: On base: Liedka, 2015; Ivanova, Koleva, 2020.

5. Conclusion

According to the research carried by D. Modrzejewska (2020) exist the relationship between design thinking and the organizational innovativeness. Design Thinking began it's important role especially when start-ups were start to increase in the global market. Nowadays this method plays important role as a part of dynamic, agile action on the world stage and in various sectors of business from teaching to building IT systems. Because of that method can be used as a boast in innovative activities in many sectors. The publication describes main relations between design thinking and innovations and give an overview of the tools used in design thinking to boast innovativeness.

References

1. Ambrose, G., Harris, P. (2010). *Design Thinking.* Lausanne: AVA Publishing.
2. Anderson, L., Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher, 41*, 16-25.
3. Brzóska, J. (2016). Innovation as a factor of steel sector companies value growth. *Prace Instytutu Metali Nieżelaznych, 2,* 17-23.
4. Carleton, T., Cockayne, W. (2013). *Playbook for strategic foresight and innovations*. Stanford, CA: Stanford University.
5. Cross, N. (2007). *Designery ways of knowing*. Boston: Birghauser.
6. Czerwińska-Lubszczyk, A., Grebski, M.E., Grebski, W., Krawczyk, D., Kuzior, A., Wolniak, R. (2022). *Creativity and innovativeness in psychology and management*. Toruń: Dom Organizatora.
7. Dorst, K. (2011). The core of "design thinking" and its applications. *Design Studies, vol. 32,* pp. 521-532.
8. Dorst, K. (2012). Frame Innovation: Create new thinking by design. Cambridge, MA: MIT Press.
9. Drozd, R., Wolniak, R. (2021). Metrisable assessment of the course of stream-systemic processes in vector form in industry 4.0. *Quality and Quantity*, 1-16, DOI: 10.1007/s11135-021-01106-w.
10. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
11. Gajdzik, B., Grebski, M., Grebski, W., Wolniak, R. (2022). *Human factor activity in lean management and quality management.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.

12. Gajdzik, B., Wolniak, R. (2021). Digitalisation and innovation in the steel industry in Poland - selected tools of ICT in an analysis of statistical data and a case study. *Energies, 14(11),* 1-25.
13. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources, 10(1),* 1-17.
14. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies, 14(14),* 1-22.
15. Gajdzik, B., Wolniak, R. (2022). Framework for R&D&I Activities in the Steel Industry in Popularizing the Idea of Industry 4.0. Jour*nal of Open Innovation: Technology, Market, and Complexity, 8(3),* 133.
16. Gajdzik, B., Wolniak, R. (2022). Influence of Industry 4.0 Projects on Business Operations: literature and empirical pilot studies based on case studies in Poland. *Journal of Open Innovation: Technology, Market, and Complexity, 8(1),* 1-20.
17. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 68.
18. Gajdzik, B., Wolniak, R., Grebski W.W. (2023). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies, 16(2),* 1-29.
19. Gajdzik, B., Wolniak, R., Grebski, W.W. (2022). An econometric model of the operation of the steel industry in Poland in the context of process heat and energy consumption. *Energies, 15(21),* 1-26, 7909.
20. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government*. Philadelphia: CreativeSpace.
21. Grabowska, S., Grebski, M., Grebski, W., Saniuk, S., Wolniak, R. (2021). *Inżynier w gospodarce 4.0.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa – Stowarzyszenie Wyższej Użyteczności "Dom Organizatora".
22. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
23. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). Inżynier – zawód przyszłości. *Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
24. Gullberg, G., Widmark, E, Nyström, M., Landström, A. (2021). Design Thinking in Business innovation, MFE, 2006, http://www.diva-portal.org/smash/get/diva2:414819/fulltext01.pdf, 20.02.2023.
25. Hąbek, P., Wolniak, R. (2013). Analysis of approaches to CSR reporting in selected European Union countries. *International Journal of Economics and Research, 4(6),* 79-95.

26. Hąbek, P., Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity, 50(1),* 339-420.
27. Hąbek, P., Wolniak, R. (2016). Factors influencing the development of CSR reporting practices: experts' versus preparers' points of view. *Engineering Economy, 26(5),* 560-570.
28. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences, 220,* 115-123.
29. Herceg, I.V., Kuč, V., Mijušković, V.M., Herceg, T. (2020). Challenges and Driving Forces for Industry 4.0 Implementation. *Sustainability, 12*, 4208, doi:10.3390/su12104208.
30. Hobcraft, P. (2020). Improving the potential for Innovation through Design Thinking. Bonn, Germany: HYPE Simplify Innovation.
31. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny, 9*, 1000-1002.
32. Ivanova, D., Koleva, G. (2020). *Design Thinking – an innovative management approach*. Conference: Innovation in forest industry and engineering design. Sofia, Bulgaria.
33. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114*, 1-6.
34. Jonek-Kowalska, I., Wolniak, R. (2021). The influence of local economic conditions on start-ups and local open innovation system. *Journal of Open Innovations: Technology, Market and Complexity, 7(2),* 1-19.
35. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
36. Jonek-Kowalska, I., Wolniak, R., Marinina, O.A., Ponomarenko, T.V. (2022). *Stakeholders, Sustainable Development Policies and the Coal Mining Industry. Perspectives from Europe and the Commonwealth of Independent States*. London: Routledge.
37. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies, 14(13),* 1-22.
38. Kwiotkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies, 14(14),* 1-22.
39. Kwiotkowska, A., Wolniak, R., Gajdzik, B., Gębczyńska, M. (2022). Configurational paths of leadership competency shortages and 4.0 leadership effectiveness: an fs/QCA study. *Sustainability, 14(5),* 1-21.
40. Liedtka, J. (2015). Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. *Journal Production Innovation Management, 32(6),* 925-338.

41. Modrzejewska, D. (2020). The impact of Desigh Thinking on innovativeness of an organization and personal creativity of its employees. *Business Informatics, 2(56),* 43-50.
42. Olkiewicz, M., Olkiewicz, A., Wolniak, R., Wyszomirski, A. (2021). Effects of pro-ecological investments on an example of the heating industry - case study. *Energies, 14(18),* 1-24, 5959.
43. Oluyisola, O.E., Sgarbossa, F., Strandhagen, J.O. (2020). Smart Production Planning and Control: Concept, Use-Cases and Sustainability Implications. *Sustainability, 12,* 3791, doi:10.3390/su12093791.
44. Orzeł, B., Wolniak, R. (2021). Clusters of elements for quality assurance of health worker protection measures in times of COVID-19 pandemic. *Administrative Science, 11(2),* 1-14, 46.
45. Orzeł, B., Wolniak, R. (2022). Digitization in the design and construction industry - remote work in the context of sustainability: a study from Poland. *Sustainability, 14(3),* 1-25.
46. Pink D. H. (2006). A whole new mind: Why right brainers will rule the future. New York: Riverhead.
47. Plattner, H., Meinel, Ch. Leifer, L. (2015). *Design Thinking research. Building innovations.* Stanford: Springer.
48. Ponomarenko, T.V., Wolniak, R., Marinina, O.A. (2016). Corporate Social responsibility in coal industry (Practices of russian and european companies). *Journal of Mining Institute, 222,* 882-891.
49. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy.* Warszawa: CeDeWu.
50. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2021). Diagnosis of the maturity level of implementing Industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability, 13(9),* 1-38.
51. Steculа, K., Wolniak, R. (2022). Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *Journal of Open Innovation: Technology, Market, and Complexity, 8(3),* 159.
52. Steculа, K., Wolniak, R. (2022). Influence of COVID-19 Pandemic on Dissemination of Innovative E-Learning Tools in Higher Education in Poland. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 89.
53. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarzadzanie, 67,* 63-74.
54. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali*. Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.

55. Tschimmel, K. (2012). *Design Thinking as an effective Toolkit for Innovation*. Proceedings of the XXIII ISPIM Conference: Action for Innovation: Innovating from Experience. Barcelona.
56. Visser, W. (2006). *The cognitive artifacts of designing*. Lawrence Erlbaum Associates.
57. Wolniak, R, Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija, 53(4),* 709-713.
58. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
59. Wolniak, R. (2013). A typology of organizational cultures in terms of improvement of the quality management. *Manager, 17(1),* 7-21.
60. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji, 3,* 13-17.
61. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości, 3,* 20-25.
62. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. Etyka biznesu i zrównoważony rozwój. *Interdyscyplinarne studia teoretyczno-empiryczne, 1,* 109-122.
63. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
64. Wolniak, R. (2016). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
65. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3,* 127-134.
66. Wolniak, R. (2017). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2,* 139-150.
67. Wolniak, R. (2017). Analiza wskaźników nasycenia certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949 oraz zależności pomiędzy nimi. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 108,* 421-430.
68. Wolniak, R. (2017). The Corporate Social Responsibility practices in mining sector in Spain and in Poland – similarities and differences. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 111,* 111-120.
69. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6,* 247-255.
70. Wolniak, R. (2017). The use of constraint theory to improve organization of work. 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts. SGEM 2017, 24-30 August 2017, Albena, Bulgaria. *Conference proceedings. Book 1, Modern science. Vol. 5, Business and management.* Sofia: STEF92 Technology, 1093-1100.

71. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3*, 159-176.
72. Wolniak, R. (2018). Methods of recruitment and selection of employees on the example of the automotive industry. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie, 128,* 475-483.
73. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 133,* 121-136.
74. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity, 2,* 101-118.
75. Wolniak, R. (2019). Leadership in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 133,* 137-150.
76. Wolniak, R. (2019). Support in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 137,* 247-261.
77. Wolniak, R. (2019). The level of maturity of quality management systems in Poland-results of empirical research. *Sustainability, 15,* 1-17.
78. Wolniak, R. (2020). Design in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 148,* 769-781.
79. Wolniak, R. (2020). Operations in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 148,* 783-794.
80. Wolniak, R. (2020). Quantitative relations between the implementation of industry management systems in European Union countries. *Silesian University of Technology Scientific Papers. Organization and Management Series, 142,* 33-44.
81. Wolniak, R. (2021). Internal audit and management review in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 151,* 724-608.
82. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series, 151,* 725-734.
83. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series, 155,* 579-594.
84. Wolniak, R. (2022). Individual innovations. *Silesian University of Technology Scientific Papers. Organization and Management Series, 166,* 861-876.
85. Wolniak, R. (2022). Management of engineering teams. *Silesian University of Technology Scientific Papers. Organization and Management Series, 157,* 667-674.
86. Wolniak, R. (2022). Problems of Covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series, 167,* 599-608.
87. Wolniak, R. (2022). Project management in engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series, 157,* 685-698.

88. Wolniak, R. (2022). Project management standards. *Silesian University of Technology Scientific Papers. Organization and Management Series, 160,* 639-654.
89. Wolniak, R. (2022). Sustainable engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series, 160,* 655-667.
90. Wolniak, R. (2022). The role of the engineering profession in developing and implementing sustainable development principles. *Silesian University of Technology Scientific Papers. Organization and Management Series, 155,* 595-608.
91. Wolniak, R. (2022). Traits of highly innovative people. *Silesian University of Technology Scientific Papers. Organization and Management Series, 166,* 877-892.
92. Wolniak, R. (2023). European Union Smart Mobility - aspects connected with bike road systems extension and dissemination. *Smart Cities, 6,* 1-32.
93. Wolniak, R. Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości, 5*, 29-34.
94. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie, 116,* 203-214.
95. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie, 116,* 215-226.
96. Wolniak, R., Grebski, M.E. (2018). Innovativeness and Creativity of the Workforce as Factors Stimulating Economic Growth in Modern Economies. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie, 116,* 227-240.
97. Wolniak, R., Grebski, M.E., Skotnicka-Zasadzień, B. (2019). Comparative analysis of the level of satisfaction with the services received at the business incubators (Hazleton, PA, USA and Gliwice, Poland). *Sustainability, 10,* 1-22.
98. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji, 1*, 139-149.
99. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences, 220,* 541-547.
100. Wolniak, R., Jonek-Kowalska, I. (2021). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon), 34(3),* 376-398.
101. Wolniak, R., Jonek-Kowalska, I. (2021). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public, 37,* 132-150.
102. Wolniak, R., Jonek-Kowalska, I. (2022). The creative services sector in Polish cities. *Journal of Open Innovation: Technology, Market, and Complexity, 8(1),* 1-23.
103. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies, 13(11),* 1-16.

104. Wolniak, R., Skotnicka, B. (2011). *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
105. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
106. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
107. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the condition s of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability, 7*, 1-17.
108. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies, 15(2),* 1-23.
109. Wolniak, R., Skotnicka-Zasadzień, B., Zasadzień, M. (2019). Problems of the functioning of e-administration in the Silesian region of Poland from the perspective of a person with disabilities. *Transylvanian Review of Public Administration, 57E,* 137-155.
110. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
111. Wolniak, R., Sułkowski, M. (2016). The reasons for the implementation of quality management systems in organizations. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 92,* 443-455.
112. Wolniak, R., Wyszomirski, A., Olkiewicz, M., Olkiewicz, A. (2021). Environmental corporate social responsibility activities in heating industry - case study. *Energies, 14(7),* 1-19, 1930.

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INDUSTRY 5.0 – CHARACTERISTIC, MAIN PRINCIPLES, ADVANTAGES AND DISADVANTAGES

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Purpose: The aim of the paper is to analyze the Industry 5.0 concept and compare it with Industry 4.0.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: Industry 5.0 offers several benefits that make it worth adopting in manufacturing industries, including improved efficiency, greater quality control, sustainability, enhanced worker safety, improved customer experience, cost savings, competitive advantage, increased innovation, and positive social impact. By integrating human creativity and intuition with advanced machinery and technology, Industry 5.0 promises to create a more sustainable, flexible, and socially responsible manufacturing environment that delivers higher quality products and more meaningful jobs.
Originality/value: Detailed analysis of all subjects related to the problems connected with the Industry 5.0.

Keywords: Industry 4.0; innovation, industrial enterprise, design thinking, innovativeness.

Category of the paper: literature review.

1. Introduction

Industry 5.0 is a theoretical concept that represents the next phase of industrial development beyond Industry 4.0. While Industry 4.0 focused on the integration of advanced technologies such as automation, artificial intelligence, and the Internet of Things (IoT) into manufacturing processes, Industry 5.0 seeks to integrate these technologies with human creativity and intuition to create a more collaborative and flexible manufacturing environment (Wang et al., 2023).

Overall, Industry 5.0 seeks to create a manufacturing environment that is not only technologically advanced but also human-centric, sustainable, and socially responsible.

The aim of the paper is to analyze the Industry 5.0 and compare it with industry 4.0.

2. The characteristic of Industry 5.0

Industry 5.0 represents a new era of manufacturing, characterized by the integration of advanced technologies and human creativity to create a more collaborative and flexible manufacturing environment. While Industry 4.0 emphasized automation and technology-driven efficiency, Industry 5.0 seeks to integrate human workers more fully into the manufacturing process, working collaboratively with machines to maximize productivity and quality (Taverner et al., 2021).

One of the key features of Industry 5.0 is a greater emphasis on collaboration. Instead of seeing machines and humans as separate entities, Industry 5.0 seeks to create a manufacturing environment where workers and machines work together, leveraging each other's strengths to achieve greater productivity and quality (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). This collaboration is made possible by advanced technologies like collaborative robots, augmented and virtual reality, and real-time monitoring and feedback systems.

Another important aspect of Industry 5.0 is a greater emphasis on human creativity and intuition. While Industry 4.0 introduced the concept of smart factories, Industry 5.0 takes this to a new level by leveraging technology to help workers express their ideas and designs more fully. Technologies like virtual and augmented reality can help workers visualize and test new products and designs in a more immersive and interactive way, leading to greater innovation and creativity in the manufacturing process (Sindhvani et al., 2022).

In addition to these features, Industry 5.0 also places a greater emphasis on sustainability and social impact. By promoting a circular economy model and responsible resource use, Industry 5.0 seeks to create a more sustainable manufacturing process that minimizes waste and reduces environmental impact (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021). It also recognizes the impact that the manufacturing industry can have on workers and communities, and seeks to create a more positive and supportive working environment through technologies like digital assistants and advanced safety systems.

Overall, Industry 5.0 offers several benefits that make it worth adopting in manufacturing industries. These include improved efficiency, greater quality control, sustainability, enhanced worker safety, improved customer experience, cost savings, competitive advantage, increased innovation, and positive social impact. By integrating human creativity and intuition with advanced machinery and technology, Industry 5.0 promises to create a more sustainable, flexible, and socially responsible manufacturing environment that delivers higher quality products and more meaningful jobs. As manufacturing continues to evolve, Industry 5.0 offers

an exciting glimpse into the future of manufacturing and the potential for human-machine collaboration to create a better world (Rachmawati et al., 2022).

The role of human factor in Industry 5.0 is essential, as this new era of manufacturing places a greater emphasis on collaboration between humans and machines. While Industry 4.0 was characterized by a high level of automation and technology-driven efficiency, Industry 5.0 seeks to integrate human workers more fully into the manufacturing process, leveraging their creativity, intuition, and problem-solving skills to maximize productivity and quality.

In Industry 5.0, machines and humans are seen as complementary rather than separate entities. Advanced technologies like collaborative robots, augmented and virtual reality, and real-time monitoring and feedback systems are used to help workers express their ideas and designs more fully, while machines take care of the more repetitive and physically demanding tasks. This collaboration leads to a more flexible and responsive manufacturing process that can better adapt to changing market demands and customizations (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

Another important aspect of the human factor in Industry 5.0 is the promotion of worker well-being and job satisfaction. By creating a more supportive and positive working environment through technologies like digital assistants and advanced safety systems, Industry 5.0 seeks to empower workers and promote their well-being. This can lead to increased job satisfaction, productivity, and innovation, as workers feel more engaged and valued in their work.

Human factors also play a key role in the quality control process in Industry 5.0. While machines can provide data and insights into product quality, humans bring their intuition and experience to the process, identifying and addressing issues that may not be immediately apparent through data analysis. By combining the insights of both machines and humans, Industry 5.0 can deliver higher quality products that meet the needs of customers and the market (Olsen, 2023).

The role of the human factor in Industry 5.0 is essential, as this new era of manufacturing seeks to integrate human workers more fully into the manufacturing process and leverage their creativity, intuition, and problem-solving skills. By promoting collaboration between humans and machines, creating a more supportive and positive working environment, and combining the insights of both machines and humans in the quality control process, Industry 5.0 promises to create a more flexible, responsive, and socially responsible manufacturing environment that delivers higher quality products and more meaningful jobs (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023).

The role of sustainability in Industry 5.0 is crucial, as this new era of manufacturing places a greater emphasis on responsible resource use and minimizing environmental impact. While Industry 4.0 was focused primarily on automation and efficiency, Industry 5.0 seeks to

create a more sustainable manufacturing process that minimizes waste and reduces environmental impact (Ozedemir and Hekim, 2018).

One of the key features of Industry 5.0 is the promotion of a circular economy model. This model seeks to minimize waste and maximize the use of resources by designing products that can be reused, repurposed, or recycled at the end of their lifecycle. Advanced technologies like artificial intelligence, machine learning, and the Internet of Things can be used to optimize the use of resources, reduce energy consumption, and minimize waste (Akundi et al., 2022).

Another important aspect of sustainability in Industry 5.0 is the use of renewable energy sources. By transitioning to renewable energy sources like solar, wind, and hydroelectric power, manufacturers can reduce their carbon footprint and minimize their impact on the environment. This transition can be facilitated by advanced technologies like energy storage systems, smart grids, and real-time energy monitoring and management systems (Adel, 20220).

In addition to these features, Industry 5.0 also seeks to promote social sustainability by creating a more positive and supportive working environment for employees. This can be achieved through technologies like digital assistants, advanced safety systems, and real-time feedback and recognition systems. By promoting worker well-being and job satisfaction, Industry 5.0 can empower workers and create a more positive and sustainable working environment (Longo et al., 2020).

Overall, the role of sustainability in Industry 5.0 is essential, as this new era of manufacturing seeks to create a more responsible and sustainable manufacturing process that minimizes waste and reduces environmental impact. By promoting a circular economy model, transitioning to renewable energy sources, and creating a more supportive and positive working environment, Industry 5.0 promises to create a more sustainable, flexible, and socially responsible manufacturing environment that delivers higher quality products and more meaningful jobs (Bakir, Dahlan, 2022).

The role of creativity in Industry 5.0 is critical, as this new era of manufacturing places a greater emphasis on innovation and customization. While Industry 4.0 was characterized by a high level of automation and technology-driven efficiency, Industry 5.0 seeks to integrate human creativity more fully into the manufacturing process, leveraging it to generate new ideas and designs that can maximize productivity and quality.

In Industry 5.0, machines and humans work together as collaborators, with machines taking care of the more repetitive and physically demanding tasks, and humans contributing their creativity, intuition, and problem-solving skills to the process. Advanced technologies like augmented and virtual reality, 3D printing, and real-time monitoring and feedback systems are used to help workers express their ideas and designs more fully, while machines take care of the more routine tasks (Ma et al., 2022).

Another important aspect of creativity in Industry 5.0 is the promotion of design thinking, a human-centered approach to problem-solving that emphasizes empathy, collaboration, and experimentation. By encouraging workers to think outside the box and explore new ideas

and solutions, Industry 5.0 can create a more innovative and responsive manufacturing process that can better adapt to changing market demands and customizations.

Creativity also plays a crucial role in the customization of products in Industry 5.0. By using advanced technologies like machine learning and artificial intelligence, manufacturers can collect and analyze data on customer preferences and behaviors, and use this information to create customized products that meet the specific needs and desires of individual customers (Aslam et al., 2020).

The role of creativity in Industry 5.0 is critical, as this new era of manufacturing seeks to integrate human creativity more fully into the manufacturing process, leveraging it to generate new ideas and designs that can maximize productivity and quality. By promoting collaboration between humans and machines, encouraging design thinking, and using data analytics to customize products, Industry 5.0 promises to create a more flexible, innovative, and responsive manufacturing environment that delivers higher quality products and more meaningful jobs.

3. Comparision between industry 4.0 and industry 5.0

Industry 4.0 represented a significant shift in the manufacturing industry, driven by the integration of advanced technologies such as automation, artificial intelligence, and the Internet of Things (IoT). Industry 5.0 builds on these technologies but focuses on integrating human creativity and intuition to create a more collaborative and flexible manufacturing environment. Here are some of the main important differences between Industry 4.0 and 5.0 (Laskowska, Laskowski, 2023; Lee et al., 2022; Ivanov, 2022):

- Focus on collaboration: While Industry 4.0 emphasized automation and technology-driven efficiency, Industry 5.0 seeks to integrate human workers more fully into the manufacturing process, working collaboratively with machines to maximize productivity and quality.
- Greater emphasis on creativity: Industry 5.0 recognizes the importance of human creativity and intuition in manufacturing, with technologies like augmented and virtual reality helping workers to express their ideas and designs more fully.
- Increased flexibility: Industry 5.0 seeks to create more flexible and adaptable manufacturing environments, with technology like collaborative robots and real-time monitoring and feedback helping workers to respond more quickly to changing circumstances.
- Emphasis on sustainability: While Industry 4.0 introduced the concept of the circular economy, Industry 5.0 places even greater emphasis on sustainable manufacturing practices, with a focus on minimizing waste and promoting responsible resource use.

- Social impact: Industry 5.0 recognizes that the manufacturing industry has a significant impact on workers and communities, and seeks to create a more positive and supportive working environment through technologies like digital assistants and advanced safety systems.
- Integration of blockchain technology: While blockchain technology was not a central feature of Industry 4.0, Industry 5.0 sees it as an essential tool for ensuring the transparency and security of supply chain transactions.
- Increased use of personalized products: While Industry 4.0 saw the beginnings of personalized manufacturing, Industry 5.0 takes this to a new level, with technologies like 3D printing allowing for greater customization and more individualized products.

In conclusion, while Industry 4.0 represented a significant step forward in the manufacturing industry, Industry 5.0 seeks to take these technologies to the next level by integrating human creativity and intuition with advanced machinery and technology. By doing so, Industry 5.0 promises to create more sustainable, flexible, and socially responsible manufacturing environments that deliver higher quality products and more meaningful jobs.

4. Advantages and disadvantages of Industry 5.0

Industry 5.0 represents the next phase of industrial development that aims to create a more collaborative and flexible manufacturing environment that integrates human creativity and intuition with advanced technologies. On the basis of literature analysis we can distinguish following industry 4.0 advantages (Javaid et al., 2020; Johri et al., 2021; Cillo et al., 2022):

- Improved efficiency and productivity: The integration of advanced technologies such as automation, artificial intelligence, and the Internet of Things (IoT) can improve efficiency and productivity in manufacturing processes.
- Increased flexibility: The use of collaborative robots (cobots) and augmented reality (AR) and virtual reality (VR) technologies can enable manufacturing processes to be more flexible and responsive to changes.
- Higher quality products: Industry 5.0 can lead to higher quality products through improved production processes and increased use of real-time feedback and guidance.
- Reduced downtime: Predictive maintenance and real-time monitoring can help reduce downtime in manufacturing processes.
- Better supply chain management: The use of blockchain technology can improve the transparency and security of supply chain transactions.
- More personalized products: Industry 5.0 can enable more personalized products through the use of digital manufacturing technologies.

- Increased worker safety: Collaborative robots and augmented reality technologies can help reduce the risk of accidents and injuries in the workplace.
- Enhanced creativity: By integrating human creativity and intuition with advanced technologies, Industry 5.0 can lead to new and innovative products and solutions.
- Improved customer satisfaction: The use of digital manufacturing technologies and personalized products can improve customer satisfaction and loyalty.
- Reduced waste: The implementation of a circular economy model can reduce waste and promote sustainability in manufacturing processes.
- Greater cost savings: Industry 5.0 can lead to cost savings through increased efficiency, reduced downtime, and improved supply chain management.
- Increased transparency: Blockchain technology can improve transparency in supply chain transactions and promote trust among stakeholders.
- More meaningful jobs: Industry 5.0 can create more meaningful jobs that require creativity and problem-solving skills.
- Improved social impact: The focus on the well-being of workers and the community can improve the social impact of manufacturing.
- Competitive advantage: By implementing Industry 5.0, companies can gain a competitive advantage through improved efficiency, increased flexibility, and higher quality products.

While Industry 5.0 promises numerous benefits, there are also some potential disadvantages that should be considered. Here are main important possible disadvantages of Industry 5.0 (Grabowska et al., 2022; Ghibakholl et al., 2022; Di Marino et al., 2023):

- High initial costs: Implementing Industry 5.0 technologies such as collaborative robots, augmented reality, and blockchain can require significant upfront investment.
- Disruption of traditional manufacturing jobs: The increasing automation and use of robots in Industry 5.0 may lead to job displacement and require retraining of workers.
- Cybersecurity risks: As Industry 5.0 relies on interconnected digital systems, there may be a higher risk of cybersecurity threats, such as hacking and data breaches.
- Complex systems: Industry 5.0 technologies are complex and may require specialized expertise, making it more challenging to manage and maintain.
- Integration challenges: Integrating Industry 5.0 technologies with existing systems and processes can be challenging, requiring significant time and resources.
- Ethical concerns: As Industry 5.0 may lead to increased automation, there may be ethical concerns regarding the impact on workers, such as job displacement, and the ethical use of technology.
- Environmental impact: While Industry 5.0 aims to promote sustainability through a circular economy model, there may still be environmental impacts, such as energy consumption and waste production.

- Limited adoption: The adoption of Industry 5.0 technologies may be limited by the availability of resources, expertise, and regulatory barriers.
- Resistance to change: Resistance to change from traditional manufacturing processes and technologies may hinder the adoption of Industry 5.0.
- Dependence on technology: As Industry 5.0 technologies become increasingly integrated into manufacturing processes, there may be a risk of dependence on technology, making it more challenging to operate without it.

5. Conclusion

Industry 5.0 offers several benefits that make it worth adopting in manufacturing industries, including improved efficiency, greater quality control, sustainability, enhanced worker safety, improved customer experience, cost savings, competitive advantage, increased innovation, and positive social impact. By integrating human creativity and intuition with advanced machinery and technology, Industry 5.0 promises to create a more sustainable, flexible, and socially responsible manufacturing environment that delivers higher quality products and more meaningful jobs.

References

1. Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of Cloud Computing*, *11(1),* 40.
2. Akundi, A., Euresti, D., Luna, S., Ankobiah, W., Lopes, A., Edinbarough, I. (2022). State of Industry 5.0-Analysis and Identification of Current Research Trends. *Applied System Innovation, 5(1),* DOI: 10.3390/asi5010027.
3. Aslam, F., Wang, A.M., Li, M.Z., Rehman, K.U. (2020). Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework. *Information*, *11(2),* doi:10.3390/info11020124.
4. Bakir, A., Dahlan, M. (2022). Higher education leadership and curricular design in industry 5.0 environment: a cursory glance. *Development and Learning in Organizations*.
5. Cillo, V., Gregori, G.L., Daniele, L.M., Caputo, F., Bitbol-Saba, N. (2022). Rethinking companies' culture through knowledge management lens during Industry 5.0 transition. *Journal of Knowledge Management*, *26(10),* 2485-2498.

6. Di Marino, C., Rega, A., Vitolo, F., Patalano, S. (2023). Enhancing Human-Robot Collaboration in the Industry 5.0 Context: Workplace Layout Prototyping. *Lecture Notes in Mechanical Engineering*, 454-465.
7. Drozd, R, Wolniak, R. (2021). Metrisable assessment of the course of stream-systemic processes in vector form in industry 4.0. *Quality and Quantity*, 1-16, DOI: 10.1007/s11135-021-01106-w.
8. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
9. Gajdzik, B., Grebski, M., Grebski, W., Wolniak, R. (2022). *Human factor activity in lean management and quality management.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.
10. Gajdzik, B., Wolniak, R. (2021). Digitalisation and innovation in the steel industry in Poland - selected tools of ICT in an analysis of statistical data and a case study. *Energies*, *14(11),* 1-25.
11. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources*, *10(1),* 1-17.
12. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, *14(14),* 1-22.
13. Gajdzik, B., Wolniak, R. (2022). Framework for R&D&I Activities in the Steel Industry in Popularizing the Idea of Industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(3),* 133.
14. Gajdzik, B., Wolniak, R. (2022). Influence of Industry 4.0 Projects on Business Operations: literature and empirical pilot studies based on case studies in Poland. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-20.
15. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 68.
16. Gajdzik, B., Wolniak, R., Grebski, W.W. (2022). An econometric model of the operation of the steel industry in Poland in the context of process heat and energy consumption. *Energies*, *15(21),* 1-26, 7909.
17. Gajdzik, B., Wolniak, R., Grebski, W.W. (2023). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions, *Energies*, *16(2),* 1-29.
18. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
19. Ghibakholl, M., Iranmanesh, M, Mubarak, M.F., Mubarik, M. Rejeb, A. Nilashi, M. (2022). Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. *Sustainable Production and Consumption*, *33*, 716-737.

20. Grabowska, S., Saniuk, S., Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. *Scientometrics*, *127(6),* 3117-3144, https://doi.org/10.1007/s11192-022-04370-1.
21. Grabowska, S., Grebski, M., Grebski, W., Saniuk, S., Wolniak, R. (2021). *Inżynier w gospodarce 4.0.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa – Stowarzyszenie Wyższej Użyteczności "Dom Organizatora".
22. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
23. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
24. Gullberg, G., Widmark, E, Nyström, M., Landström, A. (2021). *Design Thinking in Business innovation.* MFE, 2006, http://www.diva-portal.org/smash/get/diva2:414819/fulltext01.pdf, 20.02.2023.
25. Hąbek, P., Wolniak, R. (2013). Analysis of approaches to CSR reporting in selected European Union countries. *International Journal of Economics and Research*, *4(6),* 79-95.
26. Hąbek, P., Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity*, *50(1),* 339-420.
27. Hąbek, P., Wolniak, R. (2016). Factors influencing the development of CSR reporting practices: experts' versus preparers' points of view. *Engineering Economy*, *26(5),* 560-570.
28. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, *220*, 115-123.
29. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, *9,* 1000-1002.
30. Ivanov, D. (2022). The Industry 5.0 framework: viability-based integration of the resilience, sustainability, and human-centricity perspectives. *International Journal of Production Research.*
31. Javaid, M., Haleem, A. (2020). Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing, *Journal of Industrial Integration and Management-Innovation and Entrepreneurship*, *5(2),* 327-348, doi: 10.1142/S2424862220500141.
32. Javaid, M., Haleem, A., Singh, R.P., Haq, M.I.U., Raina, A., Suman, R. (2020). Industry 5.0: Potential Applications in COVID-19, *Journal of Industrial Integration and Management-Innovation and Entrepreneurship*, *5(4),* 507-530, doi: 10.1142/S2424862220500220.

33. Johri, P., Singh, J.N., Sharma, A., Rastogi, D. (2021). *Sustainability of Coexistence of Humans and Machines: An Evolution of Industry 5.0 from Industry 4.0*. Proceedings of the 2021 10th International Conference on System Modeling and Advancement in Research Trends, SMART 2021, 410-414.
34. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, *114*, 1-6.
35. Jonek-Kowalska, I., Wolniak, R. (2021). The influence of local economic conditions on start-ups and local open innovation system. *Journal of Open Innovations: Technology, Market and Complexity*, *7(2),* 1-19.
36. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability*, *14(4),* 1-23.
37. Jonek-Kowalska, I., Wolniak, R., Marinina, O.A., Ponomarenko, T.V. (2022). *Stakeholders, Sustainable Development Policies and the Coal Mining Industry. Perspectives from Europe and the Commonwealth of Independent States*. London: Routledge.
38. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies*, *14(13),* 1-22.
39. Kwiotkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies*, *14(14),* 1-22.
40. Kwiotkowska, A., Wolniak, R., Gajdzik, B., Gębczyńska, M. (2022). Configurational paths of leadership competency shortages and 4.0 leadership effectiveness: an fs/QCA study. *Sustainability*, *14(5),* 1-21.
41. Laskowska, A., Laskowski, J.F. (2023). "Silver" Generation at Work—Implications for Sustainable Human Capital Management in the Industry 5.0 Era. *Sustainability (Switzerland), 15(1),* 194.
42. Lee, L.-H., Braud, T., Hosio, S., Hui, P. (2022). *ACM Computing Surveys, 54(8),* 165.
43. Longo, F., Padovano, A., Umbrello, S. (2020). Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future. *Applied Sciences-BASEL*, *10(12),* doi: 10.3390/app10124182.
44. Ma, N., Yao, X., Chen, F., Yu, H., Wang, K. (2022). Human-centric Smart Manufacturing for Industry 5.0. *Jixie Gongcheng Xuebao/Journal of Mechanical Engineering*, *58(18),* 88-102.
45. Olkiewicz, M., Olkiewicz, A., Wolniak, R., Wyszomirski, A. (2021). Effects of pro-ecological investments on an example of the heating industry - case study. *Energies, 14(18),* 1-24, 5959.

46. Olsen, C. (2023). Toward a Digital Sustainability Reporting Framework in Organizations in the Industry 5.0 Era: An Accounting Perspective. *Lecture Notes in Networks and Systems*, *557*, 463-473.
47. Orzeł, B., Wolniak, R. (2021). Clusters of elements for quality assurance of health worker protection measures in times of COVID-19 pandemic. *Administrative Science*, *11(2),* 1-14, 46.
48. Orzeł, B., Wolniak, R. (2022). Digitization in the design and construction industry - remote work in the context of sustainability: a study from Poland. *Sustainability*, *14(3),* 1-25.
49. Ozdemir, V., Hekim, N. (2018). Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, The Internet of Things and Next-Generation Technology Policy, *OMICS-A Journal of Integrative Biology, 22(1),* 65-76, doi: 10.1089/omi.2017.0194.
50. Ponomarenko, T.V., Wolniak, R., Marinina, O.A. (2016). Corporate Social responsibility in coal industry (Practices of russian and european companies). *Journal of Mining Institute*, *222*, 882-891.
51. Rachmawati, I., Multisari, W., Triyono, T., Simon, I.M., da Costa, A. (2021). Prevalence of academic resilience of social science students in facing the industry 5.0 era. *International Journal of Evaluation and Research in Education*, *10(2),* 676-683.
52. Sindhwani, R., Afridi, S., Kumar, A., Luthra, S., Singh, P.L. (2022). Can industry 5.0 revolutionize the wave of resilience and social value creation? A multi-criteria framework to analyze enablers. *Technology in Society*, *68*, 101887.
53. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy.* Warszawa: CeDeWu.
54. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2021). Diagnosis of the maturity level of implementing Industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability*, *13(9),* 1-38.
55. Steculа, K., Wolniak, R. (2022). Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(3),* 159.
56. Steculа, K., Wolniak, R. (2022). Influence of COVID-19 Pandemic on Dissemination of Innovative E-Learning Tools in Higher Education in Poland. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 89.
57. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarzadzanie*, *67*, 63-74.
58. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali.* Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.

59. Taverner, C., Trojan, L., Simion, O., Szkudlarek, E. (2021). Design culture in the era of industry 5.0: A review of skills and needs. *Cultural Management: Science and Education*, *5(1),* 41-58.
60. Wang, H., Lv, L., Li, X., Sun, C., Luo, G. (2023). A safety management approach for Industry 5.0′s human-centered manufacturing based on digital twin. *Journal of Manufacturing Systems, 66,* 1-12
61. Wolniak, R, Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija*, *53(4),* 709-713.
62. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
63. Wolniak, R. (2013). A typology of organizational cultures in terms of improvement of the quality management. *Manager*, *17(1),* 7-21.
64. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji*, *3,* 13-17.
65. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, *3,* 20-25.
66. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, *1,* 109-122.
67. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
68. Wolniak, R. (2016). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
69. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3,* 127-134.
70. Wolniak, R. (2017). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2,* 139-150.
71. Wolniak, R. (2017). Analiza wskaźników nasycenia certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949 oraz zależności pomiędzy nimi. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *108*, 421-430.
72. Wolniak, R. (2017). The Corporate Social Responsibility practices in mining sector in Spain and in Poland – similarities and differences. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *111*, 111-120.
73. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6,* 247-255.
74. Wolniak, R. (2017). The use of constraint theory to improve organization of work. 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts. SGEM 2017, 24-30 August 2017, Albena, Bulgaria. *Conference proceedings. Book 1,*

Modern science. Vol. 5, Business and management. Sofia: STEF92 Technology, 1093-1100.

75. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
76. Wolniak, R. (2018). Methods of recruitment and selection of employees on the example of the automotive industry. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, *128*, 475-483.
77. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
78. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2,* 101-118.
79. Wolniak, R. (2019). Leadership in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 137-150.
80. Wolniak, R. (2019). Support in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *137*, 247-261.
81. Wolniak, R. (2019). The level of maturity of quality management systems in Poland-results of empirical research. *Sustainability*, *15*, 1-17.
82. Wolniak, R. (2020). Design in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 769-781.
83. Wolniak, R. (2020). Operations in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 783-794.
84. Wolniak, R. (2020). Quantitative relations between the implementation of industry management systems in European Union countries. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *142*, 33-44.
85. Wolniak, R. (2021). Internal audit and management review in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 724-608.
86. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
87. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.
88. Wolniak, R. (2022). Individual innovations. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 861-876.
89. Wolniak, R. (2022). Management of engineering teams. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 667-674.
90. Wolniak, R. (2022). Problems of Covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *167*, 599-608.

91. Wolniak, R. (2022). Project management in engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 685-698.
92. Wolniak, R. (2022). Project management standards, Silesian University of Technology *Scientific Papers. Organization and Management Series*, *160*, 639-654.
93. Wolniak, R. (2022). Sustainable engineering, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *160*, 655-667.
94. Wolniak, R. (2022). The role of the engineering profession in developing and implementing sustainable development principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 595-608.
95. Wolniak, R. (2022). Traits of highly innovative people. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 877-892.
96. Wolniak, R. (2023). European Union Smart Mobility - aspects connected with bike road systems extension and dissemination. *Smart Cities, 6,* 1-32.
97. Wolniak, R. Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości*, *5,* 29-34.
98. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 203-214.
99. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
100. Wolniak, R., Grebski, M.E. (2018). Innovativeness and Creativity of the Workforce as Factors Stimulating Economic Growth in Modern Economies. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 227-240.
101. Wolniak, R., Grebski, M.E., Skotnicka-Zasadzień, B. (2019). Comparative analysis of the level of satisfaction with the services received at the business incubators (Hazleton, PA, USA and Gliwice, Poland). *Sustainability*, *10*, 1-22.
102. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1,* 139-149.
103. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
104. Wolniak, R., Jonek-Kowalska, I. (2021). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon*), *34(3),* 376-398.
105. Wolniak, R., Jonek-Kowalska, I. (2021). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, *37*, 132-150.
106. Wolniak, R., Jonek-Kowalska, I. (2022). The creative services sector in Polish cities. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-23.

107. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies*, *13(11),* 1-16.
108. Wolniak, R., Skotnicka, B. (2011). *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
109. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
110. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
111. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the condition s of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, *7, 1*-17.
112. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, *15(2),* 1-23.
113. Wolniak, R., Skotnicka-Zasadzień, B., Zasadzień, M. (2019). Problems of the functioning of e-administration in the Silesian region of Poland from the perspective of a person with disabilities. *Transylvanian Review of Public Administration*, *57E,* 137-155.
114. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
115. Wolniak, R., Sułkowski, M. (2016). The reasons for the implementation of quality management systems in organizations. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *92*, 443-455.
116. Wolniak, R., Wyszomirski, A., Olkiewicz, M., Olkiewicz, A. (2021). Environmental corporate social responsibility activities in heating industry - case study. *Energies*, *14(7),* 1-19, 1930.

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SMART MOBILITY IN A SMART CITY CONCEPT

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Purpose: The purpose of this publication is to present the most important features with which the smart mobility approach is characterized.
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 a smart city, smart mobility also plays an important role in environmental protection. Modern modes of transportation, such as electric cars and urban bicycles, reduce greenhouse gas emissions and air pollution. Thus, smart mobility contributes to improving air quality and the health of residents. As part of the smart city, smart mobility is also seen as part of improving traffic safety. Smart traffic monitoring systems and rapid response to dangerous situations, such as collisions or accidents, can help minimize accidents and collisions. Smart mobility is also one of the key elements of a smart city, which contributes to improving the quality of life for city residents by increasing mobility, reducing air pollution, improving road safety and introducing innovative transportation solutions.
Originality/value: Detailed analysis of all subjects related to the problems connected with the smart mobility in smart city.

Keywords: smart mobility, smart city, quality of life, biking.

Category of the paper: literature review.

1. Introduction

The smart city concept is an approach that aims to use modern technologies and innovative solutions to improve the quality of life in cities and increase their efficiency and sustainability (Herdiasyah, 2023). The smart city concept is divided into several areas among which one is smart mobility (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). This area is important from the point of view of the functioning of modern cities enabling them to organize transportation systems in a modern way.

The purpose of this publication is to present the most important features with which the smart mobility approach is characterized.

2. Smart city

The smart city concept refers to a comprehensive approach to urban development that uses advanced technologies and innovations to improve the quality of life of residents and the efficiency of city operations. The main areas of the smart city concept are (Ploeger, Oldenziel, 2020; Tahmasseby, 2022; Rahman, Dura, 2022):

- Transportation: Optimization of transportation systems, including innovations in public transportation, alternative modes of transportation, smart traffic and parking management, and integration of transportation systems.
- Energy: Use of renewable energy, smart energy management, monitoring of energy consumption in buildings, smart grids and energy storage.
- Environment: Air and water quality monitoring, nature conservation, green technologies and sustainable development.
- Education: Using modern educational technologies in schools and universities, creating e-learning platforms, creating innovative curricula and making knowledge accessible to everyone.
- Health: Use of telemedicine technologies, development of innovative health services, population health monitoring and disease prevention.
- Security: Use of intelligent monitoring and control systems, including video surveillance systems, alarm systems and early warning systems for threats.
- Urban services: Improving the efficiency and accessibility of urban services, such as waste, water, gas, and public lighting, through the use of IoT (Internet of Things) technologies.
- Public administration: Using advanced information technology to improve the efficiency and quality of public services, automating administrative processes and improving inter-institutional communication.

A smart city is the concept of a modern city that uses advanced information and communication technologies to improve city management and the quality of life for residents. The goal of the smart city is to ensure the sustainable development of the city, in which public infrastructure, transportation, energy, water and waste management are optimized, while contributing to environmental protection and improving air quality (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczynska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021).

The smart city concept applies solutions such as smart lighting, air quality monitoring, waste management systems, smart buildings, transportation systems, and many others. As a result, residents can enjoy more convenient and efficient services, and city authorities can better plan development and spending (Tahmasseby, 2022).

The smart city also aims to improve the quality of life for residents by increasing safety, communication, accessibility to services and sustainability. Through the use of technology, the smart city can help better manage the city during emergencies, such as pandemics and natural disasters (Sulkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023).

In the smart city concept, it is important to involve residents in the decision-making and development processes of the city. This creates a participatory model that allows for a better understanding of the needs and expectations of residents and better adaptation of technological solutions to their needs (Rahman, Dura, 2022).

3. Smart mobility

Smart mobility, also known as intelligent transportation, is the use of technology to improve the efficiency, safety and sustainability of transportation systems. As the world becomes more urbanized and the number of vehicles on the road increases, smart mobility is becoming a key component of modern life (Prajeesh, Pillai, 2022).

Smart city and smart mobility are two concepts that are closely related. Smart city is the overall concept of a smart city that uses advanced technologies and innovative solutions to improve the quality of life for residents. Within the smart city, smart mobility is one of the key elements that relates to smart and sustainable transportation (Boichuk, 2020).

Smart mobility introduces innovations in transportation that enable better use of road infrastructure, thereby improving the mobility of residents. Through the use of advanced technologies such as autonomous vehicles, intelligent traffic management systems or mobile applications, residents have access to faster, more efficient and convenient transportation methods (Ku et al., 2022).

In a smart city, smart mobility also plays an important role in environmental protection. Modern modes of transportation, such as electric cars and urban bicycles, reduce greenhouse gas emissions and air pollution. Thus, smart mobility contributes to improving air quality and the health of residents (Benevolo et al., 2016).

As part of the smart city, smart mobility is also seen as part of improving traffic safety. Smart traffic monitoring systems and rapid response to dangerous situations, such as collisions or accidents, can help minimize accidents and collisions.

Smart mobility is one of the key elements of a smart city, which contributes to improving the quality of life of city residents by increasing mobility, reducing air pollution, improving road safety and introducing innovative transportation solutions (Kunytska et al., 2023).

One of the key elements of smart mobility is the use of data to optimize transportation systems. This involves collecting data from a variety of sources, including sensors on vehicles, GPS devices and traffic monitoring cameras, and using this information to make decisions about traffic flow, routing and planning. By analyzing this data in real time, transportation authorities can make changes to reduce congestion and improve overall system performance (Wolniak, Sulkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al, 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

Another important element of smart mobility is the use of connected vehicles. This refers to vehicles equipped with sensors and communication technology that allows them to communicate with other vehicles and the infrastructure around them. Connected vehicles can provide real-time information about traffic conditions, weather and road hazards, which can help drivers make more informed decisions about routes and driving behavior (Orlowski and Romanowska, 2019).

One of the most promising applications of smart mobility is in the area of autonomous vehicles. These are vehicles capable of driving themselves without human intervention. Autonomous vehicles have the potential to revolutionize transportation, reducing accidents, increasing efficiency and reducing the environmental impact of transportation. However, many technical and regulatory challenges need to be solved before autonomous vehicles can be put on the road.

Smart mobility also includes the use of alternative modes of transportation, such as bike-sharing programs, electric scooters and ride-sharing services. By providing a variety of options for commuting, smart mobility can reduce traffic congestion and improve the overall quality of life in cities.

Some of the key advantages of using smart mobility include (Prajeesh and Pillai, 2022, Boichuk, 2020, Rahman and Dura, 2022, Benevolo et al., 2016, Kunytska et al., 2023):

- Improving the efficiency and effectiveness of transportation systems.
- Reducing traffic congestion and travel times by optimizing routes and schedules.
- Improving road safety through the use of advanced monitoring and control systems.
- Reducing the environmental impact of transportation through the use of cleaner modes of transportation, such as electric vehicles.
- Improving the quality of life in cities by reducing exhaust and noise emissions.
- Being able to make better use of existing road infrastructure through traffic optimization.
- Increasing accessibility and convenience for travelers through a variety of transportation options, including alternative modes such as bicycles and electric scooters.

- Improve trip planning by providing real-time information on traffic conditions, weather and road hazards.
- Reducing operating costs for transportation companies by optimizing routes and schedules.
- Improving public transportation management through data collection and analysis to better tailor services to passengers' needs and preferences.

However, the implementation of systems based on the smart mobility concept may encounter numerous problems that cities must overcome to achieve their full effectiveness. These can be mentioned here (Prajeesh, Pillai, 2022; Boichuk, 2020; Rahman, Dura, 2022; Benevolo et al., 2016; Kunytska et al., 2023):

- High costs: The implementation of smart mobility systems requires the investment of significant financial resources. Many cities and transportation companies may not be able to meet these costs.
- Lack of standardization: Many smart mobility technologies are still in development and lack standards and norms, which can make it difficult to integrate different systems and technologies.
- Requirement to adapt infrastructure: The introduction of new smart mobility technologies and systems may require infrastructure adaptation, which can be costly and time-consuming.
- Limited public acceptance: New technologies and systems may face resistance from the public, which may hinder their implementation.
- Privacy and data security issues: The introduction of smart mobility systems may result in the collection and processing of large amounts of data, which may create privacy and data security risks.
- Regulatory challenges: Many smart mobility technologies, such as autonomous vehicles, require regulatory and legislative alignment, which can be time-consuming and complicated.
- Technical complexity: Smart mobility systems require complex technology and infrastructure, which may require high technical skills and IT experience.
- Labor market impact: The introduction of smart mobility systems may lead to the automation of many processes, which may affect the labor market and require employees to be trained in new skills.

The implementation of smart mobility solutions can positively affect the quality of life of residents in smart cities. With the introduction of modern transportation solutions, such as autonomous vehicles and smart traffic management systems, it is possible to reduce traffic jams and the time it takes to get to work or school.

As a result, the city's residents gain more free time, which they can use to relax, meet with family or pursue their passions. In addition, improved road capacity reduces exhaust emissions and air pollution, which has a positive impact on residents' health. Smart transportation solutions can also increase road safety by monitoring traffic and responding quickly to dangerous situations. As a result, the number of accidents and collisions can be reduced, contributing to a greater sense of security for city residents (Dudycz, Piatkowski, 2018).

Smart mobility also affects the city's economic development by making it more attractive to investors and tourists. The availability of modern means of transportation, such as urban bicycles and car-sharing, can attract new people and businesses to the city. Smart mobility has a positive impact on the quality of life of the city's residents, improving their mobility, safety and comfort of travel, and influencing the city's economic development.

The use of bicycles as a means of transportation is one of the elements of smart mobility, as it introduces an innovative and sustainable solution to urban transportation. Bicycles as a means of transportation are not only environmentally friendly, but also allow people to move around quickly, cheaply and conveniently.

As part of smart mobility, urban bicycles are increasingly being introduced into cities. Bike sharing is a system of renting bicycles for short distances, usually at the city or neighborhood level. City residents can rent a bicycle from one point and return it at another point, allowing them to move around freely without having to own a bicycle (Wawre et al., 2022; Wolniak, 2023).

In addition, more and more cities are introducing modern bicycle systems that combine city bikes with intelligent traffic management systems. This allows cyclists to use dedicated bike lanes, gaining a safe and fast way to work or school.

Cyclists also have access to a variety of mobile apps that help them plan their route, find the shortest and safest route, and monitor their health and physical activity.

The introduction of urban bicycling and other innovative cycling solutions to the city is part of the smart mobility concept, as it contributes to improving the quality of life for city residents by increasing mobility, reducing air pollution and improving health through physical activity (Simonofski et al., 2023; Wolniak, 2023).

4. Conclusion

Smart mobility, also known as intelligent transportation, is the use of technology to improve the efficiency, safety and sustainability of transportation systems. As the world becomes more urbanized and the number of vehicles on the road increases, smart mobility is becoming a key part of modern life.

Smart city and smart mobility are two concepts that are closely related. Smart city is the overall concept of a smart city that uses advanced technologies and innovative solutions to improve the quality of life for residents. Within smart city, smart mobility is one of the key elements that relates to smart and sustainable transportation.

Smart mobility introduces innovations in transportation that enable better use of road infrastructure, thereby improving the mobility of residents. Through the use of advanced technologies such as autonomous vehicles, intelligent traffic management systems or mobile applications, residents have access to faster, more efficient and convenient transportation methods.

In a smart city, smart mobility also plays an important role in environmental protection. Modern modes of transportation, such as electric cars and urban bicycles, reduce greenhouse gas emissions and air pollution. Thus, smart mobility contributes to improving air quality and the health of residents.

As part of the smart city, smart mobility is also seen as part of improving traffic safety. Smart traffic monitoring systems and rapid response to dangerous situations, such as collisions or accidents, can help minimize accidents and collisions.

Smart mobility is also one of the key elements of a smart city, which contributes to improving the quality of life for city residents by increasing mobility, reducing air pollution, improving road safety and introducing innovative transportation solutions.

References

1. Benevolo, C., Dameri, R.P., D'Auria, B. (2016). Smart mobility in smart city. *Empowering Organizations.* Cham, Switzerland: Springer International Publishing, 3-28.
2. Boichuk, N. (2020). Smart mobility jako podstawowy element koncepcji inteligentnego miasta — Studium przypadku wybranych polskich miast. In: A. Budziewicz-Guźlecka, (Ed.), *Inteligentne Miasta. Rozprawy i Studia, Vol. 1153*. Szczecin: Uniwersytet Szczeciński, 59-72. ISBN 978-83-7972-402-4.
3. Drozd, R., Wolniak, R. (2021). Metrisable assessment of the course of stream-systemic processes in vector form in industry 4.0. *Quality and Quantity*, 1-16, DOI: 10.1007/s11135-021-01106-w.
4. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
5. Dudycz, H., Piątkowski, I. (2018). Smart mobility solutions in public transport based on analysis chosen smart cities. *Bus. Inform. 2*, 19-35.

6. Gajdzik, B., Grebski, M., Grebski, W., Wolniak, R. (2022). *Human factor activity in lean management and quality management.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.
7. Gajdzik, B., Wolniak, R. (2021). Digitalisation and innovation in the steel industry in Poland - selected tools of ICT in an analysis of statistical data and a case study. *Energies*, *14(11),* 1-25.
8. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources*, *10(1),* 1-17.
9. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, *14(14),* 1-22.
10. Gajdzik, B., Wolniak, R. (2022). Framework for R&D&I Activities in the Steel Industry in Popularizing the Idea of Industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(3),* 133.
11. Gajdzik, B., Wolniak, R. (2022). Influence of Industry 4.0 Projects on Business Operations: literature and empirical pilot studies based on case studies in Poland. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-20.
12. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 68.
13. Gajdzik, B., Wolniak, R., Grebski W.W. (2023). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions, *Energies*, *16(2),* 1-29.
14. Gajdzik, B., Wolniak, R., Grebski, W.W. (2022). An econometric model of the operation of the steel industry in Poland in the context of process heat and energy consumption, *Energies*, *15(21),* 1-26, 7909.
15. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
16. Grabowska, S., Saniuk, S., Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. *Scientometrics*, *127(6),* 3117-3144, https://doi.org/10.1007/s11192-022-04370-1.
17. Grabowska, S., Grebski, M., Grebski, W., Saniuk, S., Wolniak, R. (2021). *Inżynier w gospodarce 4.0.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa – Stowarzyszenie Wyższej Użyteczności "Dom Organizatora".
18. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
19. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.

20. Hąbek, P., Wolniak, R. (2013). Analysis of approaches to CSR reporting in selected European Union countries. *International Journal of Economics and Research*, *4(6),* 79-95.
21. Hąbek, P., Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity*, *50(1),* 339-420.
22. Hąbek, P., Wolniak, R. (2016). Factors influencing the development of CSR reporting practices: experts' versus preparers' points of view. *Engineering Economy*, *26(5),* 560-570.
23. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, *220*, 115-123.
24. Herdiansyah, H. (2023). Smart city based on community empowerment, social capital, and public trust in urban areas. *Glob. J. Environ. Sci. Manag., 9*, 113-128.
25. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, *9,* 1000-1002.
26. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, *114*, 1-6.
27. Jonek-Kowalska, I., Wolniak, R. (2021). The influence of local economic conditions on start-ups and local open innovation system. *Journal of Open Innovations: Technology, Market and Complexity*, *7(2),* 1-19.
28. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability*, *14(4),* 1-23.
29. Jonek-Kowalska, I., Wolniak, R., Marinina, O.A., Ponomarenko, T.V. (2022). *Stakeholders, Sustainable Development Policies and the Coal Mining Industry. Perspectives from Europe and the Commonwealth of Independent States*. London: Routledge.
30. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies*, *14(13),* 1-22.
31. Ku, D., Choi, M., Lee, D., Lee, S. (2022). The effect of a smart mobility hub based on concepts of metabolism and retrofitting. *J. Clean. Prod., 379*, 134709.
32. Kunytska, O., Persia, L., Gruenwald, N., Datsenko, D., Zakrzewska, M. (2023). The Sustainable and Smart Mobility Strategy: Country Comparative Overview. *Lecture Notes in Networks and Systems, Vol. 536.* Springer: Cham, Switzerland, 656-668.
33. Kwiotkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies*, *14(14),* 1-22.
34. Kwiotkowska, A., Wolniak, R., Gajdzik, B., Gębczyńska, M. (2022). Configurational paths of leadership competency shortages and 4.0 leadership effectiveness: an fs/QCA study. *Sustainability*, *14(5),* 1-21.

35. Maintenance_Cost_Estimate_Report.pdf, 2 February 2023.
36. Olkiewicz, M., Olkiewicz, A., Wolniak, R., Wyszomirski, A. (2021). Effects of pro-ecological investments on an example of the heating industry - case study. *Energies, 14(18),* 1-24, 5959.
37. Orłowski, A., Romanowska, P. (2019). Smart Cities Concept — Smart Mobility Indicator. *Cybern. Syst., 50*, 118-131. https://doi.org/10.1080/01969722.2019.1565120.
38. Orzeł, B., Wolniak, R. (2021). Clusters of elements for quality assurance of health worker protection measures in times of COVID-19 pandemic. *Administrative Science*, *11(2),* 1-14, 46.
39. Orzeł, B., Wolniak, R. (2022). Digitization in the design and construction industry - remote work in the context of sustainability: a study from Poland. *Sustainability*, *14(3),* 1-25.
40. Ploeger, J., Oldenziel, R. (2020). The sociotechnical roots of smart mobility: Bike sharing since 1965. *J. Transp. Hist.,* 41, 134-159. https://doi.org/10.1177/0022526620908264.
41. Ploeger, J., Oldenziel, R. (2020). The sociotechnical roots of smart mobility: Bike sharing since 1965. *J. Transp. Hist., 41*, 134-159. https://doi.org/10.1177/0022526620908264.
42. Ponomarenko, T.V., Wolniak, R., Marinina, O.A. (2016). Corporate Social responsibility in coal industry (Practices of russian and european companies). *Journal of Mining Institute*, *222*, 882-891.
43. Prajeesh, C.B., Pillai, A.S. (2022). Indian Smart Mobility Ecosystem—Key Visions and Missions. *AIP Conf. Proc., 2555*, 050005.
44. Rachmawati, I., Multisari, W., Triyono, T., Simon, I.M., da Costa, A. (2021). Prevalence of academic resilience of social science students in facing the industry 5.0 era. *International Journal of Evaluation and Research in Education*, *10(2),* 676-683.
45. Rahman, S.A.A., Dura, N.H. (2022). Malaysia smart tourism framework: Is smart mobility relevant? *Kasetsart J. Soc. Sci., 43*, 1009-1014.
46. Simonofski, A., Handekyn, P., Vandennieuwenborg, C., Wautelet, Y., Snoeck, M. (2023). Smart mobility projects: Towards the formalization of a policy-making lifecycle. *Land Use Policy*, *125*, 106474.
47. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy.* Warszawa: CeDeWu.
48. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2021). Diagnosis of the maturity level of implementing Industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability*, *13(9),* 1-38.
49. Stecuła, K., Wolniak, R. (2022). Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(3),* 159.

50. Steculа, K., Wolniak, R. (2022). Influence of COVID-19 Pandemic on Dissemination of Innovative E-Learning Tools in Higher Education in Poland. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 89.
51. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarzadzanie*, *67*, 63-74.
52. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali.* Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.
53. Tahmasseby, S. (2022). The Implementation of Smart Mobility for Smart Cities: A Case Study in Qatar. *Civ. Eng. J., 8*, 2154-2171.
54. Wawre, M., Grzesiuk, K., Jegorow, D. (2022). Smart Mobility in a Smart City in the Context of Generation Z Sustainability, Use of ICT, and Participation. *Energies*, *15*, 4651. https://doi.org/10.3390/en15134651.
55. Wolniak, R, Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija*, *53(4),* 709-713.
56. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
57. Wolniak, R. (2013). A typology of organizational cultures in terms of improvement of the quality management. *Manager*, *17(1),* 7-21.
58. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji*, *3,* 13-17.
59. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, *3,* 20-25.
60. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, *1,* 109-122.
61. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
62. Wolniak, R. (2016). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
63. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji*, *3*, 127-134.
64. Wolniak, R. (2017). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2,* 139-150.
65. Wolniak, R. (2017). Analiza wskaźników nasycenia certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949 oraz zależności pomiędzy nimi. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *108*, 421-430.

66. Wolniak, R. (2017). The Corporate Social Responsibility practices in mining sector in Spain and in Poland – similarities and differences. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *111*, 111-120.
67. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6,* 247-255.
68. Wolniak, R. (2017). The use of constraint theory to improve organization of work. 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts. SGEM 2017, 24-30 August 2017, Albena, Bulgaria. Conference proceedings. Book 1, *Modern science. Vol. 5, Business and management*. Sofia: STEF92 Technology, 1093-1100.
69. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
70. Wolniak, R. (2018). Methods of recruitment and selection of employees on the example of the automotive industry. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, *128*, 475-483.
71. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
72. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2,* 101-118.
73. Wolniak, R. (2019). Leadership in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 137-150.
74. Wolniak, R. (2019). Support in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *137*, 247-261.
75. Wolniak, R. (2019). The level of maturity of quality management systems in Poland-results of empirical research. *Sustainability*, *15*, 1-17.
76. Wolniak, R. (2020). Design in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 769-781.
77. Wolniak, R. (2020). Operations in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 783-794.
78. Wolniak, R. (2020). Quantitative relations between the implementation of industry management systems in European Union countries. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *142*, 33-44.
79. Wolniak, R. (2021). Internal audit and management review in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 724-608.
80. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
81. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.

82. Wolniak, R. (2022). Individual innovations. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 861-876.
83. Wolniak, R. (2022). Management of engineering teams. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 667-674.
84. Wolniak, R. (2022). Problems of Covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *167*, 599-608.
85. Wolniak, R. (2022). Project management in engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 685-698.
86. Wolniak, R. (2022). Project management standards, Silesian University of Technology *Scientific Papers. Organization and Management Series*, *160*, 639-654.
87. Wolniak, R. (2022). Sustainable engineering, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *160*, 655-667.
88. Wolniak, R. (2022). The role of the engineering profession in developing and implementing sustainable development principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 595-608.
89. Wolniak, R. (2022). Traits of highly innovative people. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 877-892.
90. Wolniak, R. (2023). Analysis of the Bicycle Roads System as an Element of a Smart Mobility on the Example of Poland Provinces, *Smart Cities*, *6(1),* 368-391; https://doi.org/10.3390/smartcities6010018.
91. Wolniak, R. (2023). European Union Smart Mobility - aspects connected with bike road systems extension and dissemination. *Smart Cities, 6,* 1-32.
92. Wolniak, R. (2023). European Union Smart Mobility–Aspects Connected with Bike Road System's Extension and Dissemination, *Smart Cities*, *6(2),* 1009-1042; https://doi.org/10.3390/smartcities6020049.
93. Wolniak, R. Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości*, *5,* 29-34.
94. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 203-214.
95. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
96. Wolniak, R., Grebski, M.E. (2018). Innovativeness and Creativity of the Workforce as Factors Stimulating Economic Growth in Modern Economies. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 227-240.
97. Wolniak, R., Grebski, M.E., Skotnicka-Zasadzień, B. (2019). Comparative analysis of the level of satisfaction with the services received at the business incubators (Hazleton, PA, USA and Gliwice, Poland). *Sustainability*, *10*, 1-22.

98. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1,* 139-149.
99. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
100. Wolniak, R., Jonek-Kowalska, I. (2021). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon*), *34(3),* 376-398.
101. Wolniak, R., Jonek-Kowalska, I. (2021). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, *37*, 132-150.
102. Wolniak, R., Jonek-Kowalska, I. (2022). The creative services sector in Polish cities. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-23.
103. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies*, *13(11),* 1-16.
104. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
105. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
106. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
107. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the condition s of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, *7, 1*-17.
108. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, *15(2),* 1-23.
109. Wolniak, R., Skotnicka-Zasadzień, B., Zasadzień, M. (2019). Problems of the functioning of e-administration in the Silesian region of Poland from the perspective of a person with disabilities. *Transylvanian Review of Public Administration*, *57E,* 137-155.
110. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
111. Wolniak, R., Sułkowski, M. (2016). The reasons for the implementation of quality management systems in organizations. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *92*, 443-455.
112. Wolniak, R., Wyszomirski, A., Olkiewicz, M., Olkiewicz, A. (2021). Environmental corporate social responsibility activities in heating industry - case study. *Energies*, *14(7),* 1-19, 1930.

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LEARNING ORIENTATION, FIRM PERFORMANCE AND MARKET DYNAMISM AMONG MSMEs: AN EMPIRICAL STUDY

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Purpose: The aim of the paper is to identify learning orientation of micro-, small- and medium-sized enterprises (MSMEs) in technology parks (TPs) in Poland, and their performance which they gain in the context of the dynamism of the markets operated by them.
Design/methodology/approach: This empirical study focuses on the quantitative analysis of data collected from MSMEs operating in technology parks in Poland. The study sample was composed of 182 enterprises. The two methods used for performing quantitative empirical research are: CAWI and PAPI. The conceptual framework for this research was a theory of dynamic capabilities.
Findings: This study's findings show that learning orientation is undoubtedly surveyed a MSMEs characteristic. This suggests that learning orientation is a universal phenomenon as it has features of different sizes of enterprises. Secondly, it was empirically proven that the way MSMEs were functioning in the market was neither radical nor conservative. These enterprises were rational to seek out and replace obsolete mental models. At the same time, most of them were operating in stable or moderately dynamic markets rather than in turbulent and uncertain environments. The other ones were operating in environments with slightly higher or lower volatility and uncertainty. Lastly, it was shown that the firm performance level is related to the number of employees. These findings are an argument for treating the number of employees as a non-financial measure of organisation's development.
Research implications: Replications and extensions of the current study should be directed to investigate the indirect effect of learning orientation on firm performance via moderating variable (i.e. market dynamism). At the same time, the size of enterprises may be taken into account as a control variable, for example, in the analysis of the relationship between learning orientation and firm performance.
Originality/value: The research shows that LO is not a dichotomous resource.

Keywords: learning orientation, firm performance, market dynamism, micro, small and medium-sized enterprises.

Category of the paper: research paper.

1. Introduction

In response to the constantly changing nature of the economic environment (i.e. increasing environmental concerns, government regulations, and long-term profitability, high customer expectations, intense global competition and industry 4.0 (I4.0) revolution) (Ahmed et al., 2022), enterprises are constantly looking for new opportunities on the market so that they can identify paths of development and prosperity. That is why, much attention is focused on the strategic orientations of enterprises.

There are three overarching types of strategic orientations, such as market orientation (MO), entrepreneurial orientation (EO), and learning orientation (LO) (Wales et al., 2020; Baker et al., 2022; Hyder et al., 2022). In this study, research attention is focused on learning orientation. LO has led to a significant amount of conceptual (i.e. Sinkula et al., 1997; Sheng, Chien, 2016; Alerasoul et al., 2022) and empirical research (Calantone et al., 2002; Farrell, Oczkowski, 2002; Kropp et al., 2006; Lin et al., 2008; Lam et al., 2011; Laukkanen et al., 2013; Deutscher et al., 2016; Hernández-Linares, 2018). These scholars argue that better knowledge and understanding of organisational factors such as LO that guide enterprises' approach to the pursuit of high performance are essential because markets exist in a constant state of disequilibrium. In LO descriptions, scholars have also recognised the role of market dynamism (MD) as a potentially important contextual variable (Wales et al., 2020; Baker et al., 2022; Buccieri et al., 2022). Buccieri et al. (2022) argue that spotting emerging trends to uncover profitable opportunities requires understanding the hidden needs and preferences of target markets. These issues are seen through the lens of market dynamism. Therefore, from the perspective of LO, market dynamism is not a threat, but rather an opportunity to improve development prospects. Enterprises use LO to lead the markets. Therefore, it is believed that recognising external environments in which this organisational ability is developed is reasonable. Even more so, according to Ahmed et al. (2022) SMEs are also affected by technological advances and may use their LOs to improve performance. They are embedded in the context where such advances take place, as well. However, despite the growing interest of scientists in the role of LO, so far, there has been little research on the diagnosis of the levels of various types of strategic orientations and results in micro-, small- and medium-sized enterprises (MSMEs), especially in the perspective of the dynamism of the market in which they operate. This knowledge gap in the literature specifically relates to MSMEs operating in technology parks (TPs) in Poland (Wójcik-Karpacz, 2019, 2021). Therefore, our research attention was directed to MSMEs which have signed lease agreements with TPs in Poland. It is worth emphasising that these enterprises have greater access to the experience of other entrepreneurs, which in turn is an important argument for the concentration of this community. On the other hand, the concentration of entrepreneurs in TPs favours the development of specific organisational abilities (Bednarczyk et al., 2019). It is thought that this also applies to

LO. Moreover, MSMEs are indicated as an important source of job creation and income generation in market economies, in particular those MSMEs which are oriented on growth (Zakrzewski, Skowrońska, 2019).

That is why, the following research questions (RQ) were posed:

RQ1: Is learning orientation a characteristic for MSMEs?

RQ2: Do MSMEs differ in terms of firm performance?

RQ3: What is the degree of dynamism on markets operated by MSMEs?

These three research questions directed our empirical research. In view of above arguments and the identified gaps, the purpose of this study is to identify learning orientation of MSMEs in TPs in Poland and their performance which they gain in the context of the dynamism of the markets operated by them.

The rest of the research paper is organised as follows. Firstly, we define the constructs and explain them in light of the previous literature. Next, we discuss the methodology adopted in the research paper, including the data collection and sample, and the measures used in the study. In the next part, we discuss the results. In the last section, we present implications, limitations, and possible avenues for the future research.

2. Theoritical background

The learning orientation construct was developed to identify those enterprises which are the most and the least likely to seek out and replace obsolete mental models and theory-in-use. Baker et al. (2022) argue that LO emerged from the recognition of the importance of higher order, generative learning to purge organisations of obsolete beliefs about markets, competitors and customers that hinder the ability of enterprises to learn faster and better than competitors. LO is the basis of learning used to produce a learning process (Sinkula et al., 1997).

Currently, the researchers conceptualise LO similarly, claiming that LO gives enterprises the opportunity to unlearn conventional knowledge about markets, customers, and competitors, which has become obsolete, allowing enterprises to avoid competency pitfalls and approach a decision-making process in a more proactive way (Baker et al., 2022). Sheng and Chien (2016) argue similarly that learning orientation tends to be used to create and manage knowledge. Based on the literature, learning orientation is conceived as composed of three key dimensions: commitment to learning, open-mindedness and shared vision (Sinkula et al., 1997). Due to that, the direction or "what to learn?" is influenced by the existence of shared vision within the organisation, as well as the intensity of learning which is defined as motivation determined by commitment and open-mindedness for the creation and use of knowledge (Sinkula et al., 1997; Alerasoul et al., 2022). In practice, learning orientation requires commitment to learning and openness in thinking which are used as drivers of learning in the

organisation (Wahyono, Hutahayan, 2021). Open-mindedness is the willingness to critically evaluate the organisation's operational routine and to accept new ideas, while the shared vision refers to a focus on learning across the organisation (Sinkula et al., 1997). In addition, it is worth adding that without the shared vision, learning among organisation members is of less importance (Verona, 1999). Because of that, learning orientation is used to develop new insights which may then be used to shape behaviour based on values and beliefs (Wahyono, Hutahayan, 2021). That is why, three sub-components, are traditionally recognised as those encompassing the construct of LO at the organisational level of analysis (i.e. enterprise as a whole). In this respect, a learning-oriented enterprise always encourages its staff to engage in both single-loop and double-loop learning, and to question the established routines or long-standing practices of enterprises with openness and a sense of purpose (Lam et al., 2011).

In line with the above findings, learning orientation means enterprise's ability to learn, constantly challenge assumptions previously adopted, and promote change or adaptation over time, which strongly supports the view that LO is a dynamic capability (DC).

Dynamic capabilities are necessary components for gaining significant competitive advantage. All these abilities are expected, among others, to enable enterprises to identify customer needs and business opportunities, while striving to survive and develop by responding to changes in the external environment. Business organisations do this by: adapting their processes to reduce costs, enabling cost-effective innovations; offering themselves new sets of decision choices; generating new knowledge, processes and products; and determining the best moments and ways to align and realign their core internal and external assets to their strategy (Wójcik-Karpacz, 2017; Dubey et al., 2020). This suggests that learning orientation is undoubtedly a firm characteristic that values continuous learning and endless improvement. This contributes to organisation's pursuit of a competitive advantage. If so, learning orientation may be viewed as resources that an enterprise may employ to attain competitive advantage. Learning orientation as an organisational attribute embodies the degree to which enterprises are committed to systematically challenging the fundamental beliefs and practices that define the innovation process itself (Baker, Sinkula, 1999b).

Thus, strong learning-oriented enterprises are arguably capable of promoting generative learning (Sinkula et al., 1997), which in turn facilitates innovations (Calantone et al., 2002; Lin et al., 2008; Baker et al., 2022) and sustainable competitive advantages (Slater, Narver, 1995; Baker, Sinkula, 1999a, 1999b; Calantone et al., 2002; Lin et al., 2008; Wang, 2008; Lam et al., 2011; Wahyono, Hutahayan, 2021). It is worth emphasising that a sustainable competitive advantage requires enterprises to relentlessly engage in product, administrative, technical and/or perceptual innovations faster and/or better than competitors (Baker et al., 2022). Strong learning-oriented enterprises create windows of opportunities in unpredictable markets which would otherwise be unnoticed. As a result, enterprises operating in turbulent markets integrate knowledge to shape reconfiguration activities which result in sustained performance (Bucceri, Park, 2022). Thus, inevitably, an enterprise with such characteristics

outperforms its rivals in the long run (Lam et al., 2011). However, a weak level of LO may be perceived as a threat which may make it difficult for enterprises to maintain the level of performance in new and changing conditions (Gnizy et al., 2014). For this reason, enterprises with weak levels of LO may effectively gather, disseminate and act on new learning, but intractable mental models constrain learning and innovation to adaptive and incremental ones, respectively (Baker et al., 2022).

In conclusion, an extension of resource-based view (RBV) on the dynamic capabilities perspective conceptualises LO as the ability of enterprises to proactively discover, reconcile and, if necessary, change market beliefs upon which strategic and tactical decision-making is anchored (Baker, Sinkula, 1999a; Dubey et al., 2020). Researchers emphasise that the ultimate goal of strategy and tactics is to gain some form of competitive advantage over rivals, and relative, not absolute, measures of performance are needed to look at LO in the context of firm performance (Baker et al., 2022). In the literature, LO is consistently associated with innovation success and performance improvement (Calantone et al., 2002; Lin et al., 2008; Lam et al., 2011; Baker et al., 2022).

Moreover, apart from LO, market dynamism (MD) is also a factor taken into account in the dynamic capabilities theory (Dubey et al., 2020; Wolniak, 2022). MD is defined as a degree of speed and unpredictability of change in technology and competition, and uncertainty of customer behaviour (Wang et al., 2015). In the literature, MD has been recognised as a key situational element in the dynamic capabilities view (DCV) (Eisenhardt, Martin, 2000; Schilke, 2014; Wójcik-Karpacz, 2018), which suggests that the diverse impact of dynamic capabilities (i.e. LO) on firm performance (Helfat, Winter, 2011) depends on the level of dynamism of the organisation's external environment (Eisenhardt, Martin, 2000). Nevertheless, Helfat and Winter (2011) warn that a turbulent environment is not a necessary condition for dynamic capabilities, which can exist even in stable environments. Therefore, in the face of such contradictory arguments, it is quite difficult to determine the true value of dynamic capabilities for organisation's competitive advantage. Amidst such opposing views represented by scholars, researchers have begun to advocate a more contingent view by arguing that the benefits of dynamic abilities depend not only on the existence of underlying organisational routines, but also on the context in which those abilities are implemented (Dubey et al., 2020).

3. Research methodology

3.1. Data collection and sample

Due to the fact that the sampling frame did not allow to identify the general population (enterprises with the status of tenants in technology parks in Poland) in terms of the size of enterprises measured by the number of employees (Art. 7 of the Act of 6 March 2018 - Entrepreneurs' Law, Journal of Laws of 2019, item 1292), all enterprises were surveyed.

Thus, 1 568 structured questionnaires were distributed to collect data from the managers of these enterprises (the so-called tenants). The survey was conducted from March 2017 to December 2018 using two methods, i.e. PAPI (Paper & Pen Personal Interview) and CAWI (Computer Assisted Web Interviews). The returned survey questionnaires made it possible to separate the surveys received from the self-employed (38 self-employed) and large enterprises (5 enterprises) because they were not taken into account in this research. Self-employment was excluded from this study because the LO measure used is dedicated to enterprises having employees (Gnizy et al., 2014). However, large enterprises, as mentioned, were ultimately not taken into account as research objects. As a result, 182 usable questionnaires were received and the response rate was 12%. The study sample included 93 micro-enterprises (excluding self-employment), 68 small enterprises and 21 medium-sized enterprises.

3.2. Measures

Learning orientation was operationalised using the scale ($\alpha = 0.880$), previously used by Gnizy, Baker (2014) who, in turn, had adapted it from the scale developed by Baker and Sinkula (1999a). This construct was measured through the use of six items evaluating the degree to which an enterprise relates to commitment to share vision, learning and open-mindedness. The reliability analysis of the adapted learning orientation questionnaire in the sample indicates a high reliability of this scale ($\alpha = 0.896$).

Market dynamism was operationalised using a six-item scale ($\alpha = 0.730$) created by Wang et al. (2015). Market dynamism was measured by speed and unpredictability of change in technology and competition, and uncertainty of customer behaviour ($\alpha = 0.856$).

Performance measurement was also important, as performance measurement issues are central to evaluating MSMEs' business performance. In order to measure firm performance, a well-established scale ($\alpha = 0.892$) developed by Keh et al. (2007) was used. This construct was measured through the use of three items evaluating the level firm performance, including changes in profitability, sales revenue and market share in relation to their main competitor(s). Values obtained using Cronbach's alpha values ($\alpha = 0.901$) showed very good reliability of this variable. Thus, in the study sample, the reliability of the questionnaire was close to that reported by its authors, and the selection of the sample also did not affect the level of its reliability.

4. Results and Discussion

Statistical description methods were used to analyse the empirical data. The analytical procedure began with the assessment of the reliability of individual scales (Cronbach's alpha test). The purpose of the reliability test, in this case, was to verify whether the reliability of the questionnaire in the sample was similar to that stated by its authors and whether the selection of the sample did not affect the level of reliability of the questionnaire. Three theoretical constructs were analysed for reliability, i.e. learning orientation, market dynamism, and firm performance.

In the next step, descriptive statistics were used to determine the most important information about the phenomena and groups of surveyed enterprises analysed in the study. Numerical variables were described by median, first and third quartile, minimum, maximum, and arithmetic mean with standard deviation. Statistical calculations for the purposes of this study were performed using the R 3.5 program. Table 1 presents the mean levels of variables, standard deviations, minimum, maximum, median, Q25, Q75, and p-value according to individual sizes of the analysed MSMEs.

Table 1.
Size of enterprises according to the number of employees and analysed constructs: learning orientation, market dynamism and firm performance

Construct	Size of enterprises	Mean value	Standard deviation (SD)	Min.[a]	Q25	Median	Q75	Max.[a]	p-value
Learning orientation	from 1 to 9	4,30	0,72	2,50	3,67	4,33	5,00	6,17	0,996
	from 10 to 49	4,32	0,61	2,50	4,00	4,33	4,83	5,67	
	from 50 to 249	4,33	0,97	2,00	3,83	4,50	4,83	6,50	
Market dynamism	from 1 to 9	3,83	1,03	1,00	3,33	3,83	4,33	6,50	0,295
	from 10 to 49	3,97	1,29	1,33	3,08	4,17	5,00	6,67	
	from 50 to 249	3,61	1,01	1,67	3,00	3,67	4,33	5,33	
Firm performance	from 1 to 9	4,34	1,23	1,00	3,33	4,33	5,00	7,00	**0,039***
	from 10 to 49	4,63	1,03	1,00	4,00	4,50	5,33	7,00	
	from 50 to 249	4,90	1,23	1,00	4,33	5,33	5,67	6,33	

Note.* significant at the level of $p < 0.05$; SD - standard deviation; a - some variables do not have integer minimum or maximum values because they are derived from a set of questions corresponding to its value.

Source: own elaboration.

The analysis of the data presented in Table 1 shows that medium-sized enterprises, i.e. those employing from 50 to 249 employees (4.33 on average), were characterised by a similar level of LO as small (employing from 10 to 49 employees) and micro-enterprises (excluding self-employment) (4.32 and 4.30, on average, respectively). Higher than moderate but not yet strong learning-oriented MSMEs identified in these studies according to Lam et al. (2011) indicates that these enterprises may already have been capable of more than a moderate (prudent) effort to challenge adopted assumptions and promote change or adaptation over time. In addition,

it should be noted that the least diversified group consisted of small enterprises, and the most diversified in this respect were medium-sized enterprises. This is evidenced by the recorded values of standard deviation (SD) (0.61 and 0.97, respectively), indicating that the LO level assessment differed from the arithmetic mean by 0.61 points in the group of small enterprises and by 0.97 points in the group of medium-sized enterprises. But the values of arithmetic means of the LO levels as well as the values of standard deviations from the values of the individual arithmetic means of the LO levels were statistically insignificant (a p value greater than 0.05 does not allow for defining the differences as statistically significant). However, taking into account research on business activity, even statistically insignificant results are a large carrier of information. Hence, it is also worth adding that 25% of the respondents from micro-enterprises rated LO as not higher than 3.67 points, and the remaining 75% of the respondents assessed LO as not higher than 5.00 points and not lower than 3.67 points. In turn, 25% of the respondents from small enterprises assessed LO as not higher than 4.00 points, and 75% of the respondents assessed LO as not higher than 4.83 points and not lower than 4.00 points. Moreover, 25% of the respondents from medium-sized enterprises rated LO no higher than 4.5 points, and 75% of the respondents rated LO not higher than 4.83 points and not lower than 3.83 points. This indicates that in the surveyed sample, 75% of micro, small and medium-sized enterprises were characterised by good learning orientation; therefore, according to Hernández-Linares et al., (2018) and Ahmed et al. (2022), these were more entrepreneurial oriented enterprises as such business organisations seem to be more successful in turning this learning into entrepreneurship. Almost good learning orientation could increase the reaction of these enterprises to market and customer conditions (Wahyono, Hutahayan, 2021). Alerasoul et al. (2022) explain this by the fact that enterprises with a stronger LO process information obtained internally and externally, anticipate market and environmental changes, and make the necessary adjustments in order to drive the market and thus avoid being guided by it.

Baker and Sinkula (1999b) have similar observations. These researchers argue that such enterprises scan the external environment for new technology paradigms which may offer better ways to deliver core benefits in a product category. Therefore, in the next step, the respondents also assessed changes in technology, competition and customer behaviour (external environment) in which the surveyed enterprises were operating (Wang et al., 2015).

This research shows that respondents from micro and small enterprises rated the dynamism of the environment (arithmetic mean: 3.83; 3.97; SD: 1.03; 1.29 points) as moderate, while the respondents from medium-sized enterprises perceived it as slightly more stable than moderate (arithmetic mean: 3.61; SD: 1.01). This means that the surveyed enterprises, in the opinion of the respondents, did not have to deal with high-velocity markets. The group of surveyed medium-sized enterprises and similarly the group of micro-enterprises were the least differentiated in terms of the assessment of the degree of market dynamism by the respondents. However, the observed differences between the values of arithmetic means of the MD levels,

as well as the values of standard deviations from the values of individual arithmetic means of the MD levels, did not reach the level of statistical significance.

Moreover, 25% of the respondents from small enterprises assessed the degree of MD as not higher than 3.08 points, indicating that there was no high turbulence in their environment; on the contrary, the degree of MD was low. The remaining 75% of the respondents, in turn, assessed the degree of MD as not higher than 5.00 points and not lower than 3.08 points. Thus, these respondents believe that these small enterprises have also faced a more dynamic and uncertain environment. However, the degree of MD identified does not indicate whether they were operating under highly dynamic environments in that period.

In turn, 75% of the respondents from medium-sized enterprises and micro-enterprises assessed the MD degree identically as not higher than 4.33 points and not lower than 3.33/3.0 points, respectively. This means that this group of surveyed enterprises operates in a moderately dynamic environment with regular changes which generally occur along predictable and linear paths. On the other hand, 25% of the respondents from micro and medium-sized enterprises indicated a low degree of MD, i.e.: 3.33 and 3.00 points or lower, respectively. This shows that these enterprises were perceived by the respondents as operating in markets characterised by infrequent change, where market participants tended to anticipate the changes taking place in the market. Teece (2007) argues that when the environment is relatively stable with no significant technological advances or little change in customer preferences, dynamic capabilities such as LO may be expected to be relatively less important to enterprises' competitive advantage. Wilhelm (2015) believes that organisations facing a lower level of environmental dynamism do not need to adapt their operational capabilities as often as these environments tend to reward the consistent use of existing resources and capabilities. However, Li and Liu (2014) emphasise that in a relatively stable environment, dynamic capabilities (i.e. LO) are also useful to some extent, as there may be little need to develop dynamic capabilities, i.e. only some of the typical operational business tasks. However, it should be borne in mind that the above-mentioned differences in the assessment of the degree of MD were statistically insignificant.

In conclusion, in the opinion of some of the respondents, the surveyed enterprises were characterised by slightly higher LO levels than the average ones, and they did not operate in the high-velocity environments where rapid and discontinuous changes would be commonplace. Rather, these enterprises were operating in a moderately dynamic environment with regular changes which generally followed predictable and linear paths. As may be seen, the degree of market dynamism at that time (before the Covid-19 pandemic) was apparently not high enough to require these enterprises to have very high levels of such dynamic capacity as LO.

In the next step, enterprises' performance was analysed, including changes in profitability, sales revenue, and market share in relation to their main competitor(s) (Khan et al., 2019). The desired trend of changes in the values of these measures is an upward trend (Skoczylas, Niemiec, 2016).

Continuing the analysis of statistical data, slight differences may be noticed between the values of arithmetic means relating to the levels of performance of the surveyed enterprises in relation to those of the main competitor(s). These differences were statistically significant, as indicated by their level of significance (Table 1).

The respondents from medium-sized enterprises assessed the performance of their organisations better than the respondents from micro- and small enterprises (arithmetic mean: 4.90; 4.34; 4.63 - respectively). However, the assessments of the level of performance of micro- and medium-sized enterprises made by the respondents from both these groups are more diverse than those from small enterprises, as evidenced by the recorded values of standard deviations (SD: 1.23; 1.23; 1.03 - respectively). Due to the fact that the respondents assessed the performance of their enterprises in comparison to that of competitor(s), their average score higher or lower than 4 on the seven-point Likert scale also reflects competitive dis(advantage) (Baker, Sinkula, 1999a).

Moreover, only 25% of the micro-enterprise respondents rated the level of performance of their enterprises as slightly lower than that of the main competitor(s) (3.33 points). The remaining respondents (75%) rated the level of performance of their enterprises as higher than that of the main competitor(s) (5.00 points). On the other hand, 25% of the respondents from small enterprises assessed the performance of their enterprises as comparable to that of the main competitors (4.00 points). The remaining respondents (75%) rated their organisation's performance as higher than that of their main competitor(s) (5.33 points).

In contrast, in the case of medium-sized enterprises, 25% of the respondents assessed their performance in relation to that of their competitor(s) as slightly better (4.33 points), and the remaining respondents (75%) assessed their performance as higher than that of their main competitor(s) (5.67 points). Therefore, based on the above-mentioned opinions of the respondents, it may be concluded that, in general, higher performance ratings were recorded in groups of larger enterprises than in smaller ones.

The above analyses of statistical data therefore indicate that in the surveyed group of MSMEs there were enterprises which achieved an advantage over their competitors and those that had no competitive advantage or had performance comparable to that achieved by their competitor(s).

Hence, in the next step, we decided to identify the relationship between the size of an enterprise measured by the number of employees and its performance. The non-parametric Kruskal-Wallis H test we were used to compare continuous variables among the analysed groups. Table 2 shows the significance of pairwise comparisons.

Table 2.
Size of enterprises and firm performance (post-hoc: by Dunn's test)

Number of employees and firm performance (pairwise comparisons: Dunn; p < 0.05)		
	from 1 to 9*	**from 10 to 49**
from 10 to 49	0.153	
from 50 to 249	0.016	0.153

Note: *except for self-employment.

Source: own elaboration.

Statistically significant results obtained on that basis showed a difference in the distribution of a given variable among the groups being compared. It was confirmed by the Kruskal-Wallis H test ($p < 0.05$) that firm performance was assessed better in larger enterprises. The conducted post-hoc tests indicated differences between micro- and medium-sized enterprises while assessing firm performance (Dunn, $p < 0.05$). This suggests that the size of enterprises may be included as a control variable, for example, when analysing the relationship between learning orientation and performance in the MSMEs.

In sum, these analyses only partially allowed to determine how the examined MSMEs differ or are similar to each other in terms of the level of learning orientation, firm performance, and market dynamism degree.

5. Conclusion, limitations, and future research

The descriptive statistics of the analysed variables allowed for the identification of learning orientation, firm performance, and market dynamism according to the size of the analysed MSMEs in technology parks (TPs) in Poland.

In the research sample, not all enterprises had good LO, because there were also those in which the level of LO was at a much lower level. It is worth emphasising that medium-sized enterprises on average were characterised by almost good LO, similarly to small and micro-enterprises (except for self-employment) (Table 1).

Considering that LO is one of the resources which influence the quality of market-oriented behaviours (Baker, Sinkula, 1999a, 1999b), it may be stated that the above-mentioned enterprises in TPs in Poland were rational to question whether the basic beliefs about customers, competitors and suppliers, forming the basis of their previous actions, were still the same. Thus, the way these organisations were functioning on the market was neither radical nor conservative.

At the same time, the identified average degrees of market dynamism indicated that these enterprises were operating in stable or moderately dynamic markets rather than in a turbulent and uncertain external environment. Moreover, the recorded high values of standard deviations prove that not all respondents perceived the degree of MD in which their enterprises were

operating in the same way. There were some respondents claiming that their enterprises were operating in environments with slightly higher or lower volatility and uncertainty than others. Thus, the enterprises that took part in the survey did not constitute a homogeneous group in this respect.

In sum, the assessment of changes in the external environment of the surveyed MSMEs, in the perspective of the respondents, do not indicate that these organisations operate in high-velocity environments. In addition, the analysis of the average LO levels, the values of standard deviations, as well as the values of other descriptive statistics indicate that LO is not a dichotomous resource. This means that it is not something that enterprises have or do not have. The orientation of enterprises to learning, as well market orientation (Baker, Sinkula, 1999a, 1999b) exists along a continuum, i.e. from weak (low) to strong (high) learning-oriented enterprises.

In addition, the respondents from medium-sized enterprises rated the performance of their enterprises better than respondents from micro and small enterprises (Table 1). However, the analysis of standard deviations indicates that the assessments of the levels of performance of micro- and medium-sized enterprises made by the respondents from both groups were more diverse than those from small enterprises (Table 1).

Following this lead, we examined the relationship between the size of an enterprise measured by the number of employees and its performance. The results of the statistical analysis are presented in Table 2, which show that the firm performance level is related to the number of employees. These findings are an argument for treating the number of employees as a non-financial measure of organisation's development (this result was not the aim of the current research). It should be borne in mind that the sample is not representative; therefore, the results of this study may not be generalised to the entire population of MSMEs functioning in TPs in Poland, but they may be referred to the study group. Nevertheless, this study's findings show that enterprises of different size may demonstrate different organisational and environmental characteristics.

Future research may be conducted in order to link market dynamism with learning orientation and firm performance. Hence, replications and extensions of the current study should be directed to investigate the indirect effect of learning orientation on firm performance via moderating variable (i.e. market dynamism). These issues would be the focus of the next study in the series on strategic orientations in the MSMEs in TPs in Poland.

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References

1. Ahmed, A., Bhatti, S.H., Gölgeci, I., Arslan, A. (2022). Digital platform capability and organizational agility of emerging market manufacturing SMEs: The mediating role of intellectual capital and the moderating role of environmental dynamism. *Technological Forecasting & Social Change*, *177*, 121513.
2. Alerasoul, S.A., Afeltra, G., Hakala, H., Eliana Minelli, E., Strozzi, F. (2022). Organisational learning, learning organisation, and learning orientation: An integrative review and framework. *Human Resource Management Review*, *32*, 100854.
3. Art. 7 of the Act of 6 March 2018 - Entrepreneurs' Law, Journal of Laws of 2019, item 1292.
4. Baker, W.E., Mukherjee, D., Perin, M.G. (2022). Learning orientation and competitive advantage: A critical synthesis and future directions. *Journal of Business Research, 144*, 863-873.
5. Baker, W.E., Sinkula, J.M. (1999a). The synergistic effect of market orientation and learning orientation on organizational performance. *Journal of the Academy of Marketing Science*, *27(4),* 411-427.
6. Baker, W.E., Sinkula, J.M. (1999b). Learning orientation, market orientation, and innovation: integrating and extending models of organizational performance. *Journal of Market- Focused Management*, *4(4),* 295-308.
7. Bednarczyk, M., Najda-Janoszka M., Kopera, S. (2019). *E-Przedsiębiorczość. Zasady i praktyka.* Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego, 217-218.
8. Buccieri, D., Park, J. (2022). Entrepreneurial marketing and reconfiguration towards post-entry performance: Moderating effects of market dynamism and entry mode. *Journal of Business Research*, *148*, 89-100.
9. Calantone, R.J., Cavusgil, S.T., Zhao, Y. (2002). Learning orientation, firm innovation capability, and firm performance. *Industrial Marketing Management*, *31(6),* 515-524.
10. Deutscher, F., Zapkau, F.B., Schwens, C., Baum, M., Kabst, R. (2016). Strategic orientations and performance: A configurational perspective. *Journal of Business Research*, *69(2),* 849-861.

11. Dubey, R., Gunasekaran, A., Childe, S.J., Bryde, D.J., Giannakis, M., Foropon, C., Roubaud, D., Hazen, B.T. (2020). Big data analytics and artificial intelligence pathway to operational performance under the effects of entrepreneurial orientation and environmental dynamism: a study of manufacturing organisations. *International Journal of Production Economics, 226*, 107599.
12. Eisenhardt, K.M., Martin, J.A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, *21(10/11),* 1105-1121.
13. Farrell, M.A., Oczkowski, E. (2002). Are market orientation and learning orientation necessary for superior organizational performance? *Journal of Market-Focused Management*, *5(3),* 197-217.
14. Gnizy, I., Baker, W.B., Grinstein, A. (2014). Proactive learning culture. A dynamic capability and key success factor for SMEs entering foreign markets. *International Marketing Review*, *31(5),* 477-505.
15. Helfat ,C.E., Winter S.G. (2011). Untangling dynamic and operational capabilities: strategy for the (n) ever-changing world. *Strategic Management Journal*, 32(11), 1243–1250.
16. Hernández-Linares, R., Kellermanns, F.W., López-Fernández, M.C. (2018). A note on the relationships between learning, market, and entrepreneurial T orientations in family and nonfamily firms. *Journal of Family Business Strategy*, *9*, 192-204.
17. Hyder, A.S., Sundström, A., Chowdhury, E.H. (2022). Knowledge of Network-Based Market Orientation for the Internationalization of Disruptive Innovation in SMEs. *Central European Management Journal*, *30(3),* 36-60.
18. Keh, H.T., Nguyen, T.T.M., Ng, H.P. (2007). The effects of entrepreneurial orientation and marketing information on the performance of SMEs. *Journal of Business Venturing*, *22(4),* 592-611.
19. Khan, K.U., Xuehe, Z., Atlas, F., Khan, F. (2019). The impact of dominant logic and competitive intensity on SMEs performance: A case from China, Empirical paper. *Journal of Innovation & Knowledge*, *4,* 1-11.
20. Kropp, F., Lindsay, N.J., Shoham, A. (2006). Entrepreneurial, market, and learning orientations and international entrepreneurial - Business venture performance in South African firms. *International Marketing Review, 23(5),* 504-523.
21. Lam, S,-Y., Lee, V,-H., Keng-Boon Ooi, K.,-B., Lin, B. (2011). The relationship between TQM, learning orientation and market performance in service organisations: an empirical analysis. *Total Quality Management & Business Excellence*, *22(12),* 1277-1297.
22. Laukkanen, T., Nagy, G., Hirvonen, S., Reijonen, H., Pasanen, M. (2013). The effect of strategic orientations on business performance in SMEs. A multigroup analysis comparing Hungary and Finland. *International Marketing Review*, *30(6),* 510-535.
23. Li, D., Liu, J. (2014). Dynamic capabilities, environmental dynamism, and competitive advantage: Evidence from China. *Journal of Business Resea*rch, *67*, 2793-2799.

24. Lin, C-H., Peng, C-H., Kao, D.T. (2008). The innovativeness effect of market orientation and learning orientation on business performance. *International Journal of Manpower*, *29(8),* 752-772.
25. Schilke, O. (2014). On the contingent value of dynamic capabilities for competitive advantage: the nonlinear moderating effect of environmental dynamism. *Strategic Management Journal*, *35*, 179-203.
26. Sheng, M.L., Chien, I. (2016). Rethinking organizational learning orientation on radical and incremental innovation in high-tech firms. *Journal of Business Research*, *69*, 2302-2308.
27. Sinkula, J.M., Baker, W.E. Noordewier, T.A. (1997). A framework for market-based organizational learning: linking values, knowledge, and behavior. *Journal of the Academy of Marketing Science*, *25(4),* 305-318.
28. Skoczylas, W., Niemiec, A. (2016). *Leksykon mierników dokonań*. Warszawa: CeDeWu, 235-237.
29. Slater, S.F., Narver, J.C. (1995). Market orientation and the learning organization. *Journal of Marketing*, *59(3),* 63-74.
30. Teece, D.J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*, 1319-1350.
31. Verona, G. (1999). A resource-based view of product development. *Academy of Management Review*, *24(1),* 132-42.
32. Wahyono, Dr., Hutahayan, B. (2021). The relationships between market orientation, learning orientation, financial literacy, on the knowledge competence, innovation, and performance of small and medium textile industries in Java and Bali. *Asia Pacific Management Review*, *26*, 39-46.
33. Wales, W., Beliaeva, T., Shirokova, G., Stettler, T.R., Gupta, V.K. (2020). Orienting toward sales growth? Decomposing the variance attributed to three fundamental organizational strategic orientations. *Journal of Business Research, 109*, 498-510.
34. Wang, C.L. (2008). Entrepreneurial orientation, learning orientation, and firm performance. *Entrepreneurship Theory and Practice*, *32(4),* 635-657.
35. Wang, C.L., Senaratne, Ch., Rafiq, M. (2015). Success traps, dynamic capabilities and firm performance. *British Journal of Management*, *26(1)*, 26-44.
36. Wilhelm, H., Schlömer, M., Maurer, I. (2015). How dynamic capabilities affect the effectiveness and efficiency of operating routines under high and low levels of environmental dynamism. *British Journal of Management*, *26*, 327-345.
37. Wójcik-Karpacz, A. (2017). Zdolności dynamiczne versus zdolności operacyjne [Dynamic capabilities versus operational capabilities]. *Organizacja i Kierowanie. Organization and Management*, *1(175),* 51-70.
38. Wójcik-Karpacz, A. (2018). Zdolności dynamiczne w turbulentnym otoczeniu [Dynamic capabilities in turbulent environment]. *Organizacja i Kierowanie. Organization and Management*, *4(138),* 51-69.

39. Wójcik-Karpacz, A. (2019). *Zdolności organizacyjne w kontekście wyników przedsiębiorstwa. Aspekty teoretyczne i wyniki badań empirycznych*. PWN.
40. Wójcik-Karpacz, A., Karpacz, J., Rudawska, J. (2021). Impact of market orientation on the performance of MSMEs operating in technology parks: the role of market dynamism. *Journal of Entrepreneurship, Management and Innovation, 17*, *2,* 29-52.
41. Wolniak, R. (2022). Problems of covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *167*, 599-608.
42. Zakrzewski, R., Skowrońska, A. (2019). *Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce*. Warszawa: Polska Agencja Rozwoju Przedsiębiorczości, 73-74.

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RESEARCH ON STUDENTS' PERCEPTION OF INFORMATION TECHNOLOGY SECURITY – A NEW ERA OF THREATS

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Purpose: The aim of the article is to diagnose the level of students' awareness about the security of information technology, the risks associated with it, attitudes towards threats and to identify the way of obtaining knowledge about it, protecting oneself against cyber fraud.
Design/methodology/approach: The achievements and results presented in the article were obtained on the basis of literature research and surveys conducted among 119 students. The research technique was a standardized questionnaire completed without the presence of an interviewer via a website.
Findings: On the basis of the obtained quantitative research results, the basic threats related to the use of information technology were identified, the level of students' awareness of cybersecurity and the sources of their knowledge on the subject were assessed.
Research limitations/implications: The analysis of the obtained opinions of students is only a signal of the problem of the needed changes in education on cyber security, threats and opportunities to protect against cybercrime. Research should be extended to other stakeholder groups (e.g. due to age, education, type of work performed) and in a larger area of threats. Competences of students in the field of cybersecurity as future employees are very important, as they affect the willingness to adapt and the level of involvement in new technologies.
Practical implications: The results of the survey have a practical impact on the Police as a source of information on the general knowledge of students in the field of cybersecurity, where they meet it, where they get information about protecting themselves against the threat.
Originality/value: Original research achievements include valuable research results in the area of cybersecurity among the young generation of students. Their knowledge and ability to protect, use and responsibly deal in the area of information technology security is important now and in the future. This ability also indicates gaps and/or appropriate directions of education in the topic in question.

Keywords: information technology security, cybersecurity, online safety, grandson scams.

Category of the paper: research work.

1. Introduction

One of the existential human needs is the need for security. According to Abraham Maslow, this need is on the second level of the hierarchy and refers to the values that concern the security and stability of human life. First of all, it is about job security, stable income, health, peace of mind, resources, moral and family security, and security of private property (Maslow, 2022). The world is developing faster and faster and digitalization is developing along with it. Every aspect of human life is being modernized. According to the Digital Poland Report from 2022, Poland has a very low digitization rate of approx. 40% (while the EU average is 50%). In 2021, out of 27 European Union countries, Poland was ranked 24th in The Digital Economy and Society Index (DESI), which includes 4 pillars in terms of digitization: human capital, connectivity, integration of digital technologies and digital public services, e-government. 'Poles still do not have digital competences, small and medium-sized companies do not use the latest technologies en masse. A number of actions have been taken at national level, but many have not yet been implemented' (Raport Digital Poland, 2022). Despite this, Poles show a positive attitude to change which increases every year. They see them primarily as facilitating everyday life, reducing social inequalities depending on the place of residence and increasing the possibility of finding a better job on the market. The digitization process has definitely changed the service market - it has influenced many decisions of the public and private sectors (Chądrzyński et al., 2021; Saniuk, Grabowska, 2022, pp. 537-547; Załoga, 2022, p. 544).

Digitization significantly facilitates access to medical, financial and educational services. Examples include: the portal "pacjent.gov" or "znanylekarz.pl", thanks to which you can make an appointment with a doctor, have access to the history of our treatment and get an e-prescription in a few steps. Using the "ePuap" portal, you can settle official matters with any administrative authority in Poland that provides such a service from anywhere. All the largest banks currently have their better or worse functioning banking applications for online payments, phone payments, BLIK payments and other financial services (for example, submitting a quick loan application).

Consumer behavior has also been supporting online sales for many years, ranging from grocery shopping to cosmetics, furniture or clothes (Chojnacka, 2021, pp.87-98; Morawski, 2021, pp. 241-257). It is worth noting that often when registering for the newsletter (we are placed in the company's database) we receive a discount on purchases in a given store, new service/purchase proposals, messages about discounts and sales. This is a common practice that encourages purchases on a given platform.

The proper use of digitization of educational facilities such as schools or kindergartens results in better educational results. Implementing new technologies in educational institutions develops individual and group creativity, ensures holistic development and reduces social inequalities (e.g. those related to digital exclusion) (Plebańska, Tarkowski, 2016). In the case

of education, thanks to digitization, a diverse contact of the student with the teachers is possible (via e-mail, direct conversation via Meet in Google Classroom, Zoom, Discord), also student service offices (BOS), the library (ordering books), grants, current events in the life of the university. Both parents (in kindergartens, primary and secondary schools) and students (in universities) have direct access to student attendance or grades (via electronic journal, e-index), admission procedures, etc. It should also not be forgotten that thanks to digitization of education, it was possible to conduct educational classes during the Covid'19 pandemic.

The use of technology and information systems is not only modernity and an advantage of civilization development, but also a threat. The Act of July 5, 2018 on the national cybersecurity system in art. 2, point 4 defines cyber security as "the resistance of information systems to actions that violate the confidentiality, integrity, availability and authenticity of the processed data or related services offered by these systems" (Journal of Laws of 2022, item 1863). In Poland, citizens' data is supervised by the Systems Management Department, whose tasks include, above all, supervision over ICT systems (https://www.gov.pl/web/cyfrizator/departament-zarzadzania-systemami). The Data Management Department (https://www.gov.pl/web/cyfralizacja/departament-zarzadzania-danymi) is responsible for the legal care of the data, the way they are collected and the solutions on how to use them.

Due to the growing level of digitization in Poland, the number of crimes committed remotely using ICT systems has significantly increased (in 2020, 10,420 cybersecurity incidents were recorded, including 73% related to phishing, i.e. extortion of data and/or money by impersonating an invented website, and in 2021 22,575 events were recorded - 76% concerned phishing) (Report ... CERT 2020, p. 13; Report ... CERT 2021, p. 12).

Until recently, one of the most popular fraud methods was the so-called. "keylogger" (Trejderowski, 2013), which in 2022 could even be considered "obsolete". Keylogger comes in many forms. This is a type of program or device that registers keystrokes. Today, every Internet user can effortlessly buy an online keylogger in the form of a flash drive, which records activities as long as it is connected to the device. This program can show in real time what someone is typing on the keyboard, including mainly passwords for access to, for example, a bank or e-mail. As malicious programs are also developing rapidly, today the hacker/scammer does not have to sit in front of the computer, the program can save all keyboard actions in a separate file. However, it usually required physically inserting the flash drive into the device, which forced the fraudster to construct a strategy on how to do it.

The public's awareness of the immediate reaction in the event of loss of documents (identity card, passport and other sensitive information, such as PESEL) is certainly a success (Kondek, Ożarowska, 2022a). The report of the Polish Bank Association and the Police Headquarters shows that the number of attempts to use someone else's document or forge documents is definitely decreasing every year. Thanks to this, in the last year of 2021, illegal taking of 7,885 loans for a total amount of PLN 245.2 million was prevented in Poland (Kondek, Ożarowska, 2022b). Unfortunately, the data of the National Police Headquarters show that in 2021 there

was no province in Poland where there would be no fraud using the "grandson" and "policeman" methods. At least 1,176 elderly people lost their life savings in the first half of 2021, and the losses amounted to over PLN 63 million (http://bip.kgp.policja.gov.pl/).

One of the forms of fraud is impersonating employees of public trust. Gentlemen dressed as policemen or employees of a housing cooperative could appear directly in front of the door to our apartment. This type of fraud, as a result of digitization, turned into phishing, consisting in extorting data and/or money by impersonating a made-up website (Trejderowski, 2013). Much more often, scammers use a negative message, they want to evoke a sense of fear in the recipient, which will make it more likely that he will not think twice before clicking on the link. This feeling is evoked by sending the recipient information about a fraud attempt, failure to pay for the purchase, or failure to receive the transfer. The user clicks on a link that redirects him to a page identical to the original page, enters his details (e.g. bank details) and thus makes a transfer to the scammer. The same method is used by phone, i.e. we get a "phone call from the bank" that a suspicious transfer has been detected or our account has been blocked, so the "bank employee" asks us to enter the password or PIN to the card to confirm our identity. Such a situation will never actually happen - the bank will never ask us for passwords over the phone. When we are not sure who is on the other end of the call, it is safest to hang up and contact the bank to clarify the situation.

Today, the police are flooded with fraud reports "via BLIK" or SMS "Pay for a package". The Department of Cybersecurity in Poland creates and implements a strategy for protection in cyberspace, and directly supervises the National Cybersecurity System, which since 2018 ensures the protection of digital services and supervises the achievement of a high level of security of ICT systems. At the end of 2021, due to the growing number of crimes related to cyberspace, the Central Office for Combating Cybercrime was established. Its primary tasks include detecting, combating and preventing crimes in the ICT network (https://cbzc.policja.gov.pl/).

Every day, more and more data is placed on the Internet (Chądrzyński et al., 2021). This process is called dataification. These are data of various origins, for example: from IT systems, individual, business and institutional users, from databases of private companies and institutions. It is worth mentioning when explaining this process that nothing is free on the Internet. By providing the phone number, our email, we "pay" with our data, which are placed and used in various databases. It is worth remembering that we place a significant amount of information ourselves. Thanks to portals such as Facebook, Linkedin, Instagram, we can find out, for example, how the user's education was conducted, where he currently works, what is his phone number or email address and where is he currently located? The thief no longer has to wait for an opportunity in front of the house, watch the apartment for weeks to know the schedule of the day, just visit Internet profiles. It is worth mentioning that we often bring the threat to ourselves completely unintentionally (Balibok, Matras, 2014). Such behaviors include delegating access authorizations (e.g. sharing bank login details with

another person), setting a weak password and not changing it, ignoring security rules, e.g. access control in buildings. Creating strong, complicated passwords annoys users. The need to remember passwords with many requirements - uppercase, lowercase, special characters. The biggest mistake is creating a password that we use for many login pages and creating an easy password using information that is easy to find about us (such as names of children, animals or date of birth) (Sajler-Fudro, 2022). With this information, it is enough to use a password cracker (e.g. John The Ripper), which any user can download for free using a web browser. How to create a password then? The longer the password, the longer it will take for fraudsters to guess it. Special characters make it harder for programs to guess your password. However, the best password is a meaningless password, such as Jk4lW.35jh?

Today's mobile phones include payment options, i.e. we can pay using applications thanks to near field communication (NFC) technology or pay thanks to the built-in radio frequency identification (RFID) portable payment card. An interesting, one of the modern types of fraud is neurohacking (Kotz et al., 2015). It involves remote hacking of devices necessary for the patient's life, such as an insulin pump or a pacemaker. These devices collect sensitive data about the patient and can easily become the subject of a crime (e.g. forcing the patient's ATM card data with the threat of turning off the device or administering a high dose of insulin that threatens life). At the same time, it can be useful if you want to mislead the Police institution or destroy evidence in the form of switching off, blocking access to the device or changing the data stored in it.

The article presents the results of a survey on the assessment of young people's awareness of the security of information technology, the risks associated with it and the way of obtaining knowledge about it. 119 students took part in the study, mostly young people aged between 18 and 27 (so-called Generation Z or Generation C) (Rojewska, 2019). This generation is considered the first people growing up in a fully digitized society, therefore it is assumed that they are people with a certain level of familiarity with modern computer equipment, smartphones, tablets, etc. These people have no problems with fear of new information technologies and feel good in their surroundings (they can't even imagine life without them).

2. Materials and metods

The conducted research consisted of two parts. The first part of the research consisted of literature analysis. A systematic review of the literature on the subject and a critical analysis of the content of selected publications made it possible to identify the problem and the research gap. Additional support in identifying the problem and formulating questions was the professional experience of the research co-author (as an expert).

In the second part of the study, survey questions were formulated and an online survey (CAWI - Computer-Assisted Web Interview) was conducted among students (https://forms.gle/RSYncU2DYWQvsaaY9). The basis of the pilot study was a questionnaire containing 11 open and closed questions with the possibility of giving one or more answers.

The survey was conducted among 119 students in the last few months of 2022 (from November 1, 2022 to December 31, 2022). Purposeful selection of the group was used. The respondents were university students (full-time and part-time) from various cities and fields of study. The study included 77 women (64.7%), 40 men (33.6%) and 2 people (1.7%) who did not declare their gender to the above groups. Since the study was conducted over a short period of time and most of the respondents are students of the University of Zielona Góra (almost 70%), it should be treated as a pilot study and not related to the entire population of young Poles, but to representatives of a certain group of them.

3. Research results

The survey conducted in 2022 was filled in mainly by students from Lubuskie - 83 people (69.7%), Dolnośląskie 14 people (11.8%), Mazowieckie and Wielkopolskie voivodships - 5 people each, Pomorskie, Śląskie and Zachodniopomorskie - 3 people each, Łódzkie, Małopolskie and Świętokrzyskie - 1 person each (in total from 10 out of 16 voivodeships). Among 119 students, only 11 are in technical faculties (e.g. Faculty of Mechanical Engineering, Faculty of Computer Science, Electrical Engineering and Automatics) and the remaining 108 are in humanities (e.g. Faculty of Economics and Management, Faculty of Social Sciences, Faculty of Psychology, Faculty of Pedagogy, Faculty of Nursing, Faculty of Veterinary Medicine). Most of the respondents live in rural areas - 28.6%, in cities of up to 50,000 inhabitants. inhabitants live in 26.1%, the third place is 24.4% of respondents living in medium-sized cities (100-500 thousand inhabitants), 11.4% are inhabitants of large cities (over 500 thousand inhabitants), and 9.2% are inhabitants of cities with a population between 50-100 thousand More than half of the respondents are first and second year students, i.e. those under 21 (52.1%), between 22 and 25 there were 36.1% of the respondents, and the rest are people over 26 (11.8%).

Most students, 57.1%, have dealt with fraud as victims (25.2%) or people who wanted to cheat (31.9%), but thanks to reflexes and resourcefulness they avoided fraud - compare figure 1. Other students (42.9%) do not remember or have not been victims of fraud. Nevertheless, out of the group of 119 students surveyed, 76.5% of them answered that they knew people who were victims of fraud (usually a family member or friend).

Figure 1. Students exposed to fraud.

Source: own study.

In addition, as shown in Figure 2, most students heard about scams using the "grandson" (90.8% - 108 people), "cop" (83.2% - 99 people), they also received "unknown links, e.g. in an e-mail" (90.8% - 108 people), "unknown links sent to the phone" (86.6% - 103 people), related to lotteries or prizes (79.8% - 95 peole), impersonating a "bank employee" (68.9%), by installing a virus (68.1%), related to prepayments, e.g. on OLX (61.3%), using the BLIK method (60.5%), impersonating a "ZUS employee" (31.1%), impersonating a "housing cooperative employee" (22.7%), and single cases of an attempt to extort data/money by a person impersonating a person associated with charity or cryptocurrency activities.

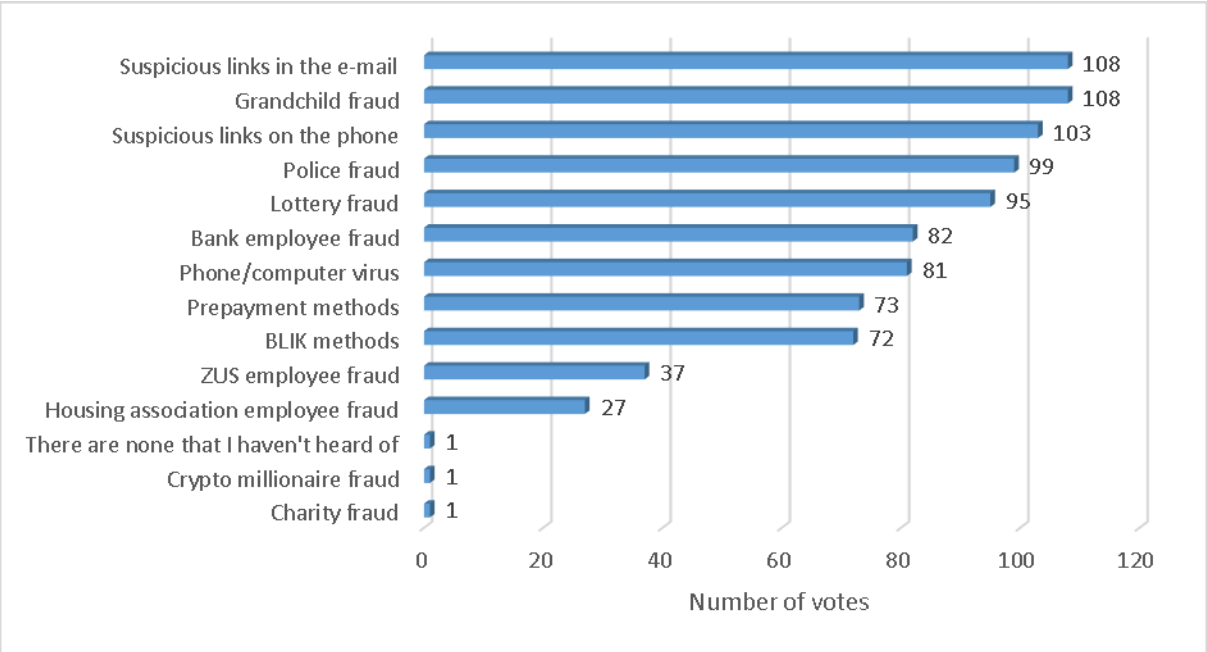

Figure 2. Fraud or extortion of money, confidential information that the respondents heard about.

Source: own study.

Where students obtain information on counteracting fraud can be found in the answers listed in Figure 3. They most often obtain information on this subject from the Internet (85.7% - 102 people), from friends and family (68.1% - 81 people), from television (44.5% - 53 people) and from bank website (40.3%), school/university website (34.5%), radio website (28.6%), official websites, e.g. Police (27.7%), press (16.8%).

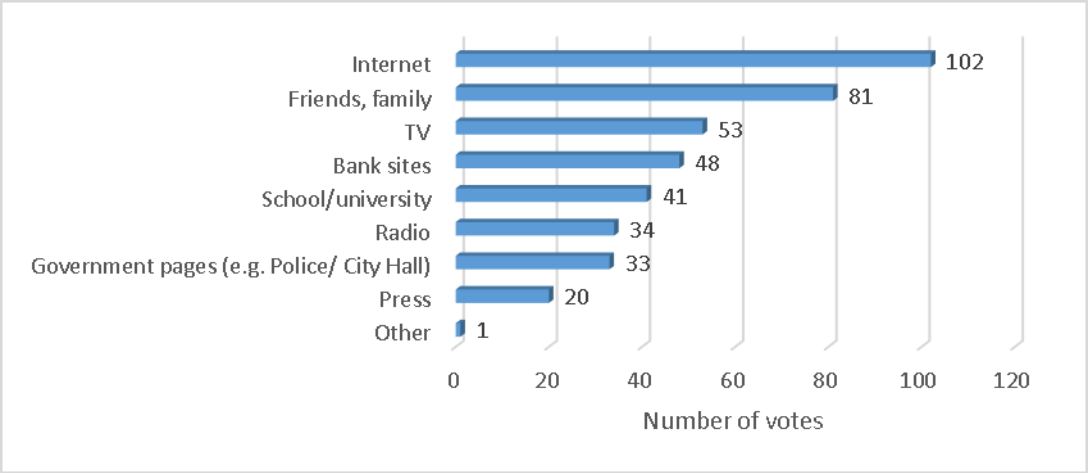

Figure 3. Collecting anti-fraud information.

Source: own study.

Students were asked to tick the answers related to the devices they trust the most when making various financial transactions. As it turns out (figure 4), students have the greatest trust in payments via a computer/laptop (30 people - very high and 40 - high sense of security), followed by Blik payments (32 people - very high and 33 - high sense of security), payments via phone (26 - very high and 34 - high sense of security), and the least trust in payments via tablet (7 and 20 respectively) and watch (8 and 12 respectively).

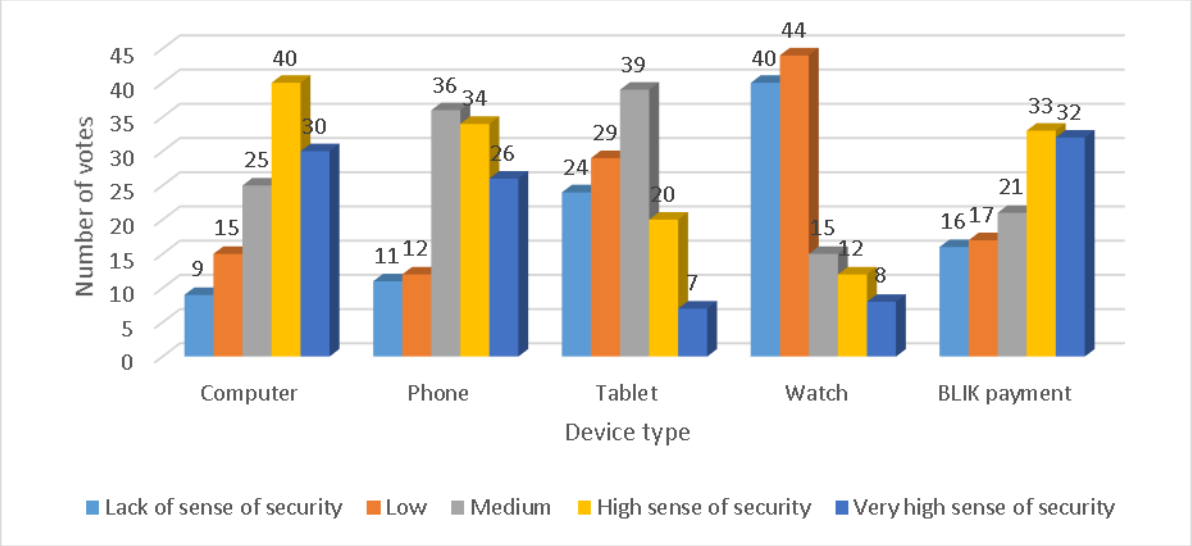

Figure 4. Devices students trust the most when making financial transactions.

Source: own study.

The computer/laptop inspires the greatest trust and sense of security among students, but it is also due to the fact that 81.5% (97 people) have an anti-virus program installed on these devices (figure 5). Only 48.7% (58 people) of students have an antivirus installed on their phone. The lack of adequate protection against viruses is certainly the reason for the lack of trust in making payments with other devices, which was shown earlier in figure 4.

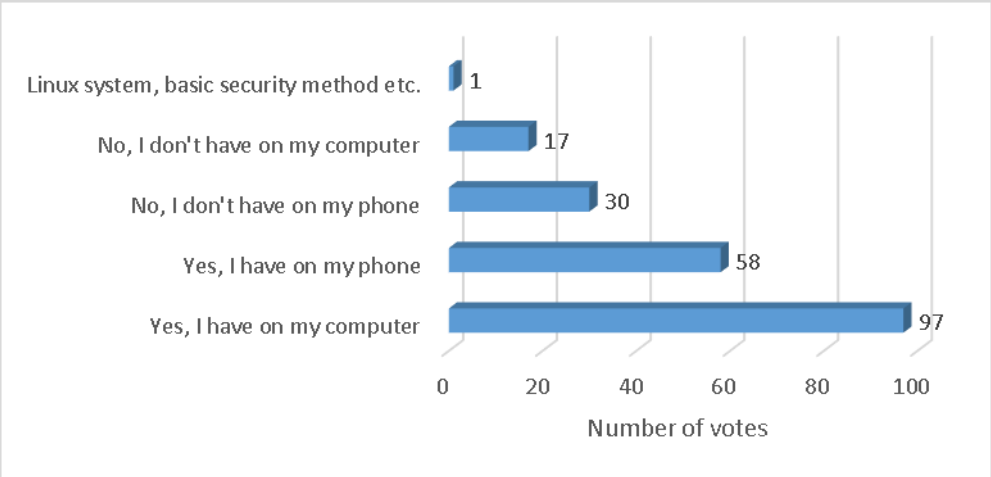

Figure 5. Devices on which students have an antivirus program installed.

Source: own study.

A n important element that banking websites or applications remind us of is the frequent change of passwords with an appropriate number of complex characters. It is also an important factor of a sense of security in the use of modern information technologies. As it turns out, 31.1% of students change their password as soon as they are reminded of it by the website/store where they are logged in (figure 6). It is alarming that 19.3% of students do not change their passwords at all, and 15.1% do it once every few years (they make up a total of 34.4% of the respondents), 14.3% of the respondents change their passwords on average once a quarter, 11.8% - once a year, and only 6.3% - once a month and 2.1% - once a week.

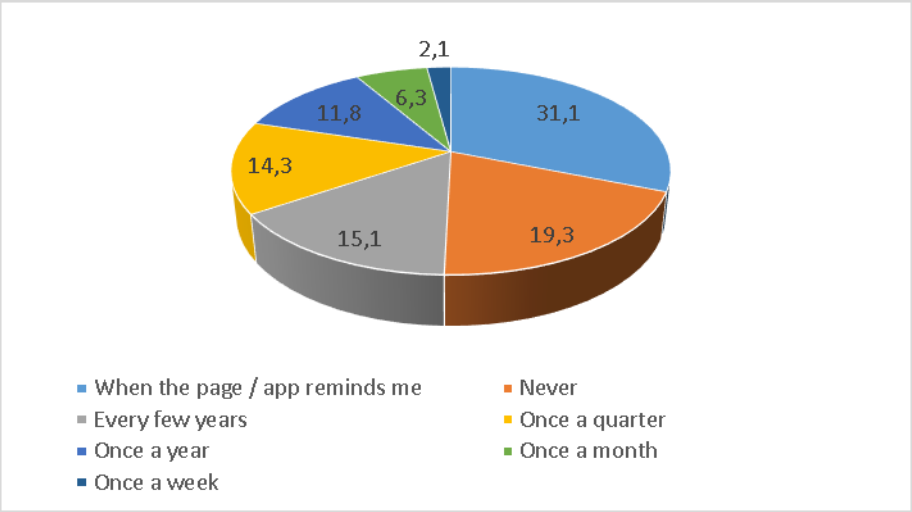

Figure 6. Password change frequency [%].

Source: own study.

Many students, as many as 31.1%, very often use the same password for many accounts, often - 28.6%, and some even always - 3% (total 62.7%). The second group are students who rarely use the same password for many accounts and they constitute a group of 20.2% of the respondents, very rarely - 8.7%, never - 8.4% (37.3% in total) - figure 7.

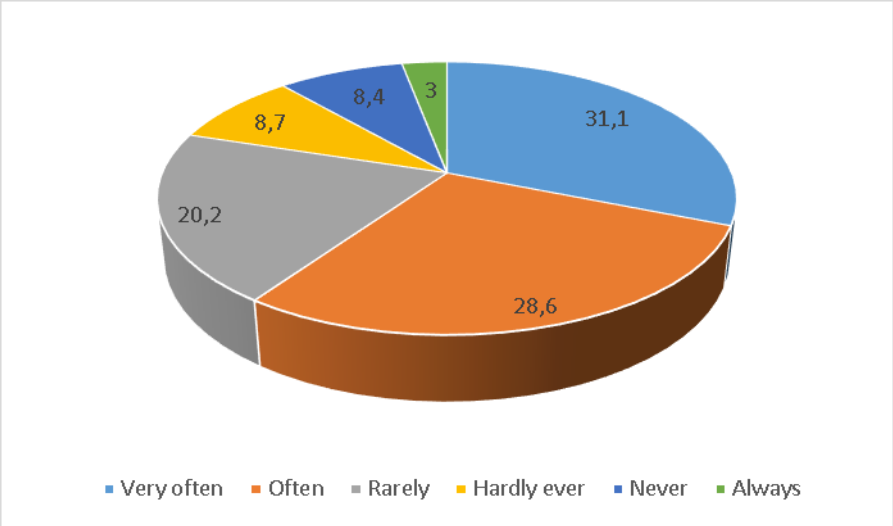

Figure 7. Frequency of using the same password for multiple accounts [%].
Source: own study.

The high frequency of using the same password for many accounts results from the problem of remembering a large number of passwords and a large number of accounts (computer, social networks, online stores). Figure 8 summarizes students' responses to writing down passwords in notebooks, calendars, or cards. It turns out that 43.7% of students do not save their passwords, and 10.1% used to write them down and now do not (they make up a group of 53.8% of the respondents). The remaining 46.2% of respondents save passwords to varying degrees so as not to lose them.

The next question concerned students who save their passwords in a computer/laptop browser so that there is no need to remember them or write them down on paper/calendar. This activity is always performed by 7.6% of students. 35.3% of students save their passwords in the browser frequently, 34.5% do it sometimes and 22.6% never do it.

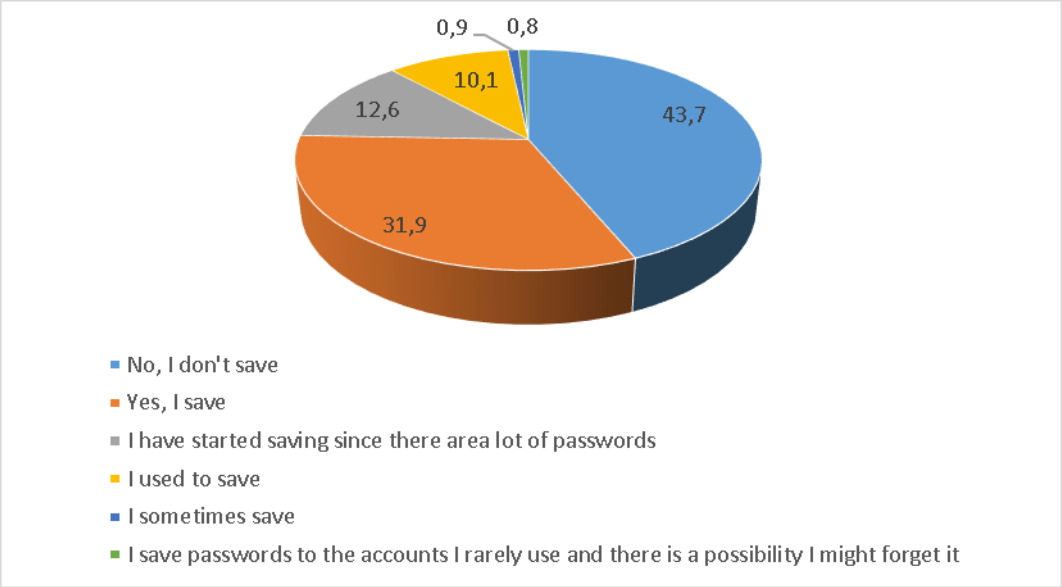

Figure 8. Saving passwords in notebooks, calendars or on cards [%].

Source: own study.

The problem in the case of saving passwords in the browser of a computer/laptop may be damage to the website or a change of computer, because then the password will not be remembered. For young people, however, this is not a big problem, because in this case, for example, they recover lost passwords or create a new account with a new password.

4. Summary

The research described in this article are declarations of young people who are currently students of universities in Poland, who are between the ages of 18 and 27 (so-called Generation Z or Generation C). This generation grew up in a fully digitized society, therefore operating a computer, smartphone, tablet or watch (smartband) is not a problem for them and does not arouse fear (as in the case of older people).

The surveyed students have knowledge about various types of fraud and more than half (57.1%) have encountered them in person or at someone's family/friends (76.5%). They have the greatest confidence in computers/laptops (70%), which most often have pre-installed virus protection programs, and the least in watches (20%). Young people, despite being aware of the threats, do not care about cybersecurity, have no problem with technological innovations and actually consciously expose themselves to fraud (18.5% do not have an anti-virus program on a computer believed to be the safest device for financial transactions). Even if students do not change their passwords very often, they write them down on cards or on a computer in a browser. It is not very secure, but each user chooses the most convenient form of recording for himself.

Since 25.2% of students have dealt with fraud as victims, the need for further education of the young generation in the field of cybersecurity and modern information technologies as a new threat is clearly visible. Most of the surveyed students will soon become graduates of first or second degree studies and start working. The future employer will probably be interested in an employee who can operate modern IT devices, but also cares about their security and shared data.

References

1. Balibok, P., Matras, A. (2014). Bankowość mobilna jako innowacyjny kanał dostępu do usług bankowych. *Rocznik Ekonomii i Zarządzania, tom 6(42), nr 2,* pp. 7-22.
2. Centralne Biuro Zwalczania Cyberprzestępczości. Retrieved from: https://cbzc.policja.gov.pl/, 2.01.2023.
3. Chądrzyński, M., Gruziel, K., Kacperska, E., Klusek, T., Utzig, M. (2021). *Polska w dobie cyfryzacji*. Warszawa: SGGW.
4. Chojnacka, M. (2021). *Organizacja przyszłości*. Gorzów Wielkopolski: Wydawnictwo Akademii im. Jakuba z Paradyża.
5. Departament Zarządzania Danymi. Retrieved from: https://www.gov.pl/web/cyfryzacja/departament-zarzadzania-danymi, 21.12.2022.
6. Departament Zarządzania Systemami. Retrieved from: https://www.gov.pl/web/cyfryzacja/departament-zarzadzania-systemami, 21.12.2022.
7. Komenda Główna Policji. Retrieved from http://bip.kgp.policja.gov.pl/, 2.11.2022.
8. Kondek, G., Ożarowska, E. (2022a). *Raport o dokumentach infoDOK (2 kwartał 2022*). 50 edycja. Retrieved from: https://zbp.pl/Aktualnosci/Wydarzenia/Raport-InfoDOK,-II-kw-%E2%80%93-maleje-liczba-prob-wyludzen-kredytow, 20.12.2022.
9. Kondek, G., Ożarowska, E. (2022b). *Raport o dokumentach infoDOK (3 kwartał 2022*). 51 edycja. Retrieved from: https://zbp.pl›infodok-2022-07-09-wydanie-51(1).pdf, 20.12.2022.
10. Kotz, D., Fu, K., Gunter, C., Rubin, A. (2015). Security for mobile and cloud frontiers in healthcare. *Communications of the ACM. Vol. 58, Iss. 8*, pp. 21-23.
11. Maslow, A.H. (2022). *Motywacja i osobowość*. Warszawa: PWN.
12. Morawski, J. (2021). Logistyka ostatniej mili - usprawnienia w obsłudze klienta. *Przedsiębiorczość i Zarządzanie*, *tom 22, zeszyt 2,* pp. 241-257.
13. Plebański, M., Tarkowski, A. (2016). *Cyfryzacja polskiej edukacji. Wizja i postulaty*. Retrieved from: https://centrumcyfrowe.pl/wp-content/uploads/2016/07/cyfryzacja-polskiej-edukacji_final.pdf, 20.12.2022.

14. Raport Digital Poland (2022). *Technologia w służbie bezpieczeństwa. Czy Polacy zostaną społeczeństwem 5.0? Edycja 2022,* Retrieved from: https://digitalpoland.org/publikacje/pobierz?id=602693cf-262c-4f2a-bfa3-9f91cfaffd3c, 2.01.2023.
15. Raport roczny CERT Polska 2020 (2021). *Krajobraz bezpieczeństwa polskiego internetu*. Warszawa: NASK PIB/CERT Polska.
16. Raport roczny CERT Polska 2021 (2022). *Krajobraz bezpieczeństwa polskiego internetu*. Warszawa: NASK PIB/CERT Polska.
17. Rojewska, M. (2019). *Milenialsi, pokolenie Z, Y, X, generacja baby boomers – kto to?* Retrieved from: https://interviewme.pl/blog/pokolenie-z, 5.10.2022.
18. Sajler-Rudro, P. (2022). Zagrożenia bezpieczeństwa w użytkowaniu systemów informatycznych – klasyfikacja i metody zapobiegania. *Nauki Ekonomiczne, tom 35,* pp. 189-214, DOI: 10.19251/ne/2022.35(11).
19. Saniuk, S., Grabowska, S. (2022). Development of Knowledge and Skills of Engineers and Managers in the Era of Industry 5.0 in the Light of Expert Research. *Scientific Papers of the Silesian University of Technology. Organization and Management Series, no. 158*, pp. 537-547. DOI: 10.29119/1641-3466.2022.158.35
20. Trejderowski, T. (2013). *Kradzież tożsamości. Terroryzm informatyczny*. Warszawa: Eneteia.
21. Ustawa z dnia 10 maja 2018 roku o ochronie danych osobowych [Dz.U. 2022, poz. 1863].
22. Ustawa z dnia 17 lutego 2005 r. o informatyzacji działalności podmiotów realizujących zadania publiczne [Dz.U. 2021, poz. 2070].
23. Ustawa z dnia 5 lipca 2018 r. o krajowym systemie cyberbezpieczeństwa [Dz.U. 2022, poz. 1863]**.**
24. Załoga, W. (2022). Digital competences of the information society era in the aspect of safety in cyberspace. *Scientific Papers of Silesian University of Technology. Organization and Management, No. 164,* pp. 541-552. DOI: http://dx.doi.org/10.29119/1641-3466.2022.164.41.

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EQUITY CROWDFUNDING IN 2020-2022: DEVELOPMENT OPPORTUNITIES AND BARRIERS IN POLAND

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Purpose: The aim of the article is to present equity crowdfunding, to explain its purpose and principles as well as to identify economic and social factors in the development of this form of fundraising in Poland in 2020-2022.
Design/methodology/approach: The study used reports from crowdfunding platforms and own re-search. The study is based mainly on descriptive, analytical and com-parative research methods.
Findings: After analyzing the data from crowdfunding platforms and the provisions of the new regulations, it can be concluded that equity crowdfunding is a dynamically developing method of financing economic projects in Poland.
Originality/value: The publication presents the results of research conducted on the basis of crowdfunding reports.

Keywords: equity crowdfunding, community, funding source.

Category of the paper: Research paper.

1. Introduction

The years 2020-2022 saw the COVID-19 pandemic, when the popularity of crowdfunding reached an all-time high in Poland. The economic shutdown contributed to the popularisation of crowdfunding and caused a revolutionary change in how Poles view crowdfunding. Crowdfunding involves setting up an online fundraiser with the goal of gaining financial backing for a new project, expanding an existing business, or supporting charity. To this end, crowdfunding platforms are used.

These are specialised websites that connect fundraisers with donors. The originator may offer certain benefits to the funders in exchange for their contributions. These may include a finished product, a price discount once the product is marketed, or shares in a company.

The project creator must be able to accept the contribution method proposed by funders. They depend on the type of crowdfunding.

There are five basic types of crowdfunding: donation-based, rewards-based, pre-sale crowdfunding, debt-based, and equity-based crowdfunding. The latter two models are crucial for business venture funding. The equity crowdfunding market is showing a growth trend and interest in equity crowdfunding is likely to increase even more due to regulatory changes involving a rise in the maximum amount of capital. The aim of the article is to present equity crowdfunding, to explain its purpose and principles as well as to identify economic and social factors in the development of this form of fundraising in Poland in 2020-2022. The paper uses the methods of literature analysis and criticism as well as analytical and comparative research methods.

2. Literature review

Equity crowdfunding is part of investment crowdfunding. It is an innovative method of financing enterprises, based on acquiring shares in a business using modern technologies (Glanc, 2020, p. 7). The financing process consists of the following stages: selection and valuation, investment, postinvestment and exit (Wilson, Testoni, 2014, p. 3). Typically, it is used to finance medium-sized investment projects falling into so called financing gap. Table 1 presents the basic characteristics of equity crowdfunding, in which an investment is a form of backing and shares in a company are a form of return.

Table 1.
Characteristics of equity crowdfunding

Entities	Backers	Type of backing	Form of return	Motivation for backers
Companies in growth or maturity stage	Numerous small, dispersed investors	Investment	Shares	Possible return on investment

Source: Own preparation based on Malinowski, 2018, p. 13.

Equity crowdfunding is usually characterised by a much greater campaign goal (e.g. Stars.Space SA – PLN 4.55 million) than in donation-based campaigns. Proper valuation of the project and formulation of clear business objectives can ensure the financial success of the business reflected in the profit earned by numerous investors (Vulkan, Astebro, Sierra, 2016, p. 38) .Compared to a standard equity issue, equity crowdfunding is considered a more democratic method of project financing designed for multiple, dispersed investors who attach importance to relationship with the issuer (Cumming, Meoli, Vismara, 2021, pp. 23-24). Crowdfunding platforms which allow, among other things, the assessment of the risk involved in projects and rejection of a large number of the proposed campaigns, play a key role in equity

crowdfunding. Such platforms are accessed by companies – businesses whose primary objective is to sell, grow, develop, profit and maximise shareholder value. Equity crowdfunding seeks to fund a company's entire business or a selected strategic or operational function, rather than a single product or service. Investors are more willing to back companies that already have a track record of sales and a positive market validation. If an entity has not yet created any product or service and has only a concept or prototype to present, it should use another crowdfunding model, such as the reward-based model (Lissowska, 2018, pp. 59-86).

The process of financing companies through equity crowdfunding in Poland is mainly based on the provisions of the Commercial Companies Code. However, it is worth noting that as of 10 November 2021 the new Regulation (EU) 2020/1503 of the European Parliament and of the Council of 7 October 2020 on European crowdfunding service providers for business, and amending Regulation (EU) 2017/1129 and Directive (EU) 2019/1937 applies. The new legislation seeks to comprehensively regulate crowdfunding platforms and changes the legal reality for crowdfunding. What is important for the development of this market is that as of 10 November 2021 equity crowdfunding has become a fully-fledged regulated part of the financial market in the European Union. The new EU guidelines introduced, among other things, supervision of part of the crowdfunding market by competent state authorities and uniform rules for the authorisation of services in the lending and investment models, as well as raised again the limit of issuance without prospectus to €5 million (although this threshold will be reduced to €2.5 million by 9 November 2023) (Regulation (EU) 2020/1503). Additionally, crowdfunding service providers were required to ensure certain safeguards to protect investors using their platforms, particularly investors who are defined as inexperienced (Regulation (EU) 2020/1503).

3. Methods

The study is based mainly on descriptive, analytical and comparative research methods. The paper compares crowdfunding platforms, both in terms of the number of participating investors, the types of projects carried out, and the invested amounts, and demonstrates that equity crowdfunding is a method of economic project funding which is becoming increasingly popular in Poland. The last part of the article is devoted to assessing the development prospects for equity crowdfunding and the opportunities and threats associated with the same.

4. Determinants of equity crowdfunding development

Ongoing digital transformation, popularisation of innovative solutions and turmoil in the banking sector and capital market (mainly related to the crisis of confidence in the market and reputational damage caused by the financial crisis) may be considered as some of the reasons for developing alternative methods of financing, including equity crowdfunding. Their purpose is to reduce or eliminate the role of a traditional financial intermediary and to decentralize traditional banking services (Crowdfunding, 2022). In addition to information technology itself as the foundation of crowdfunding, the changes in social attitudes associated with the sharing economy, i.e. sharing access to goods and services, including through technological channels, may have contributed to the emergence of this innovation.

Crowdfunding is an example of how financing services, which for centuries were mainly the domain of usurers, banks and capital markets, can also be shared (Ziobrowska, 2021, pp. 154-155). Crowdfunding is used not only by startups but also by well-established businesses. This allows them to reach new target groups or verify their valuation, for example, before a traditional IPO. A key advantage of using crowdfunding to fund a business is the ability to remain the owner of a project or business. The COVID-19 pandemic, which changed Poles' perception of equity crowdfunding, also contributed to the popularisation of various forms of crowdfunding. In 2020-2021, due to the pandemic, Poles spent a lot of time at home and had the opportunity to explore different forms of financial backing online. They began setting up and eagerly supporting online fundraisers for various causes on a massive scale (Ziobrowska, 2021, p. 107). The growth of the equity crowdfunding market has also been positively impacted by the increased limits on public equity issuance without the requirement of a prospectus or memorandum. The public offering limit in the early days of the equity crowdfunding market was €100 thousand. Following the changes in 2018 and the raising of the issue limit to €1 million without the obligation to publish a prospectus or memorandum, the market has gained a considerable momentum. Already in 2019, companies have raised more than PLN 47 million, which is over four times (440%) more than in 2018, and 2020 saw a twofold increase (110%), which is mainly due to the high volume of issues in the previous year (almost PLN 48 million). A factor driving continued market growth is the further increase in the limit for crowdfunding campaigns from €1 million in 2018 to €5 million in 2021 (Trzebiński, 2021, pp. 9-10). The Polish law implementing the European regulations provides for a two-year transition to this maximum threshold. During the transition period, the maximum threshold will be €2.5 million (Crowdfunding for Business Bill, 2022). It will also be possible to introduce a notice board, i.e. a sort of secondary market on crowdfunding platforms. Share dealing will be possible even before their IPO (Emiteo, 2022). Navigator Crowd is already working on this solution. The offering board is expected to be available to investors in 2022 (Navigator Crowd, 2022).

5. Determinants of equity crowdfunding development

All crowdfunding platforms follow a generally accepted model. After registering on the platform, a person who wants to set up a crowd fundraiser describes his/her idea, presents potential backers with the benefits of launching the project and specifies the financial conditions of the entire undertaking (i.e. specifies the minimum amount of money that is needed for launching). A time frame for raising the necessary funds is also provided (Dziuba, 2012, p. 86). The best known equity crowdfunding platforms in Poland include: Beesfund, Crowdway and CrowdConnect. The first one, Beesfund has been operating since 2012 and is the first equity crowdfunding platform in Poland (Beesfund, 2022). Chart 1 shows the value of all investments made on the largest equity crowdfunding platforms in Poland between 2017 and 2021.

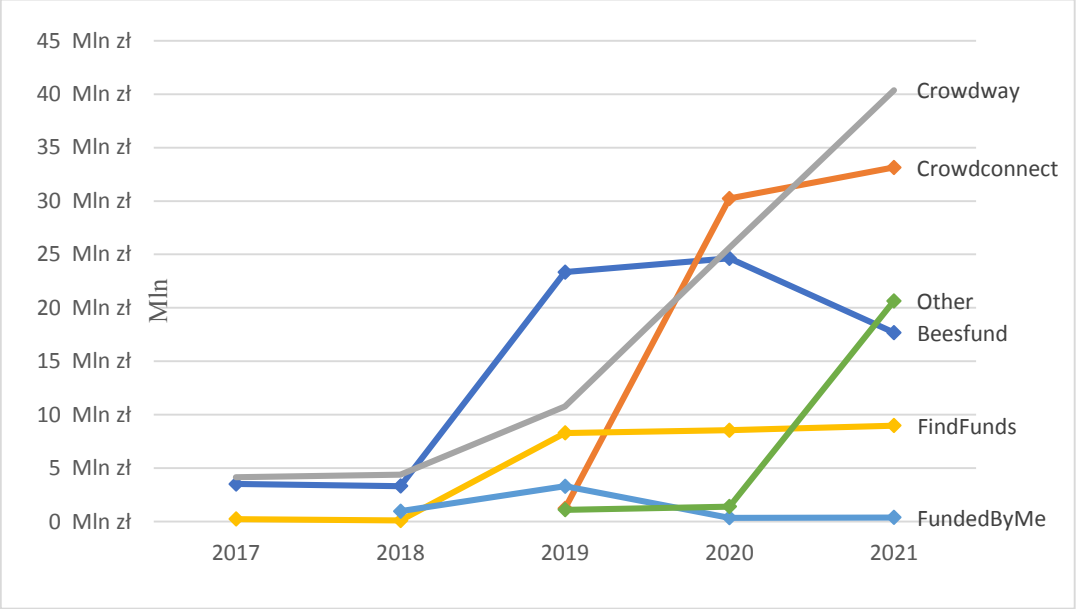

Figure 1. Total value of investments made on the largest equity crowdfunding platforms in Poland between 2017 and 2021.

Source: Own preparation based on Crowdway (2022).

Issuance of shares through equity crowdfunding are campaigns which are not always successful and raise funds exceeding the goal. Table 2 shows the equity crowdfunding platforms operating in Poland in 2020-2021.

Table 2.
Equity crowdfunding platforms in 2020-2021 (completed issues)

Platform	Number of companies		Number of investors		Total amount raised (PLN)		Achieved 100% of goal and beyond	
	2020	2021	2020	2021	2020	2021	2020	2021
Beesfund	31	26	22,193	3,639	24,639,068	17,677,553	4	2
Crowdway	12	18	6,226	8,580	25,641,750	40,360,261	7	7
CrowdConnect	12	14	2,866	1,554	30,239,604	33,132,420	11	9
FindFunds	8	7	478	306	8,550,450	8,979,500	7	7
SmartFunds	-	2	-	169	-	2,715,000	-	2
FundedByMe	1	1	36	11	358,679	385,000	-	-
shareVestors.com	3	-	40	-	1,400,240	-	1	-
Emiteo	-	2	-	3779	-	8,499,985	-	2
Forc.ee	-	1	-	23	-	600,000	-	1
Investoor	-	1	-	3	-	18,240	-	-
Navigator Crowd	-	1	-	1	-	1,216,190	-	-
Prosper Capital	-	2	-	-	-	2,075,572	-	-
Raisemana.com	-	1	-	203	-	323,901	-	1
StockAmbit	-	2	-	-	-	4,118,650	-	-
Total	**67**	**80**	**31,839**	**18,488**	**90,829,790**	**121,180,144**	**30**	**31**

Source: Own preparation based on Crowdway.pl (2022).

Currently, there are fourteen platforms (Crowdway, ZPP, 2022). It can be seen that in 2021 their number doubled in relation to the previous year. The largest number of companies presented their offerings on the Beesfund platform – both in 2020 (31 companies) and 2021 (26 companies), however only 6 companies among them met 100% or more of their goal. The following platforms recorded the lowest number of offerings: FundedByMe, Forc.ee, Investoor, Navigator Crowd and Raisemana.com (1 company). It should be noted that some of them did not start operating until 2021. In 2020, company offerings presented on the Beesfund platform attracted the largest number of investors (22,193 investors) and those on the FundedByME platform – the smallest number (36 investors). In 2021, the largest number of investors accepted offerings presented on Crowdway (8,580 investors) and the smallest number on Navigator Crowd (1 investor). In 2020, the highest total amount of funds was raised on the CrowdConnect platform (PLN 30,239,604) and in 2021 on the Crowdway platform (PLN 40,360,261). In 2020, the smallest amounts were raised on the FundedByMe platform and in 2021 on the Investoor platform (Crowdway, ZPP, 2022). Table 3 shows the largest equity crowdfunding investments in 2020-2021 in Poland.

Table 3.
Largest investments through equity crowdfunding during the 2020-2021 pandemic (completed issues)

Company	Number of investors	Amount raised (PLN)	Average amount per Investor (PLN)
Stars.Space	88	4,550,000	51,705
KTS Weszło	3,471	4,500,000	1,296
Kombinat Konopny (2nd issue)	736	4,500,000	6,114
Alembik Polska SA (2nd issue)	1,026	4,499,979	4,386
Tenczyńska Okovita (2021)	977	4,436,158	4,541
CanPoland SA	576	4,400,000	7,639
United Label	175	4,400,000	25,143
ConsoleWay	326	4,375,000	13,420
Mazurska Manufaktura Alkoholi	324	4,375,000	13,503
Wolf and oak distillery	1,482	4,202,820	2,836
Kombinat Konopny	895	4,200,000	4,693
Alembik Polska SA	1,204	4,185,000	3,476
Browar za miastem	647	4,180,000	6,461
Tenczynek Bezalkoholowe	1,112	4,176,000	3,755
GenXone SA	54	4,140,000	76,667
Farmy Fotowoltaiki SA	992	4,050,000	4,083
Final total	**14,085**	**69,169,957**	**4,911**

Source: Own preparation based on Crowdway.pl (2022).

Some of the most popular industries for equity crowdfunding projects include: craft spirits, gaming, marketing, sports, and renewable energy (Trzebiński, 2021, p. 13). The highest value of subscriptions for shares in the public offering was obtained by Stars.Space SA (PLN 4.55 million). Thus, the company reached a record high in Poland in terms of capital raised through crowdfunding. Stars.Space SA's offering was made on the CrowdConnect platform and was divided into two rounds. The first one was addressed to larger investors who were offered shares worth a total of PLN 1 million. In the second round, which was open to all, the company raised PLN 3.55 million. The average amount per investor was PLN 51,705. The core business of the company is predicting trends in the consumer market using artificial intelligence, Big Data analytics and VR technology. The company is currently developing products inspired by outer space and, in collaboration with the social networking platform TikTok and the Rossmann drugstore chain, has launched its first cosmetics line, Stars from the Stars (CrowdConnect, 2022).

The second place was taken jointly by: KTS Weszło and Kombinat Konopny which raised PLN 4.5 million. Kombinat Konopny broke the time record of Polish equity crowdfunding by raising PLN 4.5 million from 736 investors in just 7 minutes. The previous time record was set by CanPoland, which raised 4.4 million PLN in 11 minutes in early 2021. Both issues by Kombinat Konopny and the issue by CanPoland were promoted by the Crowdway platform. The average amount per investor in Kombinat Konopny was PLN 6,11424 (Crowdway, 2022). Kombinat Konopny is a company specialising in the cultivation and processing of hemp. The funds raised will be used, among other things, to expand the herbal plant, the product portfolio and to expand abroad. It is worth noting that in the first issue in 2020 Kombinat raised PLN 4.2 million in 38 minutes. Kombinat Konopny has revised its forecasts for the coming years and estimates that it will reach 5 million in revenue in 2022. In 2023, the company's profit is expected to amount to PLN 2 million, 2 years later to PLN 6 million (Kombinat Konopny, 2022).

KTS Weszło was valued at PLN 22.5 million and offered 20% of the share capital. It raised PLN 4.5 million on the Emiteo platform from 3,471 new shareholders in 1.5 hours. The average amount per investor was PLN 1,296 (Emiteo, 2022). The funds obtained by KTS Weszło S.A. will be spent on the development of the infrastructure and the functioning of the club, however the investors were most interested in the idea of developing an application for day-to-day management of the club by the community of shareholders. The application, referred to by its originators as a real life equivalent of football manager computer games, is to enable each holder of KTS Weszło shares not only to appoint members of the management board, but also to vote in current club affairs. KTS Weszło is additionally planning to create a sports and educational centre, combining the functions of a club's stadium, a pitch rented for training and amateur games, and a football academy (Emisja Weszło, 2022).

The success of the crowd fundraisers discussed above paves the way for many other interesting ventures. In crowdfunding, the most important task is to present an idea on the crowdfunding platform in the most detailed and interesting manner possible. This will determine the success of the fundraiser and the future success of the project. Thus, campaigns that are appreciated by younger people – largely internet users – but above all those that are easy to present and generate excitement are more likely to benefit from this type of funding. This is why crowdfunding methods are often used – successfully – by developers of online games or physical products.

6. Crowdfunding development opportunities and barriers

Equity crowdfunding may be analysed in terms of opportunities and barriers related to its further development in Poland. The first part will discuss opportunities. It may be concluded that the new funding regulations will contribute to further development of equity crowdfunding. Until now, there have been many doubts about the proper performance of such activity. From the perspective of crowdfunding platforms, the new regulations will contribute to the professionalisation of the market, as well as allow platforms to carry out crossborder operations throughout the EU.

From the perspective of investors, the new regulations will provide better protection, as well as greater exit opportunities. The growth of the equity crowdfunding market will also be positively impacted by the increased limits on public equity issuance without the requirement of a prospectus or memorandum (Emiteo, 2022).

An unquestionable advantage of crowdfunding is that by using an internet platform, the originator of a project can reach a considerable number of people who are potentially interested in its realisation. Crowdfunding allows the establishment of a bilateral relationship – on the one hand, it is a great way for the investor to grasp investment opportunities that, in the past, were difficult to find or even unavailable to private investors. On the other hand, from a entrepreneur's perspective, it is a unique opportunity to create a community which believes in the founder's vision and wants to build and expand the business together. With crowdfunding platforms available and a multitude of information channels, reaching potential investors and customers is definitely becoming easier than it was a few years ago. The community centred around the project will naturally drive web traffic, stimulating interest in new consumers. A community characterised by investor experience and numerous business contacts facilitates reaching new investors even more. Investors are actively involved in the development of the project, sharing their knowledge with the company, however, the right to decide on the direction of the project's development is retained by the entrepreneur. Companies that execute crowdfunding issues maintain almost complete control over the project, which is often not possible with professional investors or Venture Capital funds. Investment crowdfunding ensures growth capital in exchange for shares in a company. Until now, such a mechanism has only been in place in the stock market. Investment crowdfunding is an opportunity for companies in the growth stage, for which another form of raising funds is impossible or would be a barrier to growth (Crowdfunding, 2022).

Crowdfunding is not without its risks. These include the risk of another entrepreneur using an idea made public. All it needs are funds for implementation. Therefore, to enter the world of crowdfunding a copyright registration will be necessary. The main barriers to development that have significantly halted the growth of the equity crowdfunding market include, in particular, the lack of clear rules for crowdfunding platform providers, restrictions on the amount of funds

that can be raised to launch projects, the lack of mechanisms for exiting an investment, as well as insufficient safeguards to protect non-professional investors. If there is no requirement to publish a prospectus, investors may be exposed to an increased risk of failure of the project in which they are investing. The problem associated with crowdfunding is information asymmetry. Asymmetry is when the originator knows more about the project than potential funders who want to get involved (Crowdfunding, 2022). Furthermore, disinvestments, or exits from crowdfunding investments, are not always profitable. The few IPOs of companies previously offering shares outside the stock market often performed unsatisfactorily. Certain campaigns are overly long and eventually fail to raise the intended amount of funds for further development. As a result, companies often hold off on launching offerings. Another barrier to the development of equity crowdfunding in Poland is the issue of managing the community that has invested in a company. There are no accepted and common best market practices in place yet, and it seems that they would be conducive to the proper development of equity crowdfunding in Poland (Trzebiński, 2021, pp. 9-20).

7. Conclusion

The analysis of data from crowdfunding platforms and new regulations indicates that equity crowdfunding, as a method of financing businesses, is thriving in Poland. The offerings that appear on crowdfunding platforms are increasingly interesting and reach higher and higher financial goals. In crowdfunding, as in other forms of alternative financing, there are numerous risks associated with investments.

Above all, there should not be unreasonable valuation expectations towards the companies, and there needs to be more offerings from entities that are more mature and are profitable and still in a strong upward trend. It is important to examine the market in which the companies operate, assessing its stage of development, growth potential and competitive potential. An analysis of the barriers to entry for entrepreneurs is also a significant factor. Barriers that may be encountered are those related to the scale of operations and regulatory constraints. The development of equity crowdfunding will certainly be accelerated by further information and promotion campaigns. This form of equity crowdfunding – raising awareness among both entrepreneurs and potential investors lies with crowdfunding platforms. The author believes that the presented issue will encourage researchers dealing with economics, finance and management to explore the area of equity crowdfunding as it is still an insufficiently researched phenomenon due to its innovative nature.

It is worth noting that the article doesn't exhaust the entire subject matter discussed in it. Main cause it the breadth and importance of the issues studied, due to the difficulties associated with empirical analysis how crowdfunding will develop in the post-pandemic world as well as the fact of constantly emerging new models of crowdfunding and new legal regulations in this area.

References

1. *Crowdfunding w świetle nowych regulacji unijnych. Co zmienia Rozporządzenie ECSP*. Retrived from: https://www.parp.gov.pl/component/content/article/66850:crowdfunding-w-swietle-nowychregulacji-unijnych-co-zmienia-rozporzadzenie-ecsp, 1.02.2022.
2. Cumming, D., Meoli, M., Vismara, S. (2021). Does equity crowdfunding democratize entrepreneurial finance? *Small Business Economics, Vol. 56*, DOI: 10.1007/s11187-019-00188-z.
3. Dziuba. D.T. (2012). Rozwój systemów crowdfundingu – modele, oczekiwania i uwarunkowania. *Problemy Zarządzania, vol. 10, no. 3(38),* DOI: 10.7172/1644-9584.38.6.
4. Glanc, J. (2020) Equity crowdfunding as a regulatory question. Zürich: Dike Verlag AG.
5. Lissowska, M. (2018). Crowdfunding – zjawisko, problemy, regulacja. *Gospodarka Narodowa, No. 1(293)*, DOI: 10.33119/GN/100568.
6. Malinowski, B.F. (2018). Crowdfunding udziałowy dla startupów i nie tylko. Retrived from: http://firma.um.warszawa.pl/wpcontent/uploads/2018/07/Crowdfunding_udzialowy_dla_start upow_i_nie_tylko_-_Bartosz_Filip_Malinowski.pdf, 10.02.2022.
7. Projekt ustawy o finansowaniu społecznościowym dla przedsięwzięć gospodarczych (Crowdfunding for Business Bill). Retrived from: https://legislacja.rcl.gov.pl/projekt/12346354 (Poland), 11.02.2022.
8. Regulation (EU) 2020/1503 of the European Parliament and of the Council of 7 October 2020 on European crowdfunding service providers for business, and amending Regulation (EU) 2017/1129 and Directive (EU) 2019/1937 (European Union).
9. Trzebiński, A. (2021). *Crowdfunding udziałowy 3.0*. Gdańsk: Związek Przedsiębiorstw Finansowych w Polsce.
10. Vulkan, N., Åstebro, T., Sierra, M. (2016). Equity crowdfunding: A new phenomena. *Journal of Business Venturing Insights, Vol. 5*, DOI: 10.1016/J.JBVI.2016.02.001.
11. Wilson, K.E., Testoni, M. (2014). Improving The Role of Equity Crowdfunding in Europe's Capital Markets. *Bruegel Policy Contribution*, https://dx.doi.org/10.2139/ssrn.2502280.
12. www.beesfund.com.
13. www.crowdconnect.pl.
14. www.crowdway.pl.

15. www.emisja.weszlo.com.
16. www.emiteo.pl.
17. www.kombinatkonopny.pl.
18. Ziobrowska, J. (2021). *Gospodarka współdzielenia a kształtowanie się współczesnych stosunków gospodarczych* (unpublished doctoral dissertations). Wrocław University of Economics.
19. Ziobrowska, J. (2021). Wpływ pandemii COVID-19 na gospodarkę współdzielenia w Polsce. In: W. Nowak, K. Szalonka (eds.), *Zdrowie i style życia: ekonomiczne, społeczne i zdrowotne skutki pandemii*. Wrocław University, DOI: 10.34616/142085.

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THE E-COMMERCE MARKET IN CONDITIONS OF UNCERTAINTY – DEVELOPMENT PERSPECTIVES. CASE STUDY

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Purpose: The aim of the article is to present the development perspective of the e-commerce market area and courier services, taking into account the time of uncertainty (the prospect of a pandemic), based on selected data from the Pointpack company and secondary data.
Design/methodology/approach: The topic includes an analysis (case study) based on the example of Pointpack and data that has been examined by experts, as well as secondary data, a report on the state of the e-commerce market in Poland.
Findings: The analysis showed a significant development of the e-commerce market and consumer activity despite the times of uncertainty (pandemic, war).
Research limitations/implications: The research has been limited to data obtained from a single source and limited resources (a selected segment of the market and consumers), hence future research can be extended to different levels and theoretical areas. It is important to conduct further research in this area to increase their universality. An interesting comparative study would be an analysis of consumer behavior in the perspective of sending and receiving parcels in selected regions of the country.
Practical implications: The described data and case study analyzes may indicate to organizations that the introduction of courier services to points of sale (or service) is today a necessity and a future in acquiring new customers.
Social implications: The development of the e-commerce market associated with sending and collecting parcels in stores contributes to the development of CSR attitudes of the organization by reducing carbon dioxide to the environment and building responsible customer attitudes.
Originality/value: Case study.

Keywords: e-commerce, management, business management, enterprise.

Introduction

Today, the Internet is an essential aspect of the daily lives of consumers around the world. With the development of technology, recipients can communicate efficiently, maintain interpersonal relationships and express their opinions more than ever before (Carvalho, Fernandes, 2018). Taking into account the needs and requirements of consumers, the rapid

growth and development of the e-commerce market was only a matter of time. E-commerce is the use of the Internet for marketing, identification, payment and delivery of goods and services. Through E-Commerce technology, the Internet has revolutionized the mode of business transactions by providing Producers, Whole sellers, Retailers and Consumers with the ability to Bank, Invest, Purchase, Distribute, Communicate, Explore, and Research from virtually anywhere, anytime where there is Internet access. Most importantly, it has created electronic markets and provided opportunities for businesses to reach out from the producers to the consumers in a very direct way. Also by virtue of the Technology and Logistics, it has enabled Producers, Wholesalers, Retailers and consumers' immediate access to these electronic markets. E-commerce is powered by the internet, where customers can access an online store to browse through, and place orders for products or services via their own devices (Anup, 1997). On the other hand, Brzozowska-Woś believes that e-commerce is primarily "(…) business ventures focusing on individual electronic transactions, for which networks are a place for the exchange of information, services and goods, including the company's relations with its market environment" (Brzozowska-Woś, 2014, p. 5). Thanks to the digital technologies used, e-commerce provides a direct connection of business partners, and also increases the attractiveness of the business environment and new opportunities for consumers (Hajli, 2014).

The development of sales platforms could not exist without globalization. The globalization of markets is related, on the one hand, to the phenomenon of popularization of tastes, preferences, lifestyles and decision-making criteria by buyers, and on the other hand - to open trade and business investments. Both of these factors contribute significantly to sales and product development on an international scale (Allaire, Firsirotu, 2000; Bolkunow, 2019; Dethine, 2020). However, it should be remembered that in the environment of each organization there are constant changes that affect its functioning to a greater or lesser extent. In this aspect, can talk about the uncertainty of the environment, which is defined as the relationship between the variables of complexity and the rate of changes in the elements of the environment (Hatch, 1997). Analyzing the concept of uncertainty, it is worth paying attention to the interesting phenomenon described in the world literature "Black Swans" (Taleb, 2005). Nassim Nicholas Taleb, the creator of this term, believes that "Black Swans" mean events and phenomena that are unpredictable, unreal. They don't seem to happen, but they do happen anyway. The opposite to this definition is the phenomenon of "White Swans", i.e. events that are understandable and orderly for the overall development strategy of the company. Unfortunately, companies are often unable to prepare for unpredictable events. The contemporary "Black Swan" was the COVID-19 pandemic (Kotnis, 2014).

Global pandemics have escalated significantly over the years, e.g. SARS in 2003, H5N1 in 2006 and H1N1 in 2009, each of which hampered economic activity and economic growth (Chung, 2015). Currently, researchers are observing the effects of the global COVID-19 and the war in Ukraine, which introduced a state of chaos, uncertainty in business and paralyzed many sectors of socio-economic life for a long time, stopping trade, tourism and closing borders

between countries (Soto-Acosta, 2020). Many scientists have long predicted that global pandemics could force entrepreneurs to take new business actions. The COVID-19 crisis has significantly accelerated the expansion of e-commerce towards new companies, customers of the sales offer (Hudecheck et al., 2020). It gave customers access to a significant variety of products, taking into account the convenience and security associated with contactless delivery of parcels. This solution has been introduced by the largest e-commerce providers Alibaba, Amazon and JD, using automated technologies such as self-driving cars, robots and drones to safely deliver "contactless" deliveries to customers (Lin, 2020). Many companies have moved their activities to the Internet, selling on sales platforms, e.g. Marketplace (Facebook), OLX, Allegro, Vinted and others. It should be noted that the economic, social and geopolitical situation affects the moods and habits of consumers. Brands, both local and global, in the face of the challenges of war had to change their plans and existing schemes of marketing activities. Since the pandemic, can see that consumers' expectations towards business have increased - brands are expected to take a specific position, active social assistance and solidarity, especially with the Ukrainian society. Research shows that the COVID-19 crisis has led people in many OECD countries to significantly reduce their physical interactions. For example, in the United States, retail and food service sales fell by 7.7% in February-April 2020 compared to the same period in 2019. However, sales in grocery stores and non-store retailers (mainly e-service providers) increased by 16% and 14.8%, respectively. In the EU, retail sales via mail order houses or online in April 2020 increased by 30% compared to April 2019, while overall retail sales decreased by 17.9%. The resulting shifts from traditional retail to e-commerce are likely to be significant across countries (OECD, 2020).

Due to the growing number of customers in Poland who have become active participants in the e-commerce market, the study of their behavior and habits has become an important area of consideration not only for academics, but also for many business organizations. Knowledge about buyers is extremely important for the company's operations and affects the building of sales strategies (Karczewska, 2010). Customer preferences are constantly changing, which is why it seems advisable to study and analyze customer behavior related to sending and receiving shopping shipments, which are presented in the methodological part of the article.

E-commerce: development perspectives

Decision making in enterprises under conditions of uncertainty is much more difficult and requires different actions in risky situations and conditions (Tyszka, 2010). It should be noted that uncertainty increases primarily with the volatility and speed of events, which are difficult to predict and at the same time control from the management of the organization. The geopolitical crisis (today the war in Ukraine, previously the pandemic) has also contributed

to the formation of a new type of customer, who is characterized by greater uncertainty of tomorrow, purchasing/financial restrictions and increased price sensitivity, as well as environmental (awareness of nature protection, care of the environment). Contemporary literature defines the importance of e-commerce platforms that facilitate virtual interactions and provide informative and insightful product information (Chandna, Salimath, 2018; Li et al., 2020) that consumers can recognize as economic benefits (Zhang et al., 2017). Customers use e-commerce platforms to interact and buy products from retailers, while retailers can provide consumers with various online shopping opportunities, maintain relationships and support (Wagner et al., 2020). The most common and popular transaction models are presented in Table 1.

Table 1.
The most popular types of e-commerce

TYPE	DESCRIPTION
B2B	**Business to business** Businesses sell products/serivces to other businesses
B2C	**Business to consumer** Businesses sell products/services to non-business customers (online retail store)
C2C	**Consumer to consumer** Consumers sell to other consumers (e.g. marketplaces)
C2B	**Consumer to business** Consumers sell to businesses (e.g. influencer marketing services)

Source: Own analysis based on *Techtarget* Wesley Chai, Brian Holak.

Depending on the type of goods and services, the appropriate channel should be selected. The e-commerce market is very wide and is directly related to both the end customer and the business customer (partner). An important part of the e-commerce market is the Marketplace. This is a site where many online retailers offer to sell their products. Marketplace allows you to search for products and their purchases directly in one place (website). Sellers using marketplace platforms can more easily observe their customers' traffic on the site, thanks to which they can better adapt the way they sell online (e.g. Allegro, OLX, Alibaba, AliExpress, eBay, Erli, Etsy, Vinted or social media: Facebook marketplace). Depending on the products, there are two types of marketplace platforms: vertical and horizontal. On vertical platforms, sellers offer a wide range of products, while on the vertical market it is important to focus on selected, often specialized products (Jiang Jui-Chin, Chun-An, Chih-Chien, 2008).

The rapid development of the e-commerce market is also associated with the constant transfer of the sale of goods and services from a stationary position to the online space (marketplace). The Polish e-commerce market is currently experiencing a boom. In 2021, 87% of Poles shopped online compared to 68% in 2020 (*Research Gre Scale Study - 4th wave*, 2021).

Researchers of the e-commerce and related markets predict that by 2027 the share of sales platforms in the entire market area will increase (Fig. 1.)

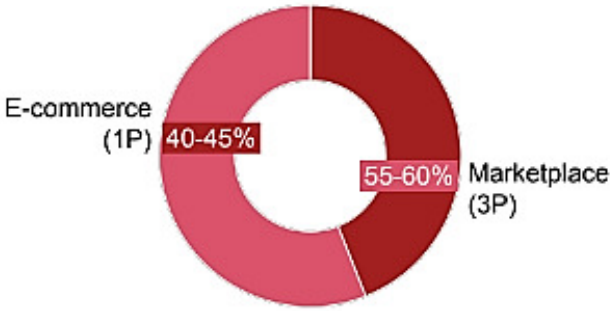

Figure 1. Share of the platform model in online sales in 2027.

Source: Strategy&, report *Prospects for the development of the e-commerce market in Poland 2018-2027*

It is worth mentioning that despite the development trend in the area of sales platforms, not all new proposals are popular among Polish consumers. A good example is the foreign Shopee platform, the potential of which was not sufficient to compete with the domestic Allegro brand (Dąbrowska-Cydzik, 2023).

Methods and Results[1]

As already mentioned in the earlier parts of the article, research on selected consumer behavior and trends in the e-commerce market comes from Pointpack's own sources. The Pointpack company is closely related to the e-commerce market, which undoubtedly grows along with the development of this sector. The company is one of the most important technological partners in the country, building IT solutions and maintenance services for the commercial and courier industries in the area of infrastructure of the first and last mile of city logistics. The company focuses on building synergies and scale resulting from the integration of many partners by creating a business space for coopetition in traditional and online trade, logistics and on-demand services. As an integrator, it enables sending and receiving shipments at points (PUDO)[2] and courier machines (APM) through technological cooperation of retail chains, courier companies and payment partners (e.g. PEP). In addition, Pointpack enables partners to create new and additional services, increase profits and attract new customers, strengthening the position of their brands in the market. The company also supports the development of a network of shared courier machines (APM). Currently, Pointpack cooperates with over 17 000 points throughout Poland (including the largest retail chains), the largest couriers (Poczta-Polska, DHL, DHL Express, DPD, FedEx, Orlen Paczka, GLS). Since the

[1] The material presented in this section comes from the company's own research.

[2] PUDO point (Pick Up and Drop Off point) - collection of the parcel outside the place of residence (e.g. chain of stores).

beginning of its operations (2011), the company has handled over 48 million shipments. Each month, on average, it handles about 2.5 million shipments throughout Poland (Pointpack, 2023).

In order to present the development of the e-commerce market, this article adopts the case study research method based on selected data from the Pointpack company. Some researchers postulate the importance of increasing the share of qualitative methods in research on management sciences (Sławińska, Witczak, 2012, p. 108; Czakon, 2006, p. 9; Czakon, 2009, p. 13). The subject of the case study method may be the process implemented by the enterprise (Dyer, Nobeoka, 2000, pp. 345-367). The process adopted by Pointpack is the integration of retail chains and courier companies, which ensures sending and receiving courier parcels in selected stores during everyday shopping. In this case, it is important to ask research questions about how quickly the company has developed in recent years (Q1) and how consumer behavior regarding sending and receiving parcels has changed (Q2).

The data analysis comes from the enterprise production base[3]. The data was extracted with an SQL script and analyzed in Excel. To study the behavior of consumers related to sending and receiving parcels, data from the first six months of active PUDO points were compared.

Active points (from January to June)[4]:

- 2020 - 6735 PUDO points,
- 2021 - 9768 PUDO points,
- 2022 - 16015 PUDO points.

In order to determine information on trends related to the collection of parcels by consumers (the time of the day) and distance from PUDO points, the focus was on 2022.

Active points in 2022[5]:

- 2022 – 16457 PUDO points.

The results of the database analysis are presented in the infographic (see Fig. 2).

[3] The limitation in the analysis is the number of PUDO points and a selected part of consumers who use the courier service.

[4] It should be added that the exact number of active PUDO points is approximate due to the dynamics, volatility of the market and cooperation with partners.

[5] It should be added that the exact number of active PUDO points is approximate due to the dynamics, volatility of the market and cooperation with partners.

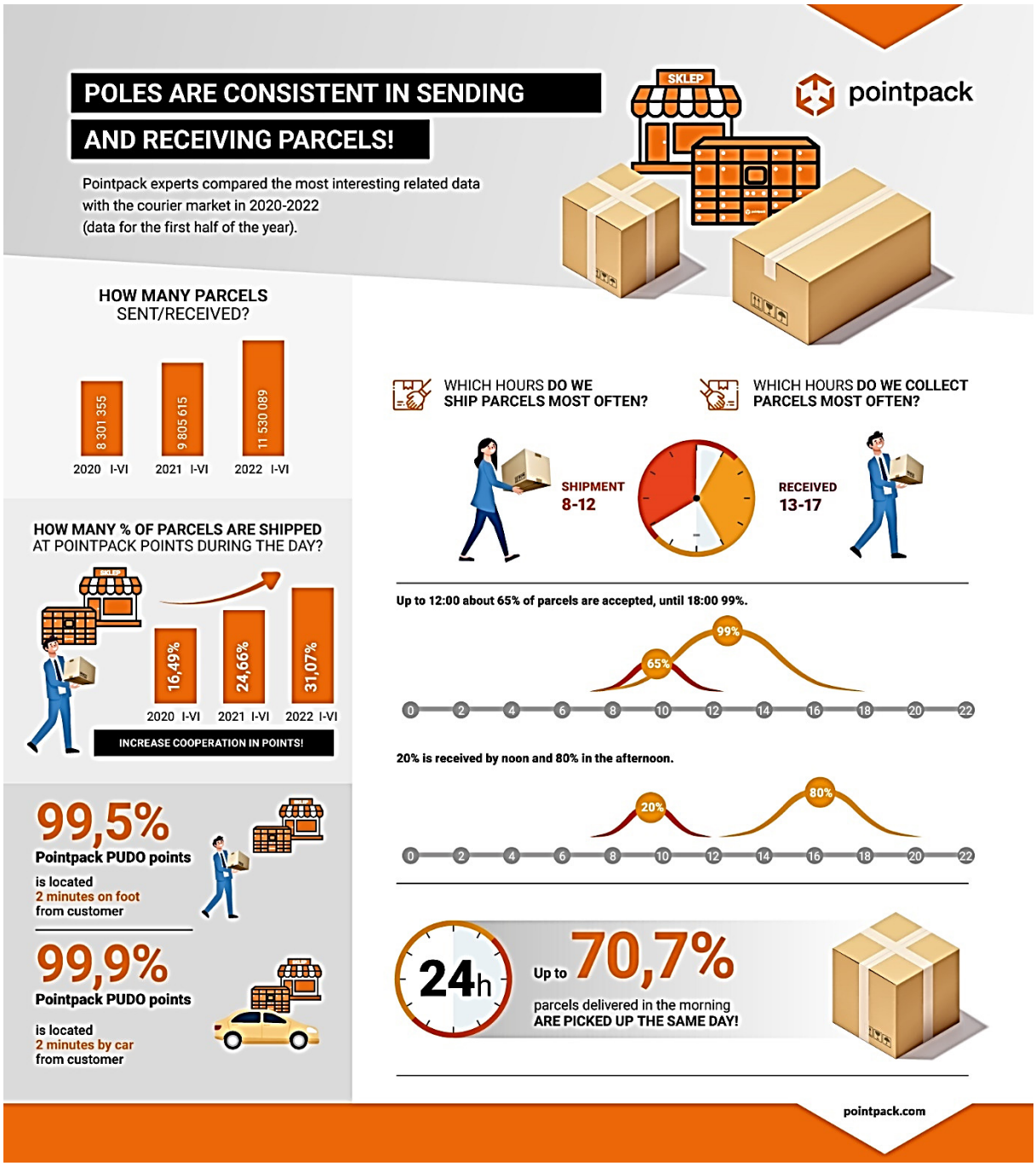

Figure 2. Consumer behavior: sending and receiving parcels.

Source: Pointpack own analyzes (internal data).

Based on the analysis of selected data (January to June in 2020, 2021, 2022), it can be observed that the number of parcels sent and received in stores is increasing. The value of the Polish postal services market is also confirmed by the report of the Office of Electronic Communications. According to it, in 2021 the value of the Polish postal services market reached approx. PLN 12.89 billion compared to PLN 11.6 billion in 2020. The volume of postal items also increased (*Report on the state of the postal market in 2021*, 2022). Almost all Pointpack PUDO points in 2022 were 2 minutes away from the customer, which confirms that the development process of the courier market is determined by the needs of individual recipients

(proximity and convenience). These results also show that Pointpack is consistently expanding its offer with new collection points, which customers can use for everyday shopping. It is also important from the perspective of a retail chain partner - with the increase in sending or receiving parcels, co-buying increases, which has a significant impact on the store's profit[6].

Internal analysis also shows that most parcels are collected by customers on the same day after delivery to the point (70.7%), which is also the result of the increase in electronic sales, as in the previously cited „Research Gre Scale Study – 4th wave". Due to the fact that Pointpack is the only company of this type in Poland that integrates retail chains and courier companies on such a large scale, the obtained data cannot be compared with other similar companies. Therefore, information on the behavior of consumers sending or collecting parcels at PUDO points at selected times of the day constitute internal analyzes of the company and may indicate a certain trend related to the collection of parcels during the hours of returning from work and doing shopping in stores on the occasion.

Summarizing the presented Pointpack data and market data, it should be noted that the growth trend of the company's development in recent years by entering into cooperation with new partners is related to the development of the e-commerce market (Q1). The dynamic development of the e-commerce sector has become one of the key purchasing channels for consumers and determines the growth of demand for this type of services. As experts from the „Polish CEP Report 2022" emphasize, the market for courier, express and postal items (CEP) in Poland has been recording uninterrupted, double-digit growth for several years, and its value has already exceeded PLN 17 billion. According to forecasts, in the years 2021-2023 it will maintain a double-digit growth rate both in terms of quantity (14.1%) and value (19.9%) (Last Mile Experts, 7R and the Cushman & Wakefield consulting agency, 2022). In the perspective of the presented data, the attitudes of consumers have changed significantly (Q2), because more courier parcels are sent and collected at PUDO points (despite the time of the pandemic), while doing shopping. Analyzes also show that e-consumers are increasingly adopting pro-ecological attitudes. The behavior and needs of consumers are also part of the ecological trend, because the deliveries of parcels to points or courier machines are part of the pro-ecological solutions (Dataplace, 2021), presented in more detail in the last part of the article.

[6] Pointpack analyzes indicate about 30% of co-buying when sending and receiving parcels at PUDO points.

Discussion and Conclusion

According to the information from the scientific reports and opinions of specialists, as well as Pointpack's own analysis, in 2020-2022 there was a high growth rate of the e-commerce market. Today, it can be observed that the current rate of growth is no longer so rapid. After the pandemic, consumers started buying offline on a regular basis, and the current social problems (inflation) may discourage them from spending more money. However, according to the researchers in the report „Prospects for the development of the e-commerce market in Poland 2018-2027", the declining economic situation on the Polish e-commerce market in 2022-2023 may be stimulated primarily by two factors:

- an influx of 2 million refugees from Ukraine, who can buy online on the Polish e-commerce market,
- a decrease in the purchasing power of money, which will make the Internet a source of lower prices for consumers (Strategy…, 2022).

Taking into account the data analysis, it should be noted that the e-commerce market is the sector of the economy that is in a development trend. The information obtained from the analysis of scientific sources and the Pointpack case study are both important for the development of science and useful in the societal perspective:

1. Key implications for science:
   - thanks to the analysis of Pointpack data, it is possible to supplement the knowledge on the development of the courier, express and parcel (CEP) market, which contributes to the development of the e-commerce sector.
   - due to the fact that Pointpack is the only enterprise of this type in Poland that integrates courier companies and retail chains on such a large scale, the obtained results cannot be compared with similar results, and they cannot be related to the general public. However, due to the state of knowledge of various experts on the development of the e-commerce market presented in the article, as well as the Pointpack data, it can be concluded that the development of the e-commerce market (despite times of uncertainty) is accelerating from year to year, which is also due to the change in consumers and their needs. Further research and analysis are needed in this area, which can provide more information on the customers' purchasing motivations and the development trends of the entire e-commerce sector.
2. Key implications for the economy:
   - the presented data, as well as the opinions of specialists and researchers, indicate that the CEP market stimulates the growth of the e-commerce industry, and the implementation of the courier service at PUDO points is important for customers who use the option of sending and receiving parcels while shopping.

- PUDO points that implement courier services provide additional benefits for customers, and thus increase the prestige of the place and are competitive on the market, because the e-commerce industry is constantly developing.
- the implementation of the courier service provides three-way benefits: the customer can send or collect the parcel while shopping (co-buying is increasing), the owner of the point earns a commission for each parcel handled and the courier reduces the number of kilometers traveled (there is no need to deliver parcels to individual locations).
- the development of courier services at PUDO points is conducive to building pro-ecological attitudes among customers as well as business partners (corporate social responsibility).

The preferences of Polish consumers related to the delivery of parcels are also presented in the Gemius report. According to the analysis, offering various forms of delivery is motivating to shop online. Although the development network of PUDO points is constantly developing, only 17% of consumers indicated that the order was shipped to a partner point. Poles invariably prefer delivery to courier machines, which was indicated by 81% of respondents, and 43% choose delivery by courier to their home or workplace (Gemius, 2022).

When analyzing customer behavior and the direction of development of the e-commerce market, it is impossible to ignore the ecological aspects, which are increasingly important in the socio-economic space. Pointpack analytical data indicate that in such a model the achievable level of CO2 emission reduction is even 30% in the last mile. For every million parcels, the length of the courier's route will be reduced by 82,000 km and the carbon footprint of each million shipments will be reduced by 13 tons of CO2[7]. Environmental awareness among Poles is also indicated by research. According to the Center for Public Opinion Research, the majority of Poles (as many as 81%) believe that their own behavior and lifestyle have a significant impact on the condition of the natural environment. The ecological awareness of consumers is gradually growing and covers more areas of everyday life (CBOS, 2020).

In addition to the ecological area, other trends on the e-commerce market that are constantly developing can be identified, important from the customer's point of view:

1. M-COMMERCE

Mobile commerce is becoming an integral part of shopping. It is one of the most important shopping channels chosen by customers. mainstream as the preferred shopping channel. Technological solutions make shopping easier, and the popularization of shopping using mobile devices will encourage e-shop owners to build solutions that will provide customers with immediate and personalized shopping.

[7] Pointpack own analyzes (internal data).

2. Q-COMMERCE

Consumers value the delivery of both parcels and purchases within a specified, fast time. The q-commerce trend assumes the delivery of e-shopping within several minutes after placing the order. So far, this solution has only worked in the e-grocery industry. However, in recent months it has also been seen that popular convenience stores or large grocery chains are expanding their online shopping offer with the q-commerce option. Retail chains often face the challenge of this trend, which also requires the involvement of mini-warehouses (dark stores) to speed up and streamline the sales process.

3. SOCIAL COMMERCE

This is one of the trends that also supports the development of other channels, such as social media. In social media, such as Facebook, Instagram or TikTok, sellers can also directly contact the customer through live commerce, and thus build real-time purchasing relationships (direct to consumer).

4. OMNICHANNEL

Omnichannel is a sales strategy that assumes that all available channels, as well as customer service, should work together to ensure the convenience of shopping in a commercial network and speed up the purchasing process. This strategy combines the experience of stationary, online sales and customer service (call center) to provide customers with convenience and the ability to choose a preferential shopping path (Chen, 2021; Bartosik-Purgat, 2019; Sala, Królewski, 2014).

The e-commerce market is changing along with changes in customer behavior, who are now entering the "post-pandemic customer" phase. This new type of consumer is primarily related to the need for new communication and strategic solutions. Enterprises and organizations, especially in times of uncertainty, should carefully observe the client and listen to his needs. In the area of the e-commerce market, accessibility, operational efficiency as well as rapid growth and profit (both on the part of the customer and the seller) are becoming more and more important. Offered products or services should be culturally up-to-date, adapted to new times and needs. As the analyzes have shown, the development of the e-commerce market is constantly growing, which is why it is necessary to conduct further research in this area, which will provide new knowledge about consumer behavior and directions of development of the socio-economic space, with particular emphasis on the development of enterprises through the implementation of new services.

References

1. Allaire, Y., Firsirotu, M. (2000). *Myślenie strategiczne.* Warszawa, pp. 238-242.
2. Anup, K.G. (1997). Securing E-commerce: A Systemic Approach. *Journal of Internet Banking and Commerce*, *2(4),* pp. 7-15.
3. Bartosik-Purgat, M. (2019). *New Media in the Marketing Communication of Enterprises in the International Market*, pp. 27-31, 90-101.
4. Bołkunow, W. (2019). Internationalization of European Small and Medium-Sized Companies. In: M. Bilgin, H. Danis, E. Demir, U. Can (Eds.), *Eurasian Business Perspectives; Eurasian Studies in Business and Economics, Vol. 10/2* (pp. 39-51). Cham, Switzerland: Springer.
5. Brzozowska-Woś, M. (2014). Kierunki rozwoju handlu elektronicznego. *Przedsiębiorstwo we Współczesnej Gospodarce – Teoria i Praktyka*, *1*, p. 5.
6. Carvalho, A., Fernandes, T. (2018). *Understanding customer brand engagement with virtual social communities: a comprehensive model of drivers, outcomes and moderator*, https://doi.org/10.1080/10696679.2017.138924, 15.12.2021.
7. CBOS (2020). *Świadomość ekologiczna Polaków*, 20.11.2021.
8. Chai, W., Holak, B. (2022). *Techtarget*, https://www.techtarget.com/searchcio/definition/e-commerce, 11.11.2022.
9. Chandna, M.S., Salimath (2018). Peer-to-peer selling in online platforms: a salient business model for virtual entrepreneurship. *J. Bus. Res*., *84*, pp. 162-174.
10. Chen, J. (2021). *4 Ecommerce trends you need to know for 2022*, https://sproutsocial.com/insights/ecommerce-trends, 30.12.2021.
11. Chung, L.H. (2015). Impact of pandemic control over airport economics: reconciling public health with airport business through a streamlined approach in pandemic control. *J. Air Transport. Manag.*, *44-45*, pp. 42-53.
12. Czakon, W. (2006). Łabędzie Poppera – case studies w badaniach nauk o zarządzaniu. *Przegląd Organizacji, 9,* pp. 9-12.
13. Czakon, W. (2009). Mity o badaniach jakościowych w naukach o zarządzaniu. *Przegląd Organizacji*, *9*, pp. 13-17.
14. Dąbrowska-Cydzik, J. (2023). *Dlaczego Shoppee nie poradziło sobie w Polsce?*, https://www.wirtualnemedia.pl/artykul/koniec-shopee-polska-dlaczego-gdzie-kupowac-w-internecie-zyskuje-allegro, 20.01.2023.
15. Dataplace: *Parcel collection points in Poland in 2021 - a new reality of the world of deliveries*, 7.06.2022.
16. Dethine, B., Enjolras, M., Monticolo, D. (2020). Digitalization and SMEs' Export Management: Impacts on resources and capabilities. *Technol. Innov. Manag. Rev., 10*, pp. 18-34.

17. Dyer, J., Nobeoka, K. (2000). Creating and Managing a High Perfomance Knowledge-Sharing Network: The Toyota Case. *Strategic Management Journal*, *21*.
18. Dziegieć, J. (2014). E-commerce. In: J. Królewski, P. Sala (eds.), *E-marketing. Współczesne trendy. Pakiet startowy,* pp. 231-244.
19. Fisher, B. (2021). *Pandemic Fuels Strong D2C Growth in Western Europe*, https://www.emarketer.com/content/pandemic-fuels-strong-d2c-growth-western-europe, 10.05.2022.
20. Gemius (2022). *E-commerce w Polsce 2022*. Gemius dla e-Commerce Polska. Warszawa: Gemius Polska, Izba Gospodarki Elektronicznej.
21. Hajli, M.N. (2014). A study of the impact of social media on consumers. *J. Mark. Res.*, *56*, pp. 387-404.
22. Hatch, J.M. (1997). *Organisation Theory, Modern, Symbolic and Postmodern*. Oxford: Oxford University Press.
23. Hudecheck, M., Sirén, C., Grichnik, D., Wincent, J. (2020). How Companies Can Respond to the Coronavirus. *MIT Sloan Management Review*, *9*.
24. Jui-Chin, J., Chun-An Ch., Chih-Chien, W. (2008). *Knowledge and Trust in E-consumers' Online Shopping Behavior.*
25. Karczewska, M. (2010). Determinanty zachowań konsumentów na rynku. *Materiały V Krakowskiej Konferencji Młodych Uczonych, „Sympozja i Konferencje KKMU*, *5*, Kraków.
26. Kotnis, M. (2014). Modele zarządzania ryzykiem w warunkach niepewności. *Zeszyty Naukowe Uniwersytetu Szczecińskiego, 65*, pp. 669-678.
27. Last Mile Experts, 7R and the Cushman & Wakefield consulting agency: *Polish CEP Report 2022,* 20.11.2022.
28. Li, X., Zhao, W., Xu, W. Pu. (2020). Measuring ease of use of mobile applications in e-commerce retailing from the perspective of consumer online shopping behaviour patterns. *J. Retailing Consum. Serv*., *55*, *Article 102093*.
29. Lin, C.Y. (2020). In the face of lockdown, China's e-commerce giants deliver. *Harvard Business Review*.
30. Lutkevich, B., Chai, W., Holak, B. (2022). *E-commerce*, https://www.techtarget.com/searchcio/definition/e-commerce, 1.08.2022.
31. OECD: *COVID-19 and the retail sector: impact and policy responses, OECD Policy Responses to Coronavirus (COVID-19)*, 10.09.2021.
32. Pointpack, http://www.pointpack.com/pl, 20.12.2022.
33. *Report on the state of the postal market in 2021*, 11.10.2022.
34. *Research Gre Scale Study - 4th wave*, 2.09.2022.
35. Sławińska, M., Witczak, H. (2012). *Podstawy metodologiczne prac doktorskich w naukach ekonomicznych.* Warszawa.

36. Soto-Acosta, P. (2020). COVID-19 Pandemic: Shifting Digital Transformation to a High-Speed Gear. *Inf. Syst. Manag.*, *37*, pp. 260-266.
37. Strategy& (2022). *Prospects for the development of the e-commerce market in Poland 2018-2027*, 5.09.2022.
38. Taleb, N. (2005). Fooled by Randomness: *The Hidden Role of Chance in Life and in the Markets.* New York: Random House and Penguin.
39. Tyszka, T. (2010). *Decyzje. Perspektywa psychologiczna i ekonomiczna*, Warszawa: Scholar.
40. Wagner, G., Schramm-Klein, H., Steinmann, S. (2020). Online retailing across e-channels and e-channel touchpoints: empirical studies of consumer behavior in the multichannel e-commerce environment. *J. Bus. Res*., *107*, pp. 256-270.
41. Zhang, T., Li, G., Cheng, K., Lai, K. (2017). Welfare economics of review information: implications for the online selling platform owner. *Int. J. Prod. Econ*., *184*, pp. 69-79.

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