

**POLITECHNIKA ŚLĄSKA**

SILESIAAN UNIVERSITY OF TECHNOLOGY

**ZESZYTY NAUKOWE**

SCIENTIFIC PAPERS

**ORGANIZACJA I ZARZĄDZANIE**  
**Zeszyt Naukowy nr 198**

ORGANIZATION AND MANAGEMENT  
Scientific Paper no. 198

**Współczesne zarządzanie**

Contemporary management

**Pod redakcją**  
**Radosława WOLNIAKA**

Edited by  
Radosław WOLNIAK

GLIWICE 2024

*Kolegium redakcyjne*

REDAKTOR NACZELNY – Dr hab. inż. Barbara KULESZ, prof. PŚ  
REDAKTOR DZIAŁU – Prof. dr hab. inż. Radosław WOLNIAK

**Wydano za zgodą  
Rektora Politechniki Śląskiej**

**ISSN 1641-3466  
ISSN 2720-751X**

© Copyright by  
Wydawnictwo Politechniki Śląskiej  
Gliwice 2024

**WYDAWNICTWO POLITECHNIKI ŚLĄSKIEJ  
ul. Akademicka 5, 44-100 Gliwice  
tel. (32) 237-13-81, faks (32) 237-15-02  
[www.wydawnictwopolitechniki.pl](http://www.wydawnictwopolitechniki.pl)**

**Sprzedaż i Marketing  
tel. (32) 237-18-48  
[wydawnictwo\\_mark@polsl.pl](mailto:wydawnictwo_mark@polsl.pl)**

## CONTENTS

<b>Foreword</b> .....	7
1. <b>Kinga BEDNARZEWSKA</b> – Business model of a patented invention developed at a university on the example of the “WAXO” beeswax quality analyzer .....	9
2. <b>Maria BERNAT, Leszek KARCZEWSKI, Martin MACHACEK</b> – Economic changes in Poland and China – culture as a leading indicator .....	27
3. <b>Artur BŁASZCZYK, Milena LE VIET-BŁASZCZYK</b> – The role of social media marketing of ESG in warehouse logistics .....	49
4. <b>Natalia BRYCHT</b> – Assessment of the usefulness of the implementation of the Kaizen method in the construction industry .....	67
5. <b>Mateusz BYCZYK</b> – Changes in teamwork and new leadership characteristics, triggered by the work form changes .....	81
6. <b>Anna CZARNY</b> – Inventory management in industrial processing enterprises in the context of crisis conditions .....	97
7. <b>Magdalena GORZELANY-DZIADKOWIEC, Krzysztof MACHACZKA</b> – Identifying elements that code the organization's genome with the spider web model to determine business development potential .....	123
8. <b>Marta GRZYB</b> – Determinants influencing the image of banks in the Polish banking system among Generation Z members .....	145
9. <b>Michał IGIELSKI</b> – Changes in companies' personnel policies – towards optimising the management of key employees (case study) .....	165
10. <b>Karolina JÓZEFOWICZ</b> – From competitiveness of enterprises to competitiveness of cities – a theoretical review .....	181
11. <b>Maria KOCOT, Małgorzata GOLIŃSKA-PIESZYŃSKA, Artur KWASEK</b> – Attributes of an agile organization leader in the light of own research .....	197
12. <b>Maria KOCOT, Damian KOCOT, Janusz SOBOŃ, Artur KWASEK</b> – Agile behaviors of enterprises in the aspect of ecological use of IT equipment .....	213
13. <b>Beata KOTOWSKA, Marta SIKORSKA</b> – Accounting profession transformation as perceived by students – results of a pilot study .....	231
14. <b>Krzysztof KRZYWDZIŃSKI</b> – State-owned enterprises in Poland – annual aggregated report – proposal .....	253
15. <b>Wojciech LEOŃSKI</b> – The role of social lending in financing enterprises .....	279
16. <b>Anna MANOWSKA, Martin BOROŠ, Anna BLUSZCZ, Katarzyna TOBÓR-OSADNIK</b> – The use of the command line interface in the verification and management of the security of IT systems and the analysis of the potential of integrating biometric data in cryptographic mechanisms .....	289
17. <b>Mateusz MIERZEJEWSKI, Mikołaj PRAŻMOWSKI</b> – Impact of global crisis on REER fluctuations – pre-inflation-pandemic assessment .....	309

18. <b>Rafał NAGAJ, Bożena GAJDZIK</b> – Energy and climate policy as a determinant of fuel poverty in Poland .....	327
19. <b>Kamil NAWROCKI, Alfred BŁASZCZYK, Alina MATUSZAK-FLEJSZMAN</b> – Impact of photovoltaics development on electricity grids – possible scenarios on the example of Poland and Germany .....	349
20. <b>Justyna OSTROWSKA, Marta SZYBA</b> – Increasing the level of municipal waste recycling in Poland, on the example of the Krakow metropolis .....	375
21. <b>Maria PILARCZYK, Robert ULEWICZ</b> – Evaluating risk in the operation of agricultural machinery based on farm size .....	393
22. <b>Anna PLATTA, Anna MIKULEC, Monika RADZYMIŃSKA</b> – Lifestyle as determinant of edible insect food consumption among selected members of Generation Z .....	409
23. <b>Iwo PODLOCH, Jakub KOCJAN, Krzysztof NOWACKI</b> – Analysis of lean manufacturing knowledge correlation models for India and the USA .....	427
24. <b>Małgorzata RATAJ, Iryna BEREZOVSKA</b> – Teaching quality assessed before, during and after Covid-19 .....	441
25. <b>Izabela RÓŻAŃSKA-BIŃCZYK, Piotr KĘDZIA, Anna MASZOREK-SZYMALA</b> – Activities supporting increased physical activity of employees as an element of building a sustainable organization – a case study .....	453
26. <b>Grzegorz SITEK</b> – Application of the ECM algorithm to the estimation of the likelihood function in financial auditing .....	475
27. <b>Ida SKUBIS, Jolanta BIJAŃSKA</b> – The role and competencies of managers in contemporary process-project organizations .....	489
28. <b>Jerzy STADNICKI, Olga NAGAITSEVA</b> – Substantiation of the optimal location of goods production using 3D printing technologies: a system approach .....	511
29. <b>Katarzyna SUKIENNIK, Michał DZIADKIEWICZ</b> – Managing environmental social responsibility in cities according to the young generation .....	527
30. <b>Anna SZOŁKIEWICZ, Małgorzata KOWALSKA</b> – Recommendations for minimising employee absences based on the analysis of absenteeism in a given enterprise .....	543
31. <b>Małgorzata TERLECKA-MACIEJEWSKA</b> – Cybersecurity in Polish security system .....	559
32. <b>Ireneusz TOMECKI</b> – Post-cloud solutions in the high-definition diagnostics of solar farms .....	569
33. <b>Anna UKLAŃSKA</b> – Integration of RPA into process management in a large retail network organization .....	581
34. <b>Piotr WERYŃSKI, Dorota DOLIŃSKA-WERYŃSKA</b> – Conditions of cultural cycle of continuation and organisational change on the example of NGOs .....	595
35. <b>Radosław WOLNIAK</b> – Cybersecurity analytics: leveraging business analytics in Industry 4.0 settings .....	619
36. <b>Radosław WOLNIAK</b> – The usage of Taguchi methods in Industry 4.0 conditions .....	637

37. <b>Marzena WÓJCIK-AUGUSTYNIAK, Marek SZAJCZYK, Mariusz CIELEMEŃCKI, Stanisław SZAREK</b> – Moving Towards Better Digital Accessibility – Current Status And Challenges .....	655
38. <b>Alina YAKYMCHUK, Małgorzata BZOWSKA-BAKALARZ, Oksana BALANDA, Justyna JUPOWICZ-KOZAK</b> – Economic basis of production of agricultural crops in Ukraine in the context of management and climate change .....	679
39. <b>Aleksandra ZYGMUNT</b> – Firms’ innovation activities as an adaptive attribute of firms’ resilience to economic shocks: evidence from Polish NUTS-2 regions .....	697



## **FOREWORD**

Presented number of Silesian University of Technology. Scientific Papers. Organization and Management Series. Contemporary management. Presented papers contain result of researches conducted by various universities. The number consists of 38 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, cultural aspects of management, logistics, leadership, production management, finances, human resources management, Smart Cities, environmental management, information management, risk management, lean manufacturing, the impact of COVID-19 pandemic on management, sustainability, project management, security management, process management, Industry 4.0, quality management, business analytics, economics and innovation management.

*Radosław Wolniak*





## **BUSINESS MODEL OF A PATENTED INVENTION DEVELOPED AT A UNIVERSITY ON THE EXAMPLE OF THE “WAXO” BEESWAX QUALITY ANALYZER**

Kinga BEDNARZEWSKA

Maria Curie-Skłodowska University; kinga.bednarzewska@mail.umcs.pl, ORCID: 0000-0002-5786-928X

**Purpose:** The research purpose is to diagnose the market for beeswax quality analyses in Poland and to develop assumptions for the business model for the commercialization of the WAXO beeswax quality analyzer.

**Design/methodology/approach:** The market analysis was conducted using Computer Assisted Self Interviewing (CASI). The study was conducted among randomly selected 124 respondents in beekeeping throughout the country. Most answered questions on behalf of beekeeping groups or associations, indicating how many members they had. Based on these data, it was determined that the interview results were representative of 2226 respondents. Assumptions for the business model were developed using the Business Model Canvas methodology about: customer segmentation, value proposition, channels, customer relationships, revenue structure, key activities, key resources, key partners, cost structure.

**Findings:** A business model was developed based on which the commercialization of the WAXO device should be carried out.

**Practical implications:** The conducted research allowed for the formulation of conclusions along with the presentation of operational initiatives necessary to introduce the device to the market and further commercialize it.

**Social implications:** The invention of a beeswax quality analyzer protects bee colonies and the natural environment by changing the awareness of the beekeeping community and taking steps to change the applicable legislation. The presented recommendations support the university authorities in making decisions regarding the commercialization strategy of WAXO and the selection of operational solutions necessary to introduce it to the market, production, sales, and customer service.

**Originality/value:** The subject of the invention is a portable electromechanical device allowing the analysis of beeswax for the presence of added impurities.

**Keywords:** commercialization, WAXO, analyzer, beeswax, business model, market diagnosis.

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

## Introduction

Bees are a particular link in the chain linking natural resources with human health and life. With the growing impact of human activity on nature, the level of contamination of natural bee products (honey, wax, wax combs) is increasing (Suyal, Pandey, 2024) which adversely affects the quality of food, cosmetic, and beekeeping products obtained from them, such as food honey, propolis, honey, cosmetics, dietary supplements (Pędziwiatr, Zawadzki, 2017).

Nectar and pollen are deposited in the hive in wax cells produced by bees. The bees' heads beat the pollen and the nectar evaporates from the water. It is closed with wax from above when it obtains the right consistency. For the beekeeper to collect ripe honey from the bees, he uncaps the wax layer with appropriate tools. Bees obtain honey and pollen from flowers and tree leaves while they produce wax themselves.

Beeswax is a mixture of fatty acid esters and long-chain alcohols, free fatty acids, alkanes, free fatty alcohols, and other substances. A review of the literature indicates that the physical properties of alkane samples (e.g., alkanes present in beeswax), in particular their ability to trap electrons, strongly depend on external factors present at the time of sample creation, such as additional substances (including impurities), the type of substrate and crystallization rate (Dekebo, Jung, 2023). These factors modify the number and energy of electron traps, which reflect changes in the structure of the resulting crystals, which can be observed by analyzing them using spectroscopic methods (Pietrow, Gagoś, Kamiński, 2013). The research described in the literature enabled the observation of phase transformations as a function of time and temperature, and thanks to the electron trapping phenomenon, they allowed the observation of local changes in the nanostructure of the samples. Impurities were visible in the obtained spectra (Pietrow et al., 2015).

Wax is used in the cosmetics industry as an additive to some products (Goik, U., Goik, T., Załęska, 2016). It is used to a broader extent in the chemical industry and in furniture production technology: waxing, surface polishing (Wilde et al., 2002), and also as an edible coating for fruits and vegetables (Kozłowicz et al., 2011). Wax is also used to make candles (Mruk, 2019). Beeswax is also used to produce wax foundation, the primary product used in beekeeping. It accelerates the rebuilding of honeycombs by bees. Thanks to it, the honeycomb is more stable and even, and honey extraction is more straightforward. Using wax foundation indirectly increases the honey yield in apiaries (Lyson, 2024). Using wax foundation (Mitsutake et al., 2021) is time-consuming and relatively expensive, which gave rise to the introduction of plastic wax foundation in Poland, but it was not accepted on the market (Bratkowski et al., 2008).

Because bees use their products as building and nutritional resources, their contamination affects the condition of the bee family. Contamination of wax and wax foundation from it is often consciously introduced by people, which is possible due to the lack of applicable standards for the quality of wax and wax foundation.

The poor quality of bee waxes available on the market results mainly from the conscious activities of entities participating in market trade. They rely on adding much cheaper substances to natural bee waxes, e.g. paraffin. This is to reduce production costs and increase profits from the business. This adversely affects the quality of food, cosmetic, and beekeeping products (food honey, propolis, wax foundation, cosmetics, dietary supplements) obtained directly or indirectly from bee waxes. Because bees use their products as construction and fennel resources, their pollution affects the condition of bee families, finally leading to their destruction. The residues of therapeutic agents used to combat varroosis<sup>1</sup> are also a problem. It often happens that beekeepers use improper drugs, often not even intended for treating bees and other animals. They also do not use the correct doses of pharmaceuticals, often inflating them and leading to their residues in the hive environment, including the wax, from where they then go to the wax foundation. It happens that beekeepers, tempted by an attractive price, buy a wax foundation on the Ukrainian market, where less restrictive regulations regarding the use of drugs apply. It happens that such wax may contain, for example, antibiotics. The research described in the literature has shown that honey ripening in honeycombs rebuilt on the wax foundation falsified with paraffin has reduced quality parameters, including higher water and some acids, which may cause its fermentation (Svečnjak et al., 2019). Potential threats to human health associated with the consumption of honey ripening in honeycombs with the addition of paraffin or stearin are also drawn to the European Food Safety Authority (EFSA) in a report published in 2020. In this context, awareness of consumer expectations towards the apiary farm is essential. The main factors convincing direct purchases are the quality and trust in the beekeeper (Bratkowski et al., 2008).

Every mistake affects the quality of the product, which is why the role of beekeepers is so essential. It is recommended that, during honey production, samples be tested for the content of water, HMF<sup>2</sup>, and substances that may be harmful to humans. They should also take care of the health of bees without using antibiotics. Otherwise, honey may hurt the human body. (Szwedziak et al., 2017).

In order to prevent beeswax adulteration, an interdisciplinary team of scientists and practitioners developed and built an innovative wax analyzer, a revolutionary solution. This invention, by changing the awareness of the beekeeping community and taking steps to change the applicable legislation, leads to the protection of bee colonies and the natural environment. This article aims to diagnose the beeswax quality analysis market in Poland and present the assumptions for the business model for the commercialization (Kruachottikul, Dumrongvute, Tea-makorn, Kittikowit, Amrapala, 2023) of the WAXO device. The presented conclusions assist the university authorities in making decisions on the commercialization strategy of WAXO and the selection of operational solutions necessary to introduce it to the market, production, sales, and customer service.

---

<sup>1</sup> It is a parasitic disease of bees.

<sup>2</sup> Hydroxymethylfurfural (HMF, 5-hydroxymethyl-2-furfural) is an organic chemical compound naturally occurring in food products.

## **Counteracting counterfeiting of beeswax by introducing the innovative WAXO beeswax quality analyzer**

The problem of adulteration of beeswax in industrial and individual trade is enormous. In the 1950s, a relationship was noticed between the quality of wax used to make wax foundation, the number of bee larvae raised, and consequently the strength of bee families. In the era of mass extinction of bee colonies, this observation becomes very topical, especially in light of the European Commission report 2018, which showed the negative impact of adulterated wax on bee colonies and honey production (European Commission, 2018). Moreover, the adulteration of wax with even a tiny amount of stearin/stearic acid makes it useless for beekeeping (Chęć et al., 2021).

A portable, electromechanical device called WAXO was developed at the Maria Curie-Skłodowska University in Lublin. The innovative WAXO wax analyzer is at the ninth level of technological readiness. WAXO is a portable electromechanical device that examines a small wax sample's physical properties in a thermally stabilized measurement chamber. It allows you to analyze beeswax for adulteration. The device allows you to quickly and at the same time relatively cheaply determine the quality of the tested wax and thus assess its usefulness in beekeeping (Final report on the implementation of pre-implementation support for the results of scientific research and development work as part of the "Innovation Incubator 2.0" project implemented by the consortium of the Maria Curie-Skłodowska University in Lublin, the John Paul II Catholic University of Lublin, the Medical University of Lublin and KUL Creative Sp. z o.o., 2020).

The device, by measuring the mechanical and thermal properties of the tested sample, allows you to assess the similarity of the tested material to pure wax from the caps. This makes it possible to eliminate a product that differs significantly from natural material for beekeeping. The measurement requires preliminary sample preparation (melting the material, forming a pellet, and bringing its temperature to the ambient temperature). The measurement is preceded by a several-minute sample conditioning period by the device and is performed for approximately 100 seconds. The device requires essential maintenance (cleaning) from time to time.

Any beekeeper can operate WAXO. This does not require prior training or technical knowledge. The measurement result is displayed on the device panel. Its interpretation is unambiguous and is based on the following messages:

- good wax,
- bad wax,
- wax of questionable quality (Bio-Tech Consulting, 2019).

The observed differences in the physical properties of alkanes and their mixtures, as well as natural waxes and artificially doped waxes, led to the development of a method for measuring these properties and determining their changes under the influence of doping. The developed method is the basis for constructing the WAXO device, the structure of which has been described in patent applications (three national and three European). These applications concern three separate design solutions related to the measurement of the physical properties of the sample. The measurement principle is based on the susceptibility of the sample to the pressure of the cutting element under specific thermal conditions, which are determined by the local thermal conductivity and wax parameters. They depend on the chemical composition of the sample and the impurities' content. By the decision of the Polish Patent Office experts, national applications received positive decisions granting patent rights (Polish Patent Office, information from 24.09.2021 for P.429881 and from 21.10.2021 for P.429877 and P.429878).

The evaluation of the tested material is based on the unique WAXO algorithm. It was developed based on the results of analyses of several thousand wax samples of various quality and from different parts of the world. The observed regularities in mechanical and thermal properties were verified during tests performed using alternative technologies, such as GC-MS and spectroscopy FTIR<sup>3</sup>. These regularities are included in the WAXO algorithm (MCSU, 2024). Polish and international patents protect WAXO technology.

The invention of a beeswax quality analyzer is being introduced to the market to an increasingly wider extent. In order to efficiently implement commercialization, a business model is necessary, the assumptions of which have been developed in this article.

The essence of every business concept is customers who purchase the offered products, goods, or services and, through this, provide the financing necessary for the further operation of the business. In the era of intense global competition for customer favors, the advantage is gained by those organizations that cannot only meet their expectations but often exceed them. In most industries, there is the so-called "customer market" where supply exceeds demand. Therefore, the bargaining power of customers is high.

## Methods

The main purpose of the research was to develop a business model on which the commercialization of the WAXO device should take place. The business model assumptions were developed using the Business Model Canvas methodology (Osterwalder, 2012). about:

---

<sup>3</sup> Fourier spectroscopy (FTIR) is a spectroscopic research technique based on the natural electromagnetic spectrum. This is the common name for the technique used to transform optical data into useful numerical data (Fourier transform).

- customer segmentation,
- value proposition,
- channels,
- customer relations,
- revenue structure,
- key activities,
- key resources,
- key partners,
- cost structure.

For the needs of the quantitative research conducted, the following detailed research purposes were also formulated:

1. Assessing the importance of poor-quality beeswax on the market.
2. Identification of the average (over one year) number of beeswax analyses needed for respondents.
3. Characteristics of beekeepers' actions in the event of a bad wax/ wax foundation analysis result.
4. Identification of information necessary for beekeepers about the quality of the tested wax.
5. Identification of the maximum gross price for performing the test (with the level of detailed result necessary for respondents) of 1 sample of beeswax in an external laboratory.
6. Identify the most advantageous option for beekeepers for wax quality analysis.
7. Identify the number of WAXO devices, if purchased, that would meet the needs of respondents.
8. Identification of sources of obtaining information about technologies and products intended for the beekeeping industry.
9. Identification of sources and frequency of purchase of beekeeping products.

A Computer Assisted Self Interviewing (CASI) was used to conduct the research. The online interview was conducted using a questionnaire. The study was conducted among randomly selected 124 respondents in beekeeping throughout the country. Most answered questions on behalf of beekeeping groups or associations, indicating how many members they had. Based on these data, it was determined that the interview results were representative of 2226 respondents.

## Results. Market analysis

Respondents participating in the study had various representation statuses. The largest part (55%) were beekeeping group representatives and expressed their members' opinions. A much smaller group of respondents (25%) were unaffiliated beekeepers, while affiliated beekeepers had a 15% share in the group of respondents. 5% of the total were representatives of the breeding apiary and beekeepers associated with each other, but speaking on their behalf.

The respondents were quite clear about the importance of the problem of poor quality beeswaxes available on the market. As many as 85% of them stated that this problem is significant (rating 5 on a scale of 1 to 5, where 1 meant that the problem does not occur and 5 that the problem is very important). 10% of respondents rated the importance of the problem as 3, and 5% - 2.

Beekeepers' awareness of the generally poor quality of beeswaxes on the market creates the need to analyze them. The research shows that every beekeeper in Poland is interested in performing an average of 1.18 annual analyses. People participating in the interview most often perform two analyses a year (35% of respondents). Slightly fewer (15%) verify the wax once a year, 15% do it five times, 10% - three times, and the least, 5%, perform analyses respectively: 10 times, 25 times, 75 times, 300 times, and even 1000 times. It should be noted that representatives of beekeeping groups reported the largest number of studies.

If they receive information about the poor quality of beeswaxes, most respondents (95%) do not buy them and look for another product. Only 5% of respondents perform another test using a different method.

For the majority of respondents (70%), the minimum scope of information about the quality of beeswax is marking the product as good, questionable, or poor quality. The WAXO device ensures this diagnostic accuracy. However, for 30% of respondents, it will be insufficient because they expect information on the percentage of impurities in the sample, along with their type.

Respondents gave various answers to the question about the maximum gross price they would pay for testing one wax sample. Most, 35% of respondents indicated the price of 50 PLN and 20% - the price of 100 PLN. The price of 20 PLN was given by 10% of respondents. The exact amount would be able to pay 200 PLN. Prices of 40 PLN, 75 PLN, 150 PLN, and 250 PLN would be acceptable to 5% of respondents. The same proportion of them were unable to provide a price level. It should be added that the maximum weighted average gross price for one wax quality test acceptable to the respondents is 74.17 PLN.

Most, 48% of the study participants would be willing to pay 50 PLN gross for one wax quality test according to the WAXO standard in an analytical laboratory. Fewer respondents (15%) indicated values of 20 PLN and 100 PLN, while 7% indicated values of 150 PLN and 200 PLN. However, 8% of respondents were unable to express their opinion. The weighted

average gross price for performing one wax quality test in the WAXO standard in an analytical laboratory, acceptable to the respondents, is 74.65 PLN.

Half of the respondents want to outsource WAXO tests to an external laboratory. Slightly less, 45% would be interested in purchasing the device. In turn, 5% do not intend to use it in any way.

85% of the study participants plan to purchase one device, and 5% of the research sample declared the purchase of over 20 devices. In turn, 10% of respondents do not intend to purchase WAXO. Respondents gain knowledge about beekeeping technologies and products from various sources. This question allowed for multiple answers. The most popular are conferences, symposia, and seminars. They were mentioned by as many as 80% of respondents. Less than 60% of them use the specialized press, as well as websites, blogs, and online articles for this purpose. The same percentage takes into account the opinions of sellers in specialist stores. Beekeeping clubs and associations are a source of knowledge for 45% of respondents, and social media, universities, and research institutes - for 40% of them. 25% of respondents learn about new products during trade fairs, while 15% use information provided by friends.

Beekeepers most often purchase beekeeping products from specialized online wholesalers (score 2.25 on a scale from 0 to 5). Slightly less popular sources of supply are online specialist stores (score 2.1) and stationary specialist stores (score 1.85). Respondents use stationary specialist wholesalers least often (score 1.05).

## **Results. Assumptions for the business model**

### **Customer segmentation**

The product is addressed to individual and business customers. Individual clients are beekeepers and their associations, e.g. beekeeping clubs. These are usually beekeeping enthusiasts who treat it as a hobby, not a source of income. They have a highly emotional attitude towards bees and are ready to take decisive actions to ensure their well-being.

Business clients include producers of wax foundations and beekeeping products. The increasing awareness among beekeeping market entities of the low quality of beeswaxes and the increasing pressure to improve them will gradually encourage them to monitor their level systematically. Economic reasons mainly guide these clients. They are interested in practical solutions, i.e. that will allow them to achieve the desired results in the shortest possible time and at the lowest possible costs.



## **Value proposition**

Customers expect solutions that ensure: quick and reliable assessment of the quality of beeswax, ease, and comfort of using the device (simplicity of use, mobility), favorable relationship between price and quality of the solution, failure-free, quick and effective removal of possible faults, manufacturer's warranty (considered more in terms of its duration rather than the scope of protection), technical support, especially in the event of problems with the functioning of the solution. Products that meet the above expectations should be addressed to customers. Therefore, the WAXO device was proposed, and - alternatively - an offer of laboratory tests performed using this device. WAXO is a portable, electromechanical device that allows you to analyze beeswax for adulteration. The device allows you to quickly and, at the same time, relatively cheaply determine the quality of the tested wax and thus assess its usefulness in apiary management. Measuring the mechanical and thermal properties of the tested sample allows you to assess the similarity of the tested material to pure wax from the cappings. This makes it possible to eliminate a product that differs significantly from natural material for beekeeping.

## **Channels**

The research shows that target customers learn about innovations in the beekeeping market primarily during conferences, symposia, and scientific seminars. They also use the specialized press, websites, blogs, and online articles. They also take into account the opinions of sellers in specialist stores, as well as members of beekeeping clubs and associations. They use social media and contacts with universities and research institutes. In order to ensure a consistent and effective system of informing customers about the availability of the product, a professional website should be created in polish and english, containing specific and accessible information about WAXO, the possibilities of purchasing it and the possibility of ordering laboratory tests using WAXO, additional support will be provided by videos promoting the device and instructional videos. In the process of product commercialization, it is important to present the device and offer laboratory tests during seminars, scientific conferences, and symposia. An additional, recommended channel for reaching customers may be study visits for members of beekeeping organizations interested in the device and international trade fairs. In order to increase awareness of the availability of the device, an essential action may be establishing cooperation with industry opinion leaders - people who enjoy authority in the beekeeping community and will disseminate positive opinions about the device, as well as disseminating information in the scientific community in the form of scientific articles or participation in conferences. For image reasons, it will be advisable to post information on social media occasionally. The WAXO beeswax quality analyzer will be sold via a website with a store option. Customers will be able to place an order using the form provided and, at the same time, pay a fee, including the sales price and shipping costs. After receiving the payment, the device

will be sent via a courier company to the address indicated in the order. Another option, less frequently used, will be direct sales for cash when presenting the device at conferences, symposia, and scientific seminars. Customers can use telephone and online technical support (helpdesk). The consultant will answer questions from customers and people interested in the device on weekdays, from 10 a.m. to 6 p.m. The device will be covered by the manufacturer's standard warranty care for one year from its purchase. In the event of a failure, the customer will have to send the device to the manufacturer, who will perform repairs free of charge and then send it back to the customer. After one year from purchasing the device, repair, and service activities will be performed for a fee.

### **Customer relationships**

In the beekeeping industry, customers prefer direct contact. To a large extent, the clients are older people who do not use information technology fluently. They prefer to ask questions during a direct conversation, ensuring they understand the answer given and thus increase their sense of security.

Therefore, the manufacturer must establish direct interpersonal relations with customers at all cooperation stages, starting from presenting the offer through handling the placed order to after-sales service. It seems desirable to establish direct contact with customers who have purchased the device to determine their opinions.

### **Revenue streams**

The research shows that customers can accept different price levels for the device. The weighted average gross price was calculated at 3450 PLN and one laboratory test was performed using it: 74.65 PLN.

While the price for the test is acceptable, the device's selling price is not. The production cost of the device is approximately 5000 PLN net. It should be remembered that the sales price must compensate not only the production costs but also the costs of R&D work and include the necessary profit margin. In this context, the sales price of the device should be in the range of 15,000-20,000 PLN net. Based on the opinions of industry experts, this price will not be disqualifying, but it will nevertheless limit the availability of the device and the effective demand for it. WAXO will be offered for a fee. The product will be covered by a one-year manufacturer's warranty, during which any faults not attributable to the customer will be removed free of charge. Customers will also benefit from periodic, paid inspections and services of the device. Laboratory testing services performed using WAXO will also be provided for a fee. It is very important to persuade decision-makers through lobbying activities to subsidize the purchase of WAXO, e.g. from the Oil Crops Promotion Fund. The forecast structure of sales revenues is presented in Table 1.

**Table 1.**  
*Forecasted revenue structure for the years 2024-2026*

Specification	Time		
	2024	2025	2026
Estimated number of WAXO sales (units)	90	100	110
The estimated sales price of WAXO (PLN)	18 000	19 000	20 000
<i>Net revenues from sales of WAXO (PLN)</i>	<i>1 620 000</i> <i>(88,52%)</i>	<i>1 900 000</i> <i>(89,1%)</i>	<i>2 200 000</i> <i>(89,58%)</i>
Estimated number of sales of WAXO laboratory services (units)	3000	3100	3200
The estimated sales price of WAXO laboratory services (PLN)	70	75	80
<i>Net revenues from WAXO laboratory services (PLN)</i>	<i>210 000</i> <i>(11,48%)</i>	<i>232 500</i> <i>(10,9%)</i>	<i>256 000</i> <i>(10,42%)</i>
<b>Total net sales revenues (PLN)</b>	<b>1 830 000</b> <b>(100%)</b>	<b>2 132 500</b> <b>(100%)</b>	<b>2 456 000</b> <b>(100%)</b>

Source: own study.

From mid-2024, sales of the device in foreign markets will be increased. Customers will not repeat the purchase of WAXO during the forecast period, and laboratory services will be renewable annually. A nominal increase in unit net selling prices was assumed: equipment (1000 PLN per year) and laboratory services (5 PLN net).

It is expected that the dominant source of revenue will be the sales of WAXO (from 88.52-89.58% share in the revenue structure). Forecasted revenues from the sale of laboratory services should constitute 10.42% to 11.48% of total net sales revenues.

### Key activities

In order to optimize the commercialization process, key activities should be defined that will motivate customers to purchase the device. The key recommended activities include:

- organizing an effective device production process - selecting and monitoring the activities of a contractor that will ensure high-quality products at affordable prices and short order fulfillment times,
- providing adequate after-sales support,
- establishing cooperation with a courier company that will deliver products to customers,
- monitoring the level of customer satisfaction,
- verification of the value of offered products and services by identifying customer expectations and preferences,
- developing the product in cooperation with users to respond quickly to their needs,
- conducting analysis of foreign markets in terms of future expansion.

Channels for reaching customers and establishing and cultivating relationships with them require key activities. The basic tool for information about the offer (WAXO and laboratory tests) will be a website with a store function. This website should be at least bilingual. The content should be presented in polish and english. The manufacturer's representatives should participate in industry fairs, conferences, symposia, and seminars, during which they will present the offer professionally. Another information medium should be articles popularizing knowledge about WAXO, published periodically in scientific and industry

magazines. A supporting measure should be the organization of study visits for representatives of the beekeeping community in the analytical laboratory, combined with presentations of the device. An essential element of promoting WAXO and laboratory tests performed with its help will be establishing cooperation with opinion leaders, i.e. people with authority in the beekeeping industry, and encouraging them to disseminate information about the device.

### **Key resources**

The key resources needed to create value for customers and establish and maintain relationships with them include:

1. Human resources:

- creators of the device - having comprehensive knowledge about WAXO, presenting it during trade fairs, conferences, symposia, and seminars, preparing articles about it, and dealing with its development (R&D),
- manager managing the work of the business unit (WAXO sales, provision of laboratory testing services),
- laboratory technicians,
- production/service workers.

2. Material resources:

- laboratory rooms with equipment,
- production and service areas with equipment.

3. Intangible resources (non-human resources):

- know-how,
- patents/patent applications,
- certificates required by law,
- website with a store function,
- promotion movie,
- instructional video.

4. Financial resources intended to cover the costs:

- remuneration of human resources,
- laboratory and production and service room equipment,
- operation of rooms,
- device production,
- providing laboratory services,
- purchasing a website with a store function,
- website domain and hosting,
- production of films: promotional and instructional,
- participation in industry fairs, conferences, symposia, and scientific seminars,

- scientific and sponsored publications,
  - R&D works.
5. Relational resources – positive relationships with customers, suppliers, employees, opinion leaders, financial institutions, and business environment institutions.

### **Key partners**

Key partners are an element of the business model describing the network of suppliers and collaborators on whom the efficient functioning of the venture depends (Osterwalder, Pigneur 2012). Competencies are necessary for the successful functioning of an enterprise. These competencies include:

- conducting development work in the field of developing prototypes of new products or subsequent generations of WAXO,
- certification of products in order to admit them to market circulation,
- physical production of products,
- having extensive and effective distribution channels,
- production of films: promotional and instructional.

Development work in developing prototypes of new products or the next generations of WAXO should be conducted in cooperation with external entities. The current generation of WAXO was created with the technical and conceptual cooperation of Amratech sp. z o.o., which additionally exercises substantive supervision over the certification process. The experience resulting from the cooperation so far is positive. Therefore, it is worth including this smaller entity in subsequent development projects. The Institute of Research, Attestation and Certification "OBAC" sp. z o.o. is responsible for the device certification process. Other certification bodies are available on the market, but not all of them offer the required scope of services.

The physical production of products should be outsourced to an external contractor who has the necessary competencies. It is worth considering implementing the production process in a university entity or subject to the management of a special-purpose vehicle. In this aspect, one should strive to obtain an optimal relationship between production costs and time and the quality of products.

The use of extensive and effective distribution channels is the domain of beekeeping wholesalers and chains of specialist stores. It is worth considering establishing a strategic partnership with nationwide distributors and, in the future, covering foreign countries. The production of promotional and instructional films should be commissioned to a specialized media agency. It is recommended that the services of an entity that prepares promotional recordings for the Faculty of Economics of UMCS be used.

The following entities are necessary for the smooth functioning of the enterprise: companies specializing in research, development, and implementation work:

- central distributors/central distributors of beekeeping products,
- device manufacturer,
- courier companies,
- financial institutions (if there is a need to obtain additional sources of financing).

### Cost structure

The projected costs, structure, and expected financial results in 2024-2026 are presented in Table 2.

**Table 2.**  
*Cost structure*

No.	Specification	Time		
		2024	2025	2026
<b>Beeswax Analytical Laboratory</b>				
1	<i>Number of samples</i>	3000	3100	3200
2	<b>Amortization</b>	<b>25 000,00<sup>4</sup></b>	<b>0,00</b>	<b>0,00</b>
3	<b>Laboratory technician's salary (gross + derivatives)</b>	<b>70 000,00</b>	<b>74 400,00</b>	<b>76 800,00</b>
4	<b>Electricity cost<sup>5</sup></b>	<b>9600,00</b>	<b>11 904,00</b>	<b>14 336,00</b>
5	<i>Electric energy consumption in kWh per sample</i>	3,20	3,20	3,20
6	<i>The price of 1 kWh of electrical energy in PLN</i>	1,00	1,20	1,40
7	<b>Laboratory materials costs<sup>6</sup></b>	<b>6000,00</b>	<b>6820,00</b>	<b>8000,00</b>
8	<i>Material costs in PLN (1 sample)</i>	2,00	2,20	2,50
9	<b>External services - service and repair of equipment and production of sample molds</b>	<b>500,00</b>	<b>600,00</b>	<b>700,00</b>
10	<b>External services - rental of laboratory room (15 m<sup>2</sup>)</b>	<b>5 400,00</b>	<b>5 400,00</b>	<b>5 400,00</b>
11	<b>Cost of Beeswax Analytical Laboratory</b>	<b>116 500,00</b>	<b>99 124,00</b>	<b>105 236,00</b>
<b>WAXO sales</b>				
1	Number of devices sold	90,00	100,00	110,00
2	Unit production cost	5 000,00	5 500,00	6 000,00
3	<b>Production cost</b>	<b>450 000,00</b>	<b>550 000,00</b>	<b>660 000,00</b>
4	<i>Help desk<sup>7</sup></i>	<b>12 000,00</b>	<b>12 000,00</b>	<b>12 000,00</b>
5	<b>Warranty service</b>	<b>9 000,00</b>	<b>10 000,00</b>	<b>11 000,00</b>
6	<b>WAXO sales costs</b>	<b>471 000,00</b>	<b>572 000,00</b>	<b>683 000,00</b>
<b>WAXO joint cost</b>				
1	<b>A website with a shop function</b>	5 000,00	0,00	0,00
2	<b>Domain + hosting</b>	100,00	400,00	400,00
3	<b>Videos: promotional and instructional</b>	1 500,00	0,00	0,00
4	<b>Promotion (trade fairs, symposia, press)</b>	10 000,00	20 000,00	30 000,00
5	<b>Manager's salary (gross + derivatives)</b>	96 000,00	96 000,00	96 000,00
6	<b>Joint cost</b>	<b>112 600,00</b>	<b>116 400,00</b>	<b>126 400,00</b>

<sup>5</sup> Electricity cost = (number of samples \* electric energy consumption in kWh per sample) \* price of 1 kWh of electrical energy in PLN.

<sup>6</sup> Laboratory materials costs = number of samples \* Material costs in PLN (1 sample).

<sup>7</sup> Help desk = 1000 PLN/month.

Cont. table 2.

<b>Total costs</b>				
<b>1</b>	<b>Beeswax Analytical Laboratory costs + WAXO sales + WAXO joint cost</b>	<b>700 100,00</b>	<b>787 524,00</b>	<b>914 636,00</b>
2	Beeswax Analytical Laboratory costs	16,64%	12,59%	11,50%
3	WAXO sales	67,28%	72,63%	74,67%
4	WAXO joint cost	16,08%	14,78%	13,83%
<b>Gross financial result</b>				
		1	2	2
1	Total net sales revenues (PLN)	830 000,00	132 500,00	456 000,00
2	Total costs (PLN)	700 100,00	787 524,00	914 636,00
<b>3</b>	<b>Gross financial result (PLN)</b>	<b>1 129 900,00</b>	<b>1 344 976,00</b>	<b>1 541 364,00</b>

In the tax year, each entrepreneur can use a one-off amortization limit of 100,000 PLN (Act of July 26, 1991, on personal income tax, Art. 22, section 1s). The forecast shows that the commercialization of WAXO will be economically justified. The positive values of the gross financial result in individual years of the forecast indicate this.

It should be noted that the above proposal of assumptions for the business model is not binding. It should help direct business plans and be subject to appropriate modifications in the event of changes in the external and internal conditions of the functioning of the business.

## Summary

The WAXO device, developed by scientists from the Maria Curie-Skłodowska University in Lublin, solves the problem of beekeepers' uncertainty regarding the quality of waxes and the wax foundation made from them. This problem is very important, as demonstrated in the research process. Moreover, this problem affects many entities, often causing solid emotions. The number of beekeepers in Poland slightly exceeds 90,000, while it is estimated at about 600,000 in the European Union countries. Therefore, there is actual market demand for the device. This opinion is confirmed by the author's interactions with potential clients. The device's price may be a significant problem in the commercialization process. It will be much higher than expected due to higher production costs. It seems necessary to obtain a subsidy for its purchase by customers, preferably at 50%, as is the case with other beekeeping devices.

To sum up, the diagnosis of the beeswax analysis market and the developed assumptions for the business model for the WAXO device entitle us to formulate a recommendation. The consortium authorities should decide on the entity responsible for the commercialization of the device and create formal and legal conditions enabling this process. Supervising the entity responsible for the production, warranty, and post-warranty service of the device is necessary. The key is constantly enriching the device's design by preparing and implementing a professional graphic design. The selling price of the device and the sale of laboratory services

should be adjusted to market conditions, considering the costs incurred. It is also important to intensify lobbying activities to provide customers with subsidies for purchasing WAXO. Another recommendation is to commission the creation of a website with a store function in polish and english and fully launch the beeswax analysis laboratory. Promotional activities should be undertaken, and cooperation with potential nationwide and foreign distributors should be considered to introduce the device to foreign markets (scaling<sup>8</sup> the business model). In order to popularize the device, it is reasonable to conduct R&D work and to use the device to test other products. Financing international patent protection should be suspended, and the funds allocated for this purpose should be used to develop the device.

## References

1. Bio-Tech Consulting (2019). *Analiza potencjału komercjalizacyjnego strategii komercjalizacji, wycena wynalazku.*
2. Bratkowski, J., Wilde, J., Lisner, G. (2008). Ocena jakości węzy pszczelej oferowanej na polskim rynku. *Biuletyn Naukowy Uniwersytetu Warmińsko-Mazurskiego*, 29, 27-36.
3. Bratkowski, J., Wilde, J., Miećkowska, A. (2008). Wymagania konsumentów stawiane gospodarstwom pasiecznym prowadzącym sprzedaż detaliczną miodu. *Biuletyn Naukowy Uniwersytet Warmińsko-Mazurski w Olsztynie*, 29, 37-43.
4. Chęć, M., Olszewski, K., Dziechciarz, P., Skowronek, P., Pietrow, M., Borsuk, G., Bednarczyk, M., Jasina, G., Jasina, J., Gagoś, M. (2021). Effect of stearine and paraffin adulteration of beeswax on brood survival. *Apidologie*, 52, 432-446. <https://doi.org/10.1007/s13592-020-00833-7>.
5. Dekebo, A., Jung, C. (2023). Chemical Composition and Physicochemical Properties of Beeswaxes of *Apis mellifera* and *Apis cerana*. *Journal of Apiculture*, 38(4), 367-377.
6. *EU Food Fraud Network* (2018). Coordinated Case. European Commission. *Adulteration of beeswax intended for honey production with stearin and paraffin*. Retrieved from: [https://ec.europa.eu/food/sites/food/files/safety/docs/food-fraud\\_succ-coop\\_beeswax.pdf](https://ec.europa.eu/food/sites/food/files/safety/docs/food-fraud_succ-coop_beeswax.pdf), 2.06.2024.
7. European Food Safety Authority (EFSA). Risk assessment of beeswax adulterated with paraffin and stearin/stearic acid when used in apiculture and as food (honeycomb). *EFSA Supporting Publication 2020: EN-1859*, 17(5), 1-64.
8. Goik, U., Goik, T., Załęska, I. (2016). Właściwości wosku pszczelego i jego zastosowanie w kosmetyce i kosmetologii. *Kosmetologia Estetyczna*, 5(6), 617-622.

---

<sup>8</sup> Scalability means the ability to increase the scale of operations, measured by sales revenues, more than proportionally to the increase in costs.



9. Kozłowicz, K., Sułkowska, M., Kluza, F. (2011). Powłoki jadalne i ich wpływ na jakość i trwałość owoców i warzyw. *Acta Scientiarum Polonorum. Technica Agraria*, 10(3-4), 35-45.
10. Kruachottikul, P., Dumrongvute, P., Tea-makorn, P., Kittikowit, S., Amrapala, A. (2023). New product development process and case studies for deep-tech academic research to commercialization. *Journal of Innovation and Entrepreneurship*, 12(1), 48.
11. *lyson.com.pl*. Retrieved from: <https://lyson.com.pl/blog/artykuly-pszczelarskie/weza-pszczela-dlaczego-tak-wazna-jest-jej-jakosc>, 28.03.2024.
12. Mitsutake, H., Da Silva, G.H.R., Ribeiro, L.N.D.M., De Paula, E., Poppi, R.J., Rutledge, D.N., Breitreitz, M.C. (2021). Raman imaging and chemometrics evaluation of natural and synthetic beeswaxes as matrices for nanostructured lipid carriers development. *Brazilian Journal of Analytical Chemistry*, 8(32), 116-130.
13. Mruk, H. (2019). *Pszczoły i ich produkty na usługach zdrowia ludzi*. Monografia–Zdrowie i Style życia. Wyzwania ekonomiczne i społeczne. Wydawnictwo Uniwersytetu Wrocławskiego, Wrocław, 119.
14. Osterwalder, A. Pigneur, Y. (2012). *Tworzenie modeli biznesowych. Podręcznik wizjonera*. Helion.
15. Pędziwiatr, P., Zawadzki, D. (2017). *Proces pozyskiwania i oczyszczania produktów pszczelich*. VII Seminarium Studenckie Bezpieczeństwo, 99.
16. Pietrow, M., Gagoś, M., Kamiński, D. (2013) The influence of crystal morphology on the process of positronium formation in docosane. The accessibility of electrons for trapping. *Radiat Phys Chem.*, 88, 38-44. <https://doi.org/10.1016/j.radphyschem.2013.03.032>.
17. Pietrow, M., Gagoś, M., Misiak, LE., Kornarzyński, K., Szurkowski, J., Rochowski, P., Grzegorzczak, M. (2015) Evidence for weakly bound electrons in non-irradiated alkane crystals: The electrons as a probe of structural differences in crystals. *J. Chem. Phys.*, 142, 064502. <https://doi.org/10.1063/1.4907262>.
18. *Raport końcowy z realizacji wsparcia przedwdrożeniowego wyników badań naukowych i prac rozwojowych w ramach projektu „Inkubator Innowacyjności 2.0” realizowanego przez konsorcjum Uniwersytetu Marii Curie - Skłodowskiej w Lublinie, Katolickiego, Uniwersytetu Lubelskiego Jana Pawła II, Uniwersytetu Medycznego w Lublinie oraz KUL Creative Sp. z o.o.*
19. Suyal, P., Pandey, R. (2024). Economical factitious diet for mass rearing of greater wax moth, *Galleria mellonella* (Lepidoptera: pyralidae), a promising host for entomopathogenic nematodes. *Egyptian Journal of Biological Pest Control*, 34(1), 26.
20. Svečnjak, L., Jović, O., Prđun, S., Rogina, J., Marijanović, Z., Car, J., Matošević, M., Jerković, I. (2019) Influence of beeswax adulteration with paraffin on the composition and quality of honey demined by physicochemical analyses. *1H NMR, FTIR-ATR and HS-SPME/GC-MS. Food Chemistry*, 291, 187-198.

21. Szwedziak, K., Smolka, Z., Polańczyk, E., Szopa, A., Koronczok, J. (2017). Metody oceny jakości miodu®. *Postępy Techniki Przetwórstwa Spożywczego*.
22. UMCS, Retrieved from: <https://www.umcs.pl/pl/o-waxo,20615.htm>, 9.06.2024
23. Urząd Patentowy Rzeczypospolitej Polskiej, <https://uprp.gov.pl/pl>, 5.05.2024.
24. Ustawa z dnia 26 lipca 1991 r. o podatku dochodowym od osób fizycznych, art. 22, ust. 1s.
25. Wilde, J., Gabruś, J. (2002). Opłacalne zagospodarowanie wosku w pasiekach. *Biuletyn Naukowy Uniwersytetu Warmińsko-Mazurskiego w Olsztynie*, 18(5), 45-52.

## ECONOMIC CHANGES IN POLAND AND CHINA – CULTURE AS A LEADING INDICATOR

Maria BERNAT<sup>1\*</sup>, Leszek KARCZEWSKI<sup>2</sup>, Martin MACHACEK<sup>3</sup>

<sup>1</sup> The Opole University of Technology; m.bernat@po.edu.pl, ORCID: 0000-0003-4520-662X

<sup>2</sup> The Opole University of Technology; l.karczewski@po.edu.pl, ORCID: 0000-0003-2538-7056

<sup>3</sup> VSB –Technical University of Ostrava; martin.machacek@vsb.cz, ORCID: 0000-0002-1517-6709

\* Correspondence author

**Purpose:** The article analyses two transformation variants: the Polish variant and the variant used in the People's Republic of China. This analysis was carried out in the context of the cultural background of both nations. The authors also tried to answer the question to what extent the reform programs of both economies, known as the Balcerowicz Plan and the Beijing Consensus, were culturally compatible and whether they impacted their effectiveness this. The article draws attention to the level of social acceptance of the transformation scenario adopted in the country and the role of both decision-making centralism and economic democracy in the conditions of a market economy.

**Methodology:** The review of literature.

**Findings:** As a result of the literature analysis, it was established that the reforms carried out as a result of the Balcerowicz plan took into account the cultural conditions of the Polish economy to a limited extent, which resulted in incomplete and delayed use of the potential of Polish social and intellectual capital. Chinese reforms, on the other hand, were carried out in a way that was more suited to Chinese realities, which, among other factors, enabled China to develop more dynamically without leading its economy to a periodic collapse caused by the transformation processes.

**Value of the paper:** The article is analytical and synthetic in nature and is addressed to a wide audience, primarily to decision-makers managing the economy at various levels and to students of economics and management. The article is not only retrospective in nature, but also encourages deeper reflection on the future and may be helpful to managers in making economic decisions, in which they should take into account the cultural aspect to a greater extent than before.

**Keywords:** Economic transformation, plan of Balcerowicz, Beijing Consensus, cultural adjustment.

**Category of the paper:** viewpoint, conceptual paper.

## 1. Introduction

The influence of the economy on contemporary culture is obvious and leaves no doubt, especially in the light of research (Mahbubani, 2008; Ribera-Fumaz, 2009; Bernat et al., 2017; Castells, 2017) and regional development policy (Syssner, 2009; Jasińska-Biliczak et al., 2016; Tambovtsev, 2018; Moscovitz, 2020), although the impact of culture on the economy is a rather unjustly neglected (Siewierski, 2010).

The economic system can be defined as the totality of products and legal, political and economic activities of individuals and communities as well as resources. It should be pointed out that economic system is secondary to the cultural system, because the economy as such can only develop in a certain existing cultural environment that gives meaning to economic activities. However, transformation of the economy is possible while maintaining cultural identity. Thus, an appropriately developed economic policy may be successful in a mature cultural environment that is ready for changes. The reform plan cannot be the same in every country, but must take into account historical factors and its final influence on culture and social values (Murrell, 1997).

Among certain oppositions, Confucianism (which according to M. Weber is the dominant “carrier of Chinese culture”) has been based on humility, harmony, hierarchy and community, and has firmly rejected domination over the Western world, equality and individualism. In Confucianism, there has been no tensions and oppositions that would lead to changes, question the existing tradition and convention, and there have been no conflicts between sectarian or heretical beliefs that could give rise to diversity (Weber, 2006). Moreover, since interpersonal relationships have been based on etiquette and rituals, interacting with others could cause potential anxiety. A very high power distance enhanced harmonious social relationships. Nothing can be found in the Confucian tradition that would be a source of anxiety for an individuals and that would, therefore, make them to explore and change.

The culture of Western Europe often breaks with its own tradition as irrational and contrary to the rational maximization of benefits. This approach resulting from rational actions of independent units has been manifested in the modern economy.

## 2. Poland – economic changes after 1989

The economic transformation initiated in the 1990s in Central and Eastern Europe marked a transition from a centrally managed to a market economy. It involved a comprehensive and radical change in the management goals and conditions of all economic entities. Therefore, reduction of the development gap along with the development of economic potential has

become essential. It was not yet another attempt to reform the previously existing system, but a radical, qualitative change in the previous management style (Jarmolowicz et al., 2008). Economic changes, reflected in the elimination of key institutions of the socialist economy which were then replaced with market institutions along with restructuring and privatization, seemed revolutionary (Hryniewicz, 2004). Introducing the controversial shock therapy was possible in a unique, non-repetitive moment in time. According to Balcerowicz (Balcerowicz, 1997) this was the time of extraordinary politics followed by social consent to radical reforms inflicting high social costs.

The willingness to quickly implement reforms resulted from a relatively low tendency to think long-term (LTO-WVS index 38) (Hofstede et al., 2011), since the effects of the applied economic policy tools were expected relatively quickly. The economic transformation of Poland and other Central and Eastern European countries was inextricably linked with the political transformation. Political freedom and democracy were considered as a *sine qua non* conditions for the efficiency of the market mechanism.

Prior the social and economic changes of 1989, Polish economy was a closed economy. As such, it was characterized by technological backwardness, inconvertible money, rigid prices and a shortage of goods along with rising wages. At that time the debt level was at 42 million US dollars. As a result of the undertaken restructuring measures, the International Monetary Fund and the World Bank cancelled part of the country's debt, but required the implementation of certain reforms, also known as the Washington Consensus. In fact, the initial version of this list contained 10 universal rules (recommendations) on how to establish lasting foundations for a healthy economy that will develop dynamically (Soszyńska, 2013). Implementing these reforms required adopting a foreign pattern of economic culture. It was not a European but American model which if based on social democracy and ordoliberalism, with its ethical dimension, would be culturally closer to the Polish economy and Polish society. The difficulties in selecting the right and socially accepted economic model were caused on the one hand by the past experiences of World War II and even earlier partitions of Poland and on the other hand by the success of American economy and the willingness to follow it.

The government of T. Mazowiecki, established in 1989, introduced thorough economic reforms. They were an important element of the systemic transformation, designed and implemented under the direction of Deputy Prime Minister L. Balcerowicz and western advisers. At the same time L. Balcerowicz also worked on developing comprehensive stabilization reforms and systemic changes. In October, 1989 they were officially adopted under the name of "The Economic Program of the Government – Main Assumptions and Directions", also known as the Balcerowicz plan. The economic priorities of this scheme included regaining a permanent macroeconomic balance, full liberalization of prices and foreign trade, restoring the development capacity of the economy and narrowing a serious civilization gap in the future (Gomulka, 2014). The main assumption of this plan indicated that under political freedom it was possible to freely choose the economic system of the country. For this reason, the selected

system, which was designed for the Anglo-Saxon economic culture, was culturally and socially based on private property, competition, strong and exchangeable currency and extensive foreign exchange. The system adopted for Poland was supposed to be free of state bureaucracy and trade unions' pressure.

Implementing the American economic model in Poland resulted in anti-statism, returning to economic liberalism and a conservative approach towards the economy and economic policy. In this concept, applied in the USA in the 1980s as an experiment, attention was re-focused on the supply aspect of the economy (Miłaszewicz, 2004). However, studies have not conclusively evaluated it (Wojtyna, 1988; Belka, 1991; Bieńkowski, 1995).

The political events of mid-1993 (the fall of H. Suchocka's government) had a negative impact on the effectiveness of economic policy. Firstly, the processes of implementing institutional reforms and privatization of state-owned enterprises, essential for the newly developed economy, were halted. The initial economic changes in Poland were characterized by a change in macro indicators, sensitive to political and economic changes. In 1990, GDP fell by 8%, in 1991 by another 7%. These changes were caused by a decline in production. However, in the years 1992-1994, the average annual GDP grew by 3.8%.

The boom was particularly evident in the years 1995-1997, when the average GDP growth was at 6.6%. The transformational depression and, consequently, the variable economic growth resulted in difficult social circumstances (Kaliński, 2003). They manifested particularly in an increase of unemployment, which in the years 1990-1993 affected over 2.6 million people (Rajkiewicz, 1997). Collective redundancies were a new and unknown phenomenon. Another distinctive feature of the transformation was reflected in converting hidden unemployment into overt unemployment. Even more so, the implemented changes were not socially accepted. The significant decline in employment, followed by its low growth dynamics, made unemployment a particular social problem. In 1993, 2.9 million people were unemployed with the unemployment rate at 16.4% (Kaliński, 2017). This was linked with the increasing poverty, the intensification of economic emigration, pathologies and existential difficulties (Smoleń, 2006). At the beginning of the transformation a sharp decline in the income of the population also occurred. About 12% of the population had an income qualifying for social assistance and 7% had an income below the subsistence level (Gomułka, 2014). It was not until the years 1996-2000 that a small but noticeable increase in generated income became evident. Since the end of the 1990s the economic situation of Polish society has been improving. The improvement has been caused by strong social differentiation reflected in the Gini coefficient which increased from 26.7 in 1992 to 35.4 in 2004 (World Bank, 2004).

Some changes carried out in a young democracy, which is the necessary condition for a successful structural and socio-economic transformation, were also positive. They included the agreement on the Enterprise Pact which introduced laws related to working conditions, social affairs and the privatization of state-owned enterprises. It defined legal conditions necessary to improve the economic condition of state-managed companies and their

privatization, guaranteeing employment benefits. This approach changed the mentality of employees and their responsibility for the enterprise, not only from the point of view of capital ownership, but joint ownership and joint responsibility for assets. At the same time, Polish economy suffered from a lack of domestic capital necessary for investment and development. One of the major barriers to the transformation of Polish economy was the shortage of investment capital. The pillars of this process: privatization, restructuring and modernization were challenged by the capital deficit, which exceeded the internal capacity of the economy. At the beginning of the 1990s, internal accumulation drastically weakened due to the low ability to generate profits as enterprises were only adapting to the new circumstances. The deficit also increased due to the significant decline in private savings. The level of gross domestic savings defined as the difference between GDP and total consumption amounted to 19% of GDP after the first five years of transformation and was 4 percentage points lower than in 1980. According to the analysis provided by the World Bank, in 1995, the ratio of gross domestic savings in Poland was among the lowest worldwide. It was estimated that the gap between the desired level of investment in the economy and the volume of domestic savings reached 10% of GDP in the 1990s. Only in 1998, the inflow of capital in the form of FDI covered 2/3 of this gap (Olifrowicz et al., 2002). Under these conditions, foreign capital allocated in the form of FDI became the only non-budgetary source of financing growth. The remaining forms of external capital transfer, which could stimulate the economy, were blocked due to the country's foreign debt, reaching almost USD 42 billion, and the lack of creditworthiness on international financial markets. The developing capital market did not attract significant capital located in portfolio investments. FDI has largely filled the accumulation gap and absorbed the shock caused by the decline in domestic investment. The external investment impulse triggered the multiplier effects in the economy affecting the income of enterprises and households and the increase in market demand. In terms of cultural adaptation of the investor's home country in the capital's hosting country G. Hofstede emphasized the role of the power distance. The capital flow from countries culturally characterized by a low power distance to countries with a high power distance creates certain conditions for the success of investment projects based on cultural adaptation. Researchers of the phenomenon (Bildhauer, 2005; Gesteland, 2000; Hofstede et al., 2011) identify Polish culture as a culture of relatively high distance, strongly hierarchical with a preference towards authoritarianism. Therefore, it is characterized by a relatively high power distance, which is a consequence of the centralised decision-making process typical for the economy of the past system.

In terms of FDI flows, they are mainly from Western countries to Poland, that is from countries with a relatively low power distance (power distance index below 53) (63%) to Poland – a country with a higher power distance. According to Hofstede's research this was the premise for good assimilation of managerial solutions from these countries (cultures) and was clearly reflected in the economic effects of foreign capital in the Polish economy. The possibility of implementing modern technologies and applying technical and organizational knowledge

through the inflow of FDI was one of the main reasons for opening Polish economy to foreign capital at the beginning of the 1990s, since the main endogenous barrier to the competitiveness of production was the low technological level and the decapitalisation of the production apparatus.

The deficits inherited from the centrally controlled economy led to the absorption of almost all foreign investments, also in order to meet the requirements and conditions of the IMF adopted during the Balcerowicz plan. Successive legal regulations governing foreign investments gradually made them equal to those made by domestic investors, although this was often questioned due to an earlier regime's propaganda emphasizing the exploitation of capital owners and the imperialist goals of the countries who owned the capital. On the other hand, the investment attractiveness of direct competitors from Central and Eastern Europe in the absorption of foreign capital forced to effectively improve the conditions for allocating foreign capital, and above all, not to discriminate this group of investors in the economy.

In June, 1994 further changes to the economic policy were introduced by G. Kołodko. The suggested solutions initiated a new phase of transformation which prioritised: fast economic growth, systemic and macroeconomic stabilization, and improvement of living conditions. Based on this strategy the so-called 'popiwiek'<sup>1</sup> that is, a tax on the payment of excess wages was discontinued. The aim of stopping excessive wage growth was taken over by the Tripartite Commission for Socio-Economic Affairs comprised of representatives of the government, trade unions and employers established the maximum rate of increase in wages charged as costs for business entities employing more than 50 people.

In the years 1990-2000 economic changes were determined by closer relationships established with international organizations of developed world economies. This facilitated the exchange of goods and reduced the debt. Based on the Association Agreement between Poland and the European Communities signed in December 1991 and implemented in March 1992, the transitional agreement regulating trade issues was established. In February 1994, a full so called European Agreement, entered into force on such issues as movement of labour and capital, services, legislative alignment and competition policy. In the same year, Poland applied for membership in the European Union and started negotiations and adjustment procedures (Kaliński et al., 2003).

The systemic transformation in Poland was of an unprecedented nature and significantly differed from the previous so-called institutional transformations, or from various attempts at economic reforms in the times of a centrally managed economy (Dabrowki, 2018). It was characterized by a wide range of shocking changes which were faster in politics than in the economy. As a result, economic changes were carried out under democratic conditions. Moreover, the peaceful nature of these changes should be also be emphasized (Kornai, 2006).

The typical features of the transformation in Poland include the high pace of economic changes despite rapid governmental changes. The instability and fragmentation of the political scene in Poland has been emphasized, however, it has also contributed to stronger political



competition which along with the supervision of free media, allowed to limit the scope of irresponsible and harmful activities (Ekiert, 2001). The shock therapy applied to the economy resulted in a significant decline in economic activity also known as the post-transformation recession. Despite the application of the most radical variant of the reforms, the decline in Polish GDP at the level of 18.3% in the first shock stage of the transformation was lower than in other neighbouring transition countries (Hungary – 21.5%, Czech Republic – 19.3%). This was due to the internal adaptability of domestic entities to the new circumstances and efficient launch of market mechanisms in the main segments of the economy. A cultural attribute of a higher propensity for individualism, which is the cornerstone of the market mechanism (Hofstede et al., 2011) played an important role in the activation of the market mechanisms. However, the recession itself generated negative signals for both domestic and foreign investors. Although the decline in economic activity under the conditions of structural changes was inevitable, the intensity of it has been widely discussed.

Unemployment was one of the greatest challenges of the transformation period. A particularly negative perception of this phenomenon was also induced by the centrally managed economy in which – due to the demand imbalance – unemployment did not exist.

Currently, Polish economy may be defined by high economic growth, internationalization, and the private entrepreneur sector (highlighting the small and medium-sized enterprise sector). The goal has been to develop a competitive Polish economy in the European Union. However, it is also worth noting that the economy at the current stage of development may face the same challenges it encountered during the transformation. They include the middle income trap and low innovation economy which is still based mostly on foreign capital.

### **3. Culture in change - conclusion**

The interest in culture as the primary source of changes taking place in the world and the basis for explaining and interpreting social reality was subject to periodic changes described by Harrison: “In the 1940s and 1950s, cultural studies became popular, and interest in cultural aspects of social sciences reached its climax. Later the euphoria faded, but in the last fifteen years of the 20th century the growing interest in research on culture became evident. This resulted in an attempt to investigate the progress of civilization and the development of societies from the point of view of a new paradigm focused precisely on culture” (Harrison, 2003, pp. 23-24). Thus, culture plays the essential role in changes related to the socio-economic system in contemporary Poland.

This situation is unique due to the fact that there is no precedent in which the transition from a command economy and a limited scope of civil liberties to a system based on free market. On the other hand, as the example of China shows, economic transformation and development

of a competitive market economy are possible without transition to a democratic system. Both analysed variants of reforms are to a different extent related to the cultural characteristics, which imply the level of acceptance, pace and scope of the introduced reforms. The reform plan implemented in the Central and Eastern European countries was criticized by the Chinese scientist Zhang Weiwei who rejected the transformational shock therapy introduced in Poland, Baltic countries, Romania and Hungary. According to Weiwei “Twenty years ago cities like Warsaw and Budapest were a decade ahead of Shanghai, but now they seem a decade behind, if not more”. This is a rather bitter review of the reforms that Weiwei juxtaposed with the Chinese development model (Zhang, 2016). He defines weakness in the adoption of shock therapy and the weaknesses of the ruling elite.

Implementing shock therapy corresponded to certain cultural dimensions defined by Hofstede such as a short-term, less unambiguous and more individualistic orientation and a tendency to take risks. However, the implementation of a ready-made reform pattern that is in fact culturally alien has resulted in a number of consequences destabilizing the course of reforms, and in many places the achievement of the intended goal has been questioned. In turn, the gradual strategy adopted in China was a natural consequence of the cultural paradigm of harmony and long-term orientation. Chinese reference to the Asian Tigers – countries that are culturally similar, did not systematically increase the probability of achieving the intended goals.

Currently, both China and Poland have been challenged by the middle income trap. Overcoming it requires the stimulation of the innovation mechanisms. The question arises to what extent will the cultural factors typical of these two countries be pro-innovative and to what extent will they inhibit this process? The comparison of competitive advantages in terms of cultural features (Hofstede et al., 2011) indicates that the relatively low propensity to avoid risk of Chinese culture is a premise of innovation. In the case of China, a high propensity to take risks quite effectively balances the lack of individualism, and the government’s enormous accumulation of R&D funds based on the high power distance dimension can trigger a powerful innovative impulse, which in a highly collective culture is subject to wide diffusion in the economy.

Economic institutions do not exist in a void, but are surrounded by existing social and political structures. They exist primarily among cultural patterns and structures of social awareness, such as values or ideas. For this reason, economic culture contains a number of elements that are interconnected into a specific empirical design. In terms of the cultural paradigm, the question about differences in the development of capitalism – which is a modern economic system – in some regions of the world remains open. The comparison of two different development patterns in different geographic and cultural areas indicates the actual influence of cultural heritage in shaping these models. Although due to the negative historical experiences, the social attitude towards foreign investors in both China and Poland was cautious and sometimes even negative, FDI has become an integral element of reforms in both

economies because of the initial capital deficit. FDI originating predominantly from culturally similar countries, both in Poland and in China, have adapted well in both host countries, fulfilling the role assigned to them in the economy.

#### **4. PRC-changes in the economy after 1978**

The economic collapse at the end of Mao Zedong's rule, whose reforms were counterproductive in terms of achieving the position of a world leader, resulted in a decline in the share of global GDP, reaching only 4.9% and marginalization of the role in trade to the level of 1% (Góralczyk, 2018; Gawlikowski, 2012). The market mechanism triggered by Deng unleashed enormous layers of suppressed Chinese entrepreneurship, which Góralczyk describes as Chinese DNA, which is intrinsic to low-risk avoidance cultures. Nowadays, an excellent example of this phenomenon is the city of Wenzhou, which is an exemplification of Chinese entrepreneurship and the pro-export attitude of Chinese enterprises (Bernat et al., 2012).

Chinese society very quickly found itself in the conditions of the free market, which achieved high efficiency despite, or perhaps precisely because of the lack of individualism, which, according to Smith, was to be the cornerstone of the development of the market economy. The sources of this phenomenon can be found in many different factors of Chinese national culture contained in the basic assumptions about man, his relationship with the environment, his role and place in society and space, the meaning of life and management. The features of culture that can support the economic development of the Middle Kingdom include, without giving them a place in the hierarchy of importance, a deeply rooted peasant mentality<sup>2</sup>, community mentality, community ethics and the related cult of work and family. A holistic social vision and the perception of an individual's moral development as a transition from "I" to "we", mental flexibility resulting from religious syncretism (Confucianism, Taoism, Buddhism)<sup>3</sup>, resulting from the ability to adapt to a changing environment are another of these features. Also, the economy or the awareness of the rulers that they must meet social expectations in the long run, combined with Confucian loyalty to their superiors and faith in authorities, create the ideal of an educated and hard-working man, and not a warrior who steals someone else's property. The openness and simultaneous reserve (on the principle of "take the pearl and throw away the shell") towards the countries, ideologies and economic concepts of the West allowed it to maintain its own cultural patterns. Consequently, it was possible for China, like Japan, to create its own culturally adapted economic concepts. This learned attitude, ability and willingness to appreciate other valuable ideas and incorporate them into one's beliefs is helpful in economic, scientific, technical and intellectual development, as well as in the development of creativity and innovation.

In today's China, there is also the phenomenon of the so-called vertical individualism, associated with an increasing Gini coefficient currently amounting to about 0.5 (50%), which may be an obstacle to further development. So far, there is social consent to this stratification.

Another issue is that China did not have to be "grateful" to the West, such as Poland, for ideological and political help in the transformation of the political system. For historical reasons, they were characterized by a lack of fascination with the West and a far-reaching reserve of its ideology and economic concepts of the West. So China created its economy, which Poznański calls "Confucian economy" (Poznański, 2018, pp. 16, 18, 19, 30, 37), assuming the fundamental role of morality as the main research category. The subject of this economy is not production, but the distribution of goods. It is therefore closely related to the ethics of the ancient economics of Aristotle, where the goal of human management is not to fulfil the need for immediate gratification of the individual and access to goods but to extend one's existence through posterity. The time horizon of Confucianism is not the horizon of an individual separated from the whole, the life of one person. This results in a tendency to save.

Another important assumption of the Confucian economy that distinguishes it from other economic concepts is the existence of an abundance of resources, provided, of course, their rational use. This assumption is against the ruthless struggle for resources and fosters innovation. The Western assumption about the scarcity of resources results in the emergence of the concept of a competitive struggle to the death and life, as well as the concept of population surplus and, consequently, justification of wars for the appropriation of other people's goods, as well as actions leading to depopulation. Another premise of the Confucian economy is the source of wealth: it comes from labour, not capital, which makes it a theory of labour, not of violence. In this perspective, work is not treated as a compulsion, but a kind of sanctity and its main motivation is the love for the family understood in a narrower and broader dimension. The role of the market regulator is to be played by morality rooted in a multigenerational family, not by the "invisible hand of the market". The motivation to act economically is, therefore, strictly speaking, rooted in morality, and the market is something secondary to the family, as it does not create moral principles. The Confucian approach is also to have an impact on production costs. The larger scale of operations reduces production costs. The family, the clans in which half the people in Chinese villages still live today, are therefore an institution that allows greater independence from the authorities and banks. In the Middle Kingdom, over 60% of young people live with their parents after creating their own family. Multigenerational families allow for fundraising and less dependence on banks, which is important especially for small and medium-sized family businesses, which were one of the essential mainstays of the Chinese economic miracle. In the Confucian economy, people are as important a factor of production as capital. It is therefore beneficial, and by all means justifiable, to have many children. The Chinese government, under social pressure, abandoned the one-child policy.

Confucian economics also assumed, like Adams' theory of justice (Griffin, 2002), that every human being has an innate instinct for justice and a sense of unfair treatment. The foundation of unfair treatment, too far-reaching inequalities, are monopolies that want to ensure themselves undeserved profits. Their domination is to reduce the efficiency of the economy. Too great a spread of incomes is expected to result in a loss of confidence in the authorities and, as a consequence, in social unrest and political instability, which are dangerous for the development of the economy. Thus, the role of the state in the Chinese economy is extremely important - it is the prevention of corruption, the neutralization of both state and private monopolies, and a tax policy that allows the prevention of undeserved profits and the creation of rents reaching, despite the increase in productivity, only a very limited part of the society.

The goal of the state, which has not been achieved in China so far (Gini Index at around 0.5), should be to create such equalizing mechanisms, including financial ones, that will counteract too far social stratification, create parity between the countryside and the city, and mechanisms by which the most the wealthy will finance important social investments, such as education, environmental protection or culture. The state is to be efficient thanks to the so-called meritocratic governments - very demanding Confucian ethics exams for important positions.

To sum up, it can be stated that the peasant, collective and syncretic nature of Chinese culture implies the ability, or even moral compulsion, to cooperate, based on trust, reduces transaction costs, and increases the efficiency and security of market allocation. Deng Xiaoping called the system created in the PRC "socialism with Chinese specificity". The very term imposes a unique cultural specificity as a condition for its effectiveness and the lack of pressure to disseminate it. The decisive factor was the Chinese pragmatism of Xiaoping's reforms, which provided the economy with a market mechanism with a strong role of the state.

The barrier to the success of the PRC's bold economic reforms was the deficit of internal capital. Undoubtedly, the Confucian high propensity to save fueled the supply of capital, but on a scale not adequate to the actual needs of the reforming economy. When deciding to open up to foreign capital, it was pragmatically assumed in advance that it would not come from systemically close (socialist) countries, because they did not have capital surpluses, as well as patterns of competitive economic behavior, know-how and technologies, the implementation of which together with FDI would stimulate economy. First of all, they were not culturally compatible with China. Not in They found him in the geographically and culturally close Asian Tigers, what's more, among the representatives of his nation scattered around the world. The economic success of Chinese emigrants outside the communist market economies, supported by an extremely important attribute of trust, Zwolińska defines as the first channel of capital inflow to the PRC economy (Zwoliński, 2007). Countries taking place in different system conditions Fukuyama attributes to cultural attributes, above all the role of personal and family ties based on trust in this culture, which guarantee the security of transactions (Siewierski, 2010). This unique cultural phenomenon, arising out of collectivism,

is a Chinese phenomenon that guaranteed the inflow of domestic capital with the experience gained in highly developed people. The choice of the form of capital absorption itself: FDI - not portfolio ones, also turned out to be pragmatic. The flow of capital in the form of FDI is holistic in nature, it includes a wide, clearly heterogeneous transfer of production factors. Contrary to portfolio flows, it is not limited to the transfer of money capital only. In general, it is accompanied by the migration of other factors in the form of labor, production equipment, technological and organizational know-how and elements of the entrepreneurial culture of the country from which these investments originate. In the case of FDI, we are dealing with the transfer of the entire package of values, which in theories of economic growth are treated as determinants of this process. Basing the Chinese reforms initiated in the 1970s on the models of the Asian Tigers, not Western economic leaders, was in a sense a consequence of the experience, primarily the failure of reforms undertaken in China at the beginning of the 20th century in the form of the "May 4 Movement", "Movement new culture" based on unsuccessful attempts to implement Western civilization standards in the form of democracy or condemnation of Confucianism. In the Republic of China, the transfer of Western instruments of development (Western legal order) was neglected, based on the indoctrination of the Chinese with Western ideas (Bolesta, 2006).

Xiaoping's reform program since 1978, not shocking but gradual, spread over a very long period of time, was in line with the Chinese paradigm of harmony. The application of the shock variant of marketization of the economy implemented in the 1990s by the IMF in the CEE countries in the form of a program known as the Washington Consensus would be contrary to the need for harmony inherent in Chinese society. It should be remembered that the direct effect of their implementation in the countries of Central and Eastern Europe was a recession, which China has consistently avoided for four decades (since 1979). The variant of gradual reforms is inscribed in the paradigm of harmony and long-term nature, unlike shock therapy, implemented by the Washington Consensus reform scenario.

The Chinese transformation package was limited to economic reforms and only marginally concerned with political issues. The PRC remained a communist country with an authoritarian form of governance. The tangible success of the reforms in the form of an increase in the living standards of the inhabitants was to ensure social support for the continuation of the communist form of power. Earlier, such support for reforms was also obtained by Mao Zedong, but then the motive of public approval was to ensure the country's sovereignty after a hundred years of humiliating addiction. The political system of the PRC during the economic transformation has evolved from the authoritarian one at the turn of the 1970s and 1980s (Gawlikowski, 2012) to the present form known as welfare authoritarianism. Chinese decision-making centralism, which is characteristic of the high-distance culture of power, allowed for the efficient implementation of reforms without opposition from the opposition inherent in democratic systems. Extensive state intervention in East Asia has an ancient tradition, it was also present in Japan, Singapore and South Korea (Gawlikowski, 2012). The very issue of privatization,

which is the essence of the reforms of the neoliberal Washington consensus, found no fertile ground in China. In the Confucian tradition, private property was treated distrustfully as "morally reprehensible" appropriation, which corresponded to the belief that individualism is reprehensible. The behaviour of the authoritarian system in the PRC is treated by Bolesta as a consequence of culturally conditioned patterns of social preferences (Bolesta, 2006).

Authoritarianism, devoid of opposition reviews, allowed for wide-ranging government spending to build infrastructure that created China's high investment attractiveness (World Investment Report, 2000-2018) and was able to effectively cushion the market defects in the 2008 crisis. the economy \$ 586 billion (Morrison, 2013). It is state spending that has evolved into another driving force for Chinese economic growth at the turn of the 20th and 21st centuries.

Xiaoping, when constructing the reform program, used the achievements of the Western economy in his pragmatic way, implementing a complex of economic solutions for the Western man that was completely mutually exclusive: the strength of the state being the essence of Keynesianism and the efficiency of the market mechanism on which neoliberal thought was based, a historically unique doctrine of growth was constructed. He did not directly benefit from ordoliberalism - a concept from which the Western European model of development in the form of a social market economy grew, because it was based on the values of the Christian Church, culturally alien to the inhabitants of this part of Asia. Nevertheless, the ethical value gap needed, inter alia, Confucianism has filled the Xiaopinga program with the security of its transactions. The reference to tradition was important for the social acceptance of this solution, and Confucius personified it by all means.

Combining Keynesian reforms with neoliberalism in the program, being a synthesis of contradictions, is the essence of Taoist in and yang, it allowed for the synergy effect. The socially desirable process of gradual but consistent enrichment of the society, based on the effectiveness of the market, ensured social support for the government's moves, although it was not a sine qua non-condition such as in the conditions of a democratic state. A pragmatic assumption was made of the lack of social evenness of this process, characteristic of marketization, which is reflected in Deng's words "some get rich first". The reforms based on the efficiency of the market mechanism generated extreme inequalities, the scale of which is reflected in the Gini index value at the official level of 0.474, unofficially even 0.61.

Attention should be paid to the cultural element in the process of accepting inequality. Chinese culture is a high-distance culture, in which the element of social inequality has a relatively high social acceptance, however, extreme income differences are a threat to social peace, which the authorities in Beijing take into account. The state is slowly introducing mechanisms to counterbalance growth at the expense of its pace. Officially, in the 12th five-year economic plan of the KPCH for 2011-2015, the azimuth of lower growth was adopted in exchange for its greater sustainability. On the other hand, a decline in growth could become a much stronger threat to the social peace of a country whose citizens have become accustomed

to systematically increasing incomes. Xiaoping's reforms allowed for the elimination of poverty, the removal of 200 million inhabitants from extreme poverty, and then the construction of the middle class, which in 2018 already amounted to 300 million. Paradoxically, in a socialist society, by definition classless, it is a mainstay for power. The growing prosperity of the middle class has a stabilizing dimension, and the prosperity of this group encourages them to maintain the status quo towards the ruling party (Hefele et al., 2011).

Currently, in the second decade of the twenty-first century, it has become another flywheel of growth, making it independent of foreign consumers - the primary engine driving this process. The integration of neoclassical concepts based on the effectiveness of the market mechanism and the Keynesian effectiveness of a strong state intervention, which is unacceptable for a man of Western culture, which grew out of the logic of the process of reaching the truth based on mathematics, universal rationalism, are not mutually exclusive by Chinese logic. Taoist reconciliation of the opposites in and yang is at odds with Western linearity, logical empiricism and rationalism. The paradox and contradictions in Chinese philosophy are mindful of the normal elements of the functioning of the world (Bolesta, 2006), which makes it possible to call contemporary China "a fantastic kingdom of opposites" (Strittmatter, 2018, p. 38).

The long-term approach and the lack of pressure for quick success imposed by the pressure of four-year elections in Western countries allowed for the adoption of a gradual variant of reforms and the systematic implementation of the adopted strategy. Slow, consistent reforms, almost unnoticeable for the Western world, allowed China to return to the international arena, and the consistent building of the economy's potential already resulted in the potential of the world's second economy at the end of the 20th century. The cultural attribute in the Hampden-Turner and Trompenaars catalogue in the form of external controllability, meaning high Chinese adaptability, favoured the absorption of foreign management solutions transferred with capital in the form of FDI. Chinese controllability, meaning high adaptability, has clear limits in the form of core values. Quoting the leading Chinese ideologist Zhang Zhidong, "Chinese science is the foundation and Western knowledge serves practical purposes," Fairbanks explains the instrumental and utilitarian treatment of Western knowledge (Fairbank, 2004).

Bold state investments, including in infrastructure, they created attractive conditions for private capital investments, and large projects (the Olympic Games in Beijing in 2008, the World Exhibition EXPO 2010) generated an attractive image of the country for investments, creating an image of consumption by an affluent society. Another growth driver seems to be the Chinese FDI and accompanying projects (One Belt One Road) creating an intercontinental communication and transport artery. While in the past the high savings rate based on the Confucian mentality generated the desired high capital accumulation necessary for investment, now it appears to be constraining domestic demand, which the authors of the reform intend to replace the rest of the world demand for Chinese goods from the initial phase of reforms. China is currently experiencing a "consumer miracle" with deep cultural roots.



Although Confucianism formulates the moral imperative of modesty in consumption, it points to a macroeconomic phenomenon in which household welfare builds a harmonious society (Hefele et al., 2011). The size and dynamics of Chinese consumption imply intense changes in the global market. The element of social relations, which is immanent for Chinese culture, is *guanxi*, which is often a pretext for the purchase of luxury goods, and often the object of corrupt behaviors (Bernat, 2015) China has enormous consumption reserves, considering the relatively low share of private consumption in the distribution of GDP. At the present stage, cultural heritage also turns out to be important, though not autonomous, factor influencing the effectiveness of incorporating consumption into the development mechanism.

The launch of the market mechanism, which liberated huge amounts of Chinese entrepreneurship, together with a huge wave of foreign capital initiated the economic growth of the most populous country in the world after 1978. Foreign capital has been widely implemented in the economy, taking into account and maintaining the cultural context of the host country, as well as the entire reform process, i.e. the Chinese variant of economic transformation. The role of China in capital flows at the turn of the 20th and 21st centuries Góralczyk very aptly compared to the stratagem of Chinese strategist Zhuge Liang from the Three Kingdoms era. The deficit of Zhuge's shots was prevented by sending ships with straw puppets on the water, which were indistinguishable from ships and real crew in the thick fog. When the imitation armada left the port, it was inundated with a barrage of enemy arrows. Thus, the Shu state acquired a huge supply of arrows (Góralczyk, 2018). The aforementioned metaphor clearly illustrates the Chinese strategy of changing the role of China not only in terms of capital flows but in the entire world economy. In the late 1990s, foreign capital, encouraged by extremely low labour costs and a huge reservoir of unqualified labour in China, decided to "fire its arrows" - allocate capital in the Chinese economy respecting the specific conditions imposed on it.

From the beginning of its opening, the PRC conducted a strict and, due to its high investment attractiveness, very effective policy of controlling the inflow of direct investments (Cholaj, 2008). He took care of the inflow of capital to modern fields, under the strict condition of earmarking for export at least 50% of the product resulting from this investment and the rigour of establishing a joint venture with a Chinese partner. The authoritarian form of exercising power, arousing criticism of public opinion in the West, turned out to be a desirable partner for foreigners, including Western corporations, guaranteeing the fulfillment of agreements (Siewierski, 2010). The pragmatic approach to the economy, characteristic of Chinese culture, is proved by the fact that the experiment initiated by Deng Xiaoping in 1978 in the event of a possible failure of the foreign capital absorption program created five investment enclaves in the form of Special Economic Zones with conditions privileged for foreign capital, located in sufficiently large conditions. distance from the center of the country over (2000 km). In this way, it was possible to react in time in the event of possible failures. At the same time, they are located close to Hong Kong and Taiwan - potential sources of

investment capital with a clear predominance of ethnically Chinese. The essence of this experiment is reflected in Xiaoping's phrase "to go across the river feeling the stones under my feet" (Pieczonka, 2012). Although the Chinese economy was opened to foreign capital in 1978, its actual intensive inflow took place only after 1992.

The structure of capital flowing into the economy of the Middle Kingdom proves a good adaptation of investments from the economies of culturally close countries, where over 75% of FDI inflow consistently comes from Asian, not Western countries. The decisive leaders in the allocation of foreign capital in the Chinese economy are Asian corporations, and it is they who, taking advantage of the rent of cultural similarities and spatial proximity, participate most strongly in the benefits of this market. Much of the foreign capital came and still comes from *Huaqialo* - a foreign diaspora of Chinese emigrants who have achieved economic success abroad, which is a rent of trust in the representatives of the nation who have achieved success in other system conditions and at the same time the implementation of the *guanxi* formula. The high share of capital inflow from Hong Kong and Taiwan - culturally identical - eliminated cultural barriers which are very important in the allocation of capital in the form of FDI. Western capital (from the USA and the EU) began an intensive investment expansion in China in the second half of the 1990s, and its share in annual flows never exceeded 16% of capital invested in the form of FDI (according to MOCAM). The influx of Western capital to the economy of the Middle Kingdom encountered favourable cultural conditions in several aspects. Taking into account Hofstede's observations, the flow of capital from home economies of countries representing a low power distance to the host countries of high distance is a prerequisite for the success of internationalization (Hofstede, 2000). The high distance of power implying authoritarianism of the authorities was a guarantee of contracts, while controllability turned out to be a prerequisite for a collision-free implementation of management and technological solutions in the host country's environment, which generates potentially high efficiency of foreign enterprises in China. Additionally, for foreign investors, especially from the Western cultural circle, the authoritarian power characteristic of a nation of high power distance increased the predictability of its decisions. Contrary to the opinion of the West, it was convenient for international corporations and constituted a component of the PRC's investment attractiveness (Siewierski, 2010).

The foreign capital intensively absorbed by the Chinese economy allowed for the reversal of its role, the evolution of comparative advantages and the advancement of its competitive position. The very process of absorption of this capital in China, as well as its external investment activity, are a component of the Chinese transformation strongly integrated into the cultural environment. Opening the Chinese economy to Kaifeng Deng capital resulting from the real needs of the economy turned out to be a very important engine of growth, perfectly inscribed in the powerful process of globalization. The question arises: to what extent has China benefited from this process, and how much did it generate itself, given the country's size, the deficit of capital and know-how, and cultural specificity.

## 5. Conclusions

The economic success of the PRC, measured at the rate of the longest economic growth in modern history, accompanied by an increase in the wealth of the society, is the result of unique endemic reforms adopted in this country, perfectly inscribed in the culture of society, which made their effectiveness possible. The main dimensions of Chinese culture inherent in the changes seen through the prism of Western researchers are long-term nature, collectivism, high power distance, and relatively low-risk avoidance. The avant-garde of Chinese reforms is an equally important combination of opposites in the Taoist spirit, subordinated to the paradigm of harmony, which made phenomena unacceptable in Western culture effective in South Asian culture. The nature of the reforms, well inscribed in the cultural context, ensuring their high efficiency, resulting in economic success on a global scale. The high distance of power gave social legitimacy to the decision-making centralism, which made it relatively easy to implement often difficult economic reforms and to accept their social consequences. The uniqueness of the Chinese reform program resulted from the adoption of a variant compatible with the cultural environment, the role of which in economic processes, although contemporary economic thought sees it, does not fully appreciate it. Ignoring cultural characteristics in the neoliberal reform program of the International Monetary Fund called the Washington Consensus meant that its application not in all conditions did not bring the desired effect in the form of effective economic development. The harmonious inclusion of successive growth engines in the Chinese transformation process was accompanied by progress in competitiveness in the global economy. China, although cautious towards foreigners, had a cultural predisposition to absorb foreign capital in the form of FDI, which was a very important exogenous engine of growth, a source of capital and a carrier of know-how, especially in the first phase of reforms. At the present stage of changes, the use of Chinese FDI in the world, as well as internal consumption in the growth process as the engines of economic growth, carries certain risks resulting from the cultural specificity of the Middle Kingdom society and requires a wise socio-economic policy.

## References

1. Balcerowicz, L (1997). *Socjalizm, kapitalizm, transformacja. Szkice z przełomu epok*, PWN. Warszawa: PWN.
2. Belka, M. (1991). *Reganomika. Sukces czy porażka?* Wrocław: Zakład Narodowy im. Ossolińskich.

3. Bernat, M. (2015). Zmiany w konsumpcji społeczeństwa chińskiego na początku w XXI wieku. In: L. Karczewski (Ed.), *Kulturowe i etyczne wyzwania współczesnego biznesu, gospodarki i zarządzania*. Opole: Oficyna Wydawnicza Politechniki Opolskiej.
4. Bernat, M. (2019). *Cultural Determinants of Chinese Internationalization in the Form of FDI, W: Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage*. Proceedings of the 34th International Business Information Management Association Conference (IBIMA). K.S. Soliman (Ed.), pp. 10281-10286. International Business Information Management Association.
5. Bernat, M., Zhang Fan, Wu Wenying, Qiu Xiaofei (2012). A Microcosm of the Contemporary Chinese Family Business - The Ebb and Flow of Wenzhou Model. In: A. Mariański (Ed.), *Firmy rodzinne – współczesne wyzwania przedsiębiorczości rodzinnej. Determinanty rozwoju. Przedsiębiorczość i Zarządzanie, t. XIII, c. 8*. Łódź: Społeczna Akademia Nauk.
6. Bernat, M., Bruska, A., Jasińska-Biliczak, A. (2017). Influence of the Cultural Background at Small and Medium Sized-Enterprises Innovations in Regional Dimension. Working Papers, No. 12. *Institute of Economic Research*.
7. Bieńkowski, W. (1995). *Reganomika i jej wpływ na konkurencyjność gospodarki amerykańskiej*. Warszawa: PWN.
8. Bildhauer, R.G. (2005). *Polen und Deutsche: Nachbarn die sich ergänzen. Aktuell-DAS MTM-Infomagazin, No. 3*.
9. Bolesta, A. (2006). *Chiny w okresie transformacji*. Warszawa: Wydawnictwo Akademickie DIALOG, p. 81.
10. Castells, M., Banet-Weiser, S., Hlebik, S., Kallis, G., Pink, S., Seale, K., Servon, L.J., Swartz, L., Varvariuosis, A. (2017). *Another Economy is Possible: Culture and Economy in a Time of Crisis*. Wiley & Sons.
11. Chołaj, H. (2008). *Transformujące się Chiny w globalnym świecie z perspektywy polskiej. Chiny w globalnym świecie*. Warszawa.
12. Dabrowki, I., (2018). Ekonomia złożoności a równowaga wielopunktowa. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, Ekonomia, nr 529*. Wrocław, pp. 58-70.
13. Ekiert, G. (2001). The State after State Socialism: Poland in Comparative Perspective. *IWM Working Paper, no. 6*, Vienna.
14. Fairbank, J.K. (2004). *Historia Chin, Nowe spojrzenie*. Warszawa/Gdańsk: MARABUT.
15. Gawlikowski, K. (2012). *Co to są dzisiejsze Chiny?* Retrieved from: <https://studioopinii.pl/archiwa/5998>
16. Gesteland, R.R. (2000). *Różnice kulturowe a zachowania w biznesie*. Warszawa: PWN.
17. Gomułka, S. (2014). Transformacja gospodarczo-społeczna Polski 1989-2014 i współczesne wyzwania. *Nauka, No. 3*. Warszawa: Biuro Upowszechniania i Promocji Nauki PAN.

18. Góralczyk, B. (2018). *Wielki Renesans. Chińska Transformacja i jej konsekwencje*. Warszawa: Dialog.
19. Griffin, R.W. (2002). *Podstawy zarządzania organizacjami*. Warszawa: PWN.
20. Harrison, L.E. (2003). Dlaczego kultury nie sposób przecenić? In: L.E. Harrison, S.P.P. Huntington (Ed.), *Kultura ma znaczenie, jak wartości wpływają na rozwój społeczeństw* (pp. 23-24). Poznań: Zysk i S-ka.
21. Hefe, P., Dittrich, A. (2011). Die Mittelschicht In China. *KAS Auslandsinformationenn, No. 12*.
22. Hofstede, G. (2000). *Kultury i organizacje*. Warszawa: PWE.
23. Hofstede, G., Hofstede G.J., Minkov, M. (2011). *Kultury i organizacje*. Warszawa: PWE.
24. Hryniewicz, J.T. (2004). *Polityczny i kulturowy kontekst rozwoju gospodarczego*. Warszawa: Wydawnictwo Naukowe Scholar, p. 241.
25. Jarmołowicz, W., Piątek, D. (2008). Strategie transformacji a doświadczenia wybranych krajów. Elementy analizy porównawczej. *Zeszyty Naukowe, No. 6*. Kraków.
26. Jarmołowicz, W., Szarzec, K. (2011). *Liberalne przesłanki polskiej transformacji gospodarczej*. Warszawa: PWE.
27. Jasińska-Biliczak, A. (2019). The third sector—the new path towards the entrepreneurship of the future?—polish insights. *Ad Alta: Journal of Interdisciplinary Research, 9(2)*.
28. Jasińska-Biliczak, A., Kowal, J., Hafner, J. (2016). *Innovative capacity in small regional enterprises in transition economies: An exploratory study in Poland*. Proceedings of the Twenty-second Americas Conference on Information Systems (AMCIS). San Diego, California, pp. 11-14.
29. Kaliński, J. (2017). Fazy wzrostu gospodarki polskiej po 1918 roku. *Optimum. Studia ekonomiczne, 1(85)*. doi:10.15290/ose.2017.01.85.05
30. Kaliński, J., Landau, Z. (2003). *Gospodarka Polski w XX wieku*. Warszawa: PWE, pp. 369-404.
31. Kornai, J. (2006). *The great transformation of Central Eastern Europe. Economics of Transition and Institutional Change*. doi: 10.1111/j.1468-0351.2006.00252.x
32. Mahbubani, K. (2008). *The New Asian Hemisphere: The Irresistible Shift of Global Power to the East, Public Affairs*. New York.
33. Miłaszewicz, D. (2004). Retrospektywne ujęcie roli państwa w gospodarce w myśli ekonomicznej. *Ruch Prawniczy, Ekonomiczny i Socjologiczny, LXVI, 3*, p. 198.
34. Morrison, W.M. (2013). *China's Economic Rise. History, Trends, Challenges, and Implications for the United States*. Congressional Research Service.
35. Moscovitz, H. (2020). *Regional identity and economic development in 'recovering' regions: Exploring the Walloon case*. *Regional & Federal Studies*, pp. 1-28.
36. Murrell, P.P. (1997). What is Shock Therapy? What did in Poland and Russia? In: P.P. Hare, J. Davis (Eds.), *Transition to the Market Economy. Critical Perspectives on the World Economy, vol. I*. London/New York: Routledge.

37. Olifrowicz, M., Walik-Dusińska, A., UNCTAD (2002). *Bezpośrednie inwestycje zagraniczne na świecie i w Polsce: tendencje, determinanty i wpływ na gospodarkę*. Warszawa: Ministerstwo Gospodarki.
38. Pieczonka, A. (2012). *Chińskie „Go Global”*. Dylematy i wyzwania dla Chińskiego Smoka. Retrieved from: <http://www.gochina.gov.pl/>
39. Pietrewicz, L. (2001). Wyniki i perspektywy polskich przedsiębiorstw a jakość kadry menedżerskiej. In: E. Mączyńska (Ed.), *Restrukturyzacja przedsiębiorstw w procesie transformacji gospodarki polskiej*. Warszawa: DIG.
40. Poznański, K. (2018), Konfucjanizm jako ekonomia moralna. In: W. Banach, M.A. Michalski, J. Sójka (Eds.), *Między Chinami z Zachodem. Człowiek i społeczeństwo, XLVI*. Poznań: Wydawnictwo Naukowe Wydziału Nauk Społecznych UAM.
1. Rajkiewicz, A. (1997). *Dochody i wydatki ludności. Minimum socjalne. Społeczeństwo polskie w latach 1989-1995/96. Zagadnienia polityki społecznej*. Warszawa: Wydawnictwo Uniwersytetu Warszawskiego, p. 47.
2. Ribera-Fumaz, R. (2009). From urban political economy to cultural political economy: rethinking culture and economy in and beyond the urban. *Progress in Human Geography*, 33(4), pp. 447-465. doi:10.1177/0309132508096352
3. Siewierski, J. (2010). *Kultura a rozwój gospodarczy. Analiza porównawcza Zachodu i Azji Wschodniej*. Warszawa: SGH.
4. Smoleń, M. (2006). Społeczne skutki procesów transformacji gospodarczej w wymiarze lokalnym. *Nierówności Społeczne a Wzrost Gospodarczy*, No 9, pp. 283-296.
5. Soszyńska, E. (2013). Postwaszyngtoński konsensus, czyli: czy istnieją reguły budowy zdrowej gospodarki? *Studia Ekonomiczne*, No. 139. *Współczesne problemy ekonomiczne: polityka państwa a proces globalizacji*. Katowice: Uniwersytet Ekonomiczny w Katowicach, pp. 112-121.
6. Strittmatter, K. (2018). *Chiny 5.0, Jak powstaje cyfrowa dyktatura*. Warszawa: Grupa Wydawnicza Foksal.
7. Sysner, J. (2009). Conceptualizations of Culture and Identity in Regional Policy. *Regional & Federal Studies* 19(3), 437-458, doi: 10.1080/13597560902957518.
8. Tambovtsev, V.L. (2018). Innovations and culture: Importance of the analysis methodology. *Voprosy Ekonomiki*, 9, pp. 70-94.
9. Weber, M. (2006). *Socjologia religii. Etyka gospodarcza religii światowych*. Kraków: Nomos, pp. 195-198.
10. Wojtyna, A. (1988). *Nowe trendy w zachodniej teorii ekonomii*. Kraków: Akademia Ekonomiczna, pp. 33-37.
11. World Investment Report (2000-18). New York/Geneva: United Nations Publication.
12. Zhang, W. (2016). *China Horizon: Glory and Dream of a Civilizational State*. New York: World Century Publishing House.
13. Zwoliński, A. (2007). *Chiny – historia, teraźniejszość*. Kraków: WAM, pp. 267-268.

### Footnotes

1. An acronym for PPWW, short for Polish: Super-normative wages tax.
2. The peasant mentality, according to Góralczyk ([www.youtube.com/watch?v=pEZmwyi2ZZo](http://www.youtube.com/watch?v=pEZmwyi2ZZo)), is of decisive importance for understanding Chinese reforms. It is closely connected with Confucianism, with collectivist (group) ethics, with the ethics of relations, with rational submission to older and more experienced people, who wish us well. It is first and foremost the priority of the community over the individual. In this ethics, there is no such emphasis on the individual, his claims of rights against the community, as in individualist ethics. The individual feels part of something greater than himself - the family, the state as a family of families, and finally, the entire cosmos, enjoying it. Its self-realization is the self-realization of the group, and not the group itself - an artificially mentally isolated individual, separated from the totality of being. The peasant mentality is one with nature and life. Farmers who come into contact with nature daily find it easier to unite with it, merge, identify and "dissolve into being", in a mystical experience of unity with the world, with its order and harmony. It is different with people locked in concrete jungles. Until today in China, even in multi-million cities, you can see people living there walking in their housekeeping corridors or streets near their homes in multi-storey high-rise buildings. Thus, the individual is valued in the peasant mentality for the ability to adapt to the whole, and not for individualism ("a protruding nail must be hammered in").
3. The same Chinese attend Confucian, Taoist and Buddhist temples. In the West, this would be considered a betrayal of beliefs. The Western mentality (especially in countries with a high uncertainty avoidance index, but not only) means "you are with us or against us". Inhabitants of the Far East countries have a different mind. They can worship wise people with the same zeal, so their mind is not exclusive, but inclusive. There is no such struggle and competition in the religious market as in the Western world.





## THE ROLE OF SOCIAL MEDIA MARKETING OF ESG IN WAREHOUSE LOGISTICS

Artur BŁASZCZYK<sup>1\*</sup>, Milena LE VIET-BŁASZCZYK<sup>2</sup>

<sup>1</sup> Faculty of Mechanical Engineering, Lodz University of Technology; artur.blaszczyk@p.lodz.pl,  
ORCID: 0000-0001-6371-0294

<sup>2</sup> Faculty of Management, University of Lodz; milena.le.viet.blaszczyk@uni.lodz.pl,  
ORCID: 0000-0003-1237-4205

\* Correspondence author

**Purpose:** Due to the relatively low level of exploration of the topic of ESG in social media marketing communications, the authors of this text decided to diversify the purpose of the article: 1. to explore the topic of ESG activities in warehouse logistics and its communication in SM; 2. to carry out and present the results of quantitative research involving statistical analysis of the results of social media marketing publications on ESG.

**Design/methodology/approach:** The following research question was posed by analogy: P1. Which area of ESG activity is most attractive to customers from the perspective of engagement on LinkedIn? The research hypothesis was then stated: H1. There is a statistically significant relationship between the amount of storage space and the marketing performance of publications on LinkedIn and is positive in nature. To achieve the stated objectives and verify the hypotheses, a two-stage research process was designed. It began with a literature analysis and synthesis and was followed by a quantitative study of marketing performance.

Among other things, the first stage of the research defined the key areas of ESG activity in the real estate market. This division became the basis for the second, quantitative stage of the research. The study consisted of an analysis of online data from November 2022 - July 2023 compiled from the results of 140 posts published on the social media platform LinkedIn. This is because the pilot study, as well as the analysis of the literature, showed that this is the platform most often chosen to communicate ESG activities. Statistical analysis included: a comparison of client engagement scores in publications on key ESG areas in the real estate market, and a correlation analysis of warehouse space and social media marketing scores.

**Findings:** It was observed that in most cases, communication of ESG-related activities formed the majority of a company's total communication on its LinkedIn profile. It proves that the most frequently communicated ESG area on LinkedIn is environmental aspects. However, they are associated with the lowest average engagement. Subsequently, Pearson's correlation coefficient has been used to examine the severity of the relation between the different variables. Once the analysis is executed, it may be concluded that there is a statistical significant correlation between the size of the warehouse and the outcome of publications communicating ESG on LinkedIn. A stronger correlation occurred in the analysis of engagement scores.

**Practical implications:** It was found that there is a very high correlation between the size of the warehouse and consequently the ranking of developers in Europe and the results of publications communicating ESG on LinkedIn. Based on the results, it can be recommended

that further research should be pursued in the direction of engaging customers in ESG marketing communications.

**Social implications:** The presented article focused on exploring the topic of ESG activities in warehouse logistics and its communication in social media. The construction sector contributes significantly to greenhouse gas emissions. The sector therefore faces a number of challenges that it is socially expected to solve. Following in the footsteps of researchers, an increasing number of institutions at both the European and national levels are introducing laws and regulations to accelerate this process. EU directives, national laws and guidelines from independent institutes are aimed at forcing the industrial sector to respond and implement solutions. The ESG revolution is gaining momentum because of this. We are currently in a transitional phase, and there is still a lot of work to be done, but change is already inevitable. ESG activities that are being implemented by companies are being communicated in parallel on social media.

**Originality/value:** The results of the research evaluate the correlation between warehouse size and marketing performance, show areas of ESG, which are the most frequently communicated and the most attractive to customers from the perspective of engagement on LinkedIn. It can be a basis for future studies on the implementation of ESG activities in warehouses and can serve practitioners in selecting projects of interest and worth deploying.

**Keywords:** ESG, contemporary logistics, modern warehouses, social media marketing.

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

## 1. Introduction

Environment, social and governance (ESG) topic has gained global relevance for all stakeholders in recent years - industry, consumers, investors, communities and governments. Initiatives in this area are among the most widely used indicators for assessing a company's sustainability performance (Tang et al., 2023). Companies have begun to take ESG criteria more into account when planning their future operations and strategies (Whitelock, 2019; Gillan et al., 2021; Camilleri, 2015; Velte, 2017). These practices are most often examined in the reporting of non-financial information about companies (Miralles-Quiros et al., 2018). The beneficial consequences of ESG also include improved corporate reputation and increased consumer trust in the brand (Gillan et al., 2021; Camilleri, 2015; Kim et al., 2018). Companies are placing greater importance on social, corporate governance and environmental initiatives as a result of the beneficial effects of ESG strategies on overall business success. Nevertheless, there has been a recent hypothesis that global gross domestic product (GDP) could significantly decelerate as climate change significantly accelerates (Flavelle, 2023). Given the prevailing situation, organizations have started to pay more attention to reducing their environmental impact by incorporating sustainability benchmarks (Gundogdu et al., 2023).

Since the official introduction of the ESG concept in 2004, it has been vigorously pursued in America, Europe and other developed countries. A number of accomplishments have fostered the advancement and ripeness of social, environmental and governance drivers, as well as ESG

as a whole, such as the enactment of an ESG evaluation system, ESG exposure standards and an ESG indices system. These enablers are continually shaping a new paradigm for sustainable development. With the concept of ESG progressively turning into the mainstream, ESG has been extensively studied, practiced and disseminated in practice and has drawn the interest of scientists worldwide. Currently, there are few studies dedicated to ESG studies. More importantly, they mainly focus on ESG investment (Daugaard, 2020), the significance and relevance of ESG factors in financial decisiveness (Ziolo et al., 2019), the influence of ESG ratings on the measurement of corporate sustainability results (Drempetic et al., 2020), the importance of ESG indicators in SRI (socially responsible investing) (Widyawati, 2020) and the origin and significance of the ESG name in investment (Eccles, Viviers, 2011). Furthermore, there are literature surveys on the function and effects of corporate governance (G) in ESG (Yoshikawa et al., 2021) and studies discussing the relations between corporate social responsibility and corporate governance (Aluchna, Roszkowska-Menkes, 2019). It is noticeable at present that ESG research primarily focuses on one facet and there is not sufficient literature on social (S) and environmental (E) factors. On the other hand, governance, environmental and social layers have a major role to play in determining the future financial results and social influence of companies. Therefore, as an investment modality that embraces environmental, social and governance factors, ESG is an important driving factor for incentivizing corporate sustainability, and the mutual interaction between its strands is also a crucial point that deserves to be addressed.

A recent statistic indicates that ESG has become increasingly important (Broadstock, 2021). For example, 85% of companies in the S&P 500 index in the US submitted an ESG declaration and released their "sustainability reports" in 2018. (COSO & WBCSD, 2018). Since 2020, the demand for ESG-focused hedge funds has increased significantly (KPMG, 2023). It has been observed that companies with environmentally sensitive strategies and high ESG scores had good investment returns during the pandemic period (Broadstock, 2021; Albuquerque et al., 2020). As a result, companies are expected to pay more attention to ESG strategies in future years.

ESG in companies is an area avidly examined by researchers. In the literature, one can find surveys that combine the social media and ESG spheres, which include: strategies for communicating ESG-related activities on social media (Cho et al., 2017), the relationship between publishing ESG information on social media and company performance (Abbas, 2019), elements of ESG messages on social media (Saxton et al., 2019), consumer involvement in ESG communication on social media (Chu et al., 2020), or the impact of ESG messages on company reputation (Grover et al., 2019). However, few undertake qualitative research - those published to date include: rules and regulations in social media and their impact on limiting ESG messages (Stohl et al., 2017), co-creation of socially responsible activities with recipients of social media messages (Okazaki et al., 2020), branding of employers as socially

responsible in social media (Benitez et al., 2020) and elements of storytelling in ESG messages in social media (Araujo, Kollat, 2018).

ESG activities are also being promoted on social media by companies operating in the field of logistics and supply chain management. It is in this area where warehouses are vital links, with demand reaching record levels due to, among other things, the effects of Covid-19 and the increasing share of e-commerce in overall sales. Sustainability, corporate governance and social responsibility strategies are now becoming the cornerstones of investors, developers and tenants in the warehouse sector. Abundant surveys on the issue have demonstrated that environmentally benign approaches enhance the performance of logistics companies (Cosimato, Troisi, 2015; Cherrafi et al., 2018; Acciaro et al., 2014; Zavadzka et al., 2015; Green et al., 2012). On the other hand, the warehousing sector is one of the key contributors to worldwide greenhouse gas releases, the generation of waste, and energy and water usage. Crucially, the sector has addressed ESG challenges to ensure a more sustainable future, and above all, warehouse properties are one area of the industry that is likely to have a profound impact on the corporate governance society and environment (Newell, Marzuki, 2022). Hence, this article, embarking on a quantitative netnographic examination of social media communication of ESG activities by warehouse space developers, will help fill the research gap and advance current knowledge in this area.

## **2. Literature Review**

### **2.1. The importance of ESG**

In the wake of the change, companies have instituted a managerial approach that is responsive to "all stakeholders". The primary foundational goals of companies, which were initially deemed "profitability and value creation", have apparently evolved as a consequence of this transition to "value generation for all stakeholders". In this respect, Elkington (Elkington, 1997) suggested the "Triple Bottom Line" concept in his study. Rather than focusing purely on profitability, this approach allows companies to heed economic, social and environmental implications. The proliferation of worldwide sustainability ideas has brought CS and CSR to the forefront of company management in a continuous process. ESG principles have also been integrated into corporate policies in this respect (Whitelock, 2019; Gillan et al., 2021; Murphy et al., 2013). The idea of corporate sustainability has developed, especially with the increasing importance of this attitude in the relations between companies and their stakeholders (Perrini, Tencati, 2006). As a consequence of this approach, the need to assess companies using more criteria than their financial, economic and social impact is high-lighted (Nazari et al., 2015; Appuhami, Tashakor, 2017). In such circumstances, businesses are targeting changes that will

fulfill investor and stakeholder demands in order to bolster the trust and reputation of the brand (Gillan et al., 2021; Camilleri, 2015; Kim et al., 2018). Companies' policies for broad sustainability also incorporate many different processes, such as economic, fiscal, societal, environmental, cultural, institutional and technological drivers.

The extensive adoption of ESG practices by firms has also resulted in the enactment of CSR-specific policies (Murphy, McGrath, 2013). Depending on their sustainability goals, companies that apply the CSR concept may pursue various projects, such as engaging in activities to protect nature and the environment, and acting morally and responsibly toward society. Accordingly, companies may have the ability to benefit the environment and society beyond achieving efficiency and profitability (Berman et al., 1999; Abratt, Sacks, 1988; Steiner, G., Steiner, J.F., 2000; Moir, 2001).

Since ESG measures impose costs on companies, implementing them can have a negative impact on shareholder assets (Jha, Rangarajan, 2020; Branco, Rodrigues, 2008). The costs generated by these practices are seen as a factor that can negatively affect the value of companies due to short-term costs (Jha, Rangarajan, 2020; Branco, Rodrigues, 2008; Brammer et al., 2006; Kim, Lyon, 2015). On another hand, corporations also face the possibility of using ESG as a corporate wide cover to evade a comprehensive audit (Lokuwaduge, Heenetigala, 2017). Nonetheless, such practices are perceived as long-term investments with benefits expected to be materialized in the future (Miralles-Quiros et al., 2018). High upfront costs, especially in developing countries, may prompt companies to delay such investments, which translates into postponing the date after which the benefits will appear (Cai et al., 2016).

ESG, CSR and financial success are positively correlated, according to numerous studies in the literature (Gillan et al., 2021; De Lucia et al., 2020; Alshehhi et al., 2018; Friede et al., 2015; Ferrell et al., 2016; Margolis et al., 2009; Goll, Rasheed, 2004). Furthermore, there are instances where companies' sustainability, social responsiveness and ESG efforts have had a positive effect on financial performance (Velte, 2017; Galbreath, 2013).

Environmentally friendly initiatives can positively affect the performance of companies. Potential threats from climate change crises and global warming have increased investor demands, especially for environmentally sensitive companies (Ng et al., 2020). Despite this, multinational corporations do not have a unified ESG roadmap (Fransen, 2019), and efforts to achieve net zero emissions globally are unfortunately not at a satisfactory degree. In this context, ESG and eco-friendly initiatives are gaining popularity and importance.

In the literature, there are many studies on the virtuous impact of green policies on the performance of logistical businesses (Cosimato, Troisi, 2015; Cherrafi et al., 2018; Acciaro et al., 2014; Zavodska et al., 2015; Green et al., 2012). In addition, logistics and supply chain operations that are conceived and executed with the environment in mind have positive environmental impacts, such as reduced carbon emissions, reduced energy consumption and air pollution (Jaggernath, Khan, 2015). What's more, eco-innovative practices in processes, products and services have come into their own with the prevalent use of greener technologies

(Díaz-García et al., 2015). Consequently, the positive impact of environmental innovation practices on company performance (Fernando, Wah, 2017) has increased the number of subsequent initiatives, including ESG.

## **2.2. ESG in warehouse logistics**

Managing the supply chain sustainably is the process of the management of raw resources and services from vendors to the manufacturer/service partner to the client and back again, with a clear emphasis on improving social and environmental impacts (Nozari, Ghahremani-Nahr, 2023). Reduced barriers to trade and improved technology (Jorgensen, Knudsen, 2006) have enabled businesses and supply chains to explore expansion across multiple regions and countries, compounding the need for sustainable end-to-end supply chain management. It is also not enough for companies to promote sustainability just inside their own organization - overall supply chains in general must be sustainably managed to continue to be competitive. Advantages of having a sustainable supply chain include enhanced brand appeal, consumer loyalty and stakeholder contentment, not to mention reduced social and environmental effects (Nozari, Ghahremani-Nahr, 2023). Possessing a sustainable supply chain would also enhance visibility and clarity in the entire chain, empowering businesses to respond quickly to changes in the market and emerging circumstances.

Warehousing is one of the crucial elements of the supply chain. In the past, most companies involved in warehousing and transportation gave limited consideration to the environmental implications of their operations and failed to understand the societal ramifications of their entrepreneurial activities. Such companies perceived such factors as cost effectiveness and client satisfaction to be key performance indicators (Linton et al., 2007; Quariguasi Frota Neto et al., 2008). However, this trend is changing and now developers, investors and tenants are paying a lot of attention to ESG measures (Gundogdu, 2023). Companies have begun to specialize in environmental, social and governance sustainability, and have experience in international logistics. In addition, companies are increasingly adjusting their future goals in accordance with a strategy focusing on ESG areas. ESG environmental categories encompass such issues as environmental cleanup, reduction of emissions, recycling, consumption of both natural resources and renewable energy while businesses are operating. Social criteria cover issues such as employee relations in terms of social working conditions and human resource practices. Corporate governance criteria refer to such matters as clear and qualitative management, diversity and attendance at board meetings (Whitelock, 2019; Galbreath, 2013; Ioannou, Serafeim, 2017; Park, Jang, 2021; SASB, 2023). The following ESG activities that are being implemented at warehouses can be mentioned (Gundogdu, 2023):

- greenhouse gas releases - managing and decreasing the amount of greenhouse gas production,
- energy and transportation management - handling energy volumes, assuring energy efficiency, using renewables, reducing carbon dioxide emissions, transportation management,
- air quality - governing and undertaking efforts against detrimental emissions to the natural environment (air pollutant emissions),
- water, sewage and hazardous materials economy - reduction of raw material and chemical wastes and management of pollution and waste levels,
- impact on biodiversity - protection of biodiversity with ecological vulnerability, limiting the use of non-renewable resources or outputs,
- people's rights and relationship with the community - applying business practices which respect and safeguard human rights, managing community relations and investments,
- availability and accessibility - providing access to and quality of products and services, deploying responsible corporate practices in the marketing,
- client well-being - delivering products and services that meet clients' satisfaction, taking into account their well-being,
- data security and confidentiality - assuring clients' privacy, data and product security,
- equitable employee practices - ensuring equitability, health and welfare of employees, effective human resource management,
- engagement of stakeholders - focuses on management participation options, like involvement of respective stakeholders in the management process and the existence of diversified, autonomous and highly experienced members,
- decision-making transparency - resolutions of the board of directors, making decisions and administrative actions available to the broader public,
- management of systemic risks - identifying and managing systemic risks related to creating long-term value,
- business ethics - firms and personnel operate in compliance with business ethics,
- supply chain management - a system of control that relies on the supply chain and supply of materials.

The aforementioned ESG activities are introduced in the warehouses to varying extents and are often accompanied by social media communication.

### **2.3. Marketing communication in social media**

We are currently in a time of dynamic development of technologies that enable two-way communication of messages between brands and customers, which is particularly important in marketing activities. These include marketing tools, methods and procedures that are tailored to the expectations of digital customers, enabling the realization of the goals of their sender in

the real market conditions of enterprises (Anthony, Govindarajan, 2007). Marketing activities are carried out using, among other things, marketing communication, such as the many different ways in which companies try to inform and convince users and remind them of the products and brands they have to offer (Kotler, Keller, 2017).

Social media are defined in different ways. A commonly cited explanation is that of Kaplan and Haenlein (Kaplan, Haenlein, 2010). According to them, social media are a set of online applications founded on the conceptual and technical principles of Web 2.0 that enable the development and sharing of content generated by users. Whereas, according to Kotler and Keller (Kotler, Keller, 2017), social media is a medium which provides users with the ability to publish, share and perceive textual, graphic, audio and video content from other people. In particular, the theories outlined at this point focus on the technological component. Conversely, social media is a form of information transmission that occurs over sites or software applications that exist on the Internet, in communities and generated by their users (Polańska, 2011).

The worldwide use of social media is expanding each year. Currently, they are used by 4.76 billion users globally - more than 3% more compared to last year. Notably, users spend an estimated average of nearly 2.5 hours a day in this manner, with the most popular platforms being (Stelzner, 2023): Facebook, Instagram, LinkedIn, YouTube, Twitter, TikTok and Snapchat. On the other hand, in terms of the most used platforms by organizations, these are Facebook and Instagram. The underlying cause of widespread prevalence can be seen in the multiple benefits that emerge for both users using private fanpages on SM and for companies using business fanpages. In the case of the aforementioned first group, these may include possibilities associated with (Digital, 2023):

- filling free time,
- maintaining contact with friends and family,
- reading the news,
- checking what is being discussed,
- finding content.

Companies that are active in social media are usually not limited to one platform, but perform activities on several (Buchnowska, 2013). Each platform has its own specifics, which are associated with the ways in which companies operate within these platforms.

In terms of the business perspective, social media brings benefits mainly related to (Kotler, Keller, 2017; Stelzner, 2023):

- increased exposure and traffic,
- redirection to online shopping,
- increased sales,
- gaining customer information,
- developing a loyal community,
- stimulating business innovation.



LinkedIn is the most popular social media platform with a business focus. It serves to create business relationships, largely bringing together professionals and executives (Albrecht, 2011). Individual users can build their own profiles detailing things like employment history or work experience. The platform allows users to share valuable user-generated content, such as posts with photos or graphics or their own articles (Paliszkiwicz, 2016). Meanwhile, enterprises have the opportunity to use company profiles, where communication of branches or specific entities can be maintained. Thus, it has naturally become an appropriate space for communicating ESG activities.

### 3. Research Methodology

Due to the relatively low level of exploration of the topic of ESG in social media marketing communications, the authors of this text decided to diversify the purpose of the article:

1. to explore the topic of ESG activities in warehouse logistics and its communication in SM,
2. to carry out and present the results of quantitative research involving statistical analysis of the results of social media marketing publications on ESG.

The following research question was posed by analogy:

P1. Which area of ESG activity is most attractive to customers from the perspective of engagement on LinkedIn?

The research hypothesis was then stated:

H1. There is a statistically significant relationship between the amount of storage space and the marketing performance of publications on LinkedIn and is positive in nature.

To achieve the stated objectives and verify the hypotheses, a two-stage research process was designed. It began with a literature analysis and synthesis and was followed by a quantitative study of marketing performance.

Among other things, the first stage of the research defined the key areas of ESG activity in the real estate market (Table 1). This division became the basis for the second, quantitative stage of the research.

The study consisted of an analysis of online data from November 2022 - July 2023 compiled from the results of 140 posts published on the social media platform LinkedIn. This is because the pilot study, as well as the analysis of the literature, showed that this is the platform most often chosen to communicate ESG activities. The sample was selected purpose-fully, as the most recent 20 publications communicating ESG within the profile of companies - the largest warehouse space developers according to PropertyEU magazine's Best Logistics Developers ranking - were chosen as the research unit.

**Table 1.**  
*Key ESG areas in the warehouse properties market*

<b>Environmental</b>	<b>Social</b>	<b>Corporate Governance</b>
<b>Environmental protection</b>	<b>Relations with employees, suppliers, customers and communities</b>	<b>Standards of corporate governance, risk control and shareholder rights</b>
Greenhouse gas emissions. Carbon footprint of the investment. Electricity sources and consumption. Waste management. Water consumption and quality. Use of renewable energies. Natural resources and land use. Biodiversity. Sustainable mobility policy. Green real estate certificates. Types of supply chains used.	Labor standards and labor relations. Equality, diversity and inclusiveness. Employee engagement and well-being. Health and safety. Workplace standards and conditions. Equal employment opportunities and fair wages. Anti-discrimination policies toward women and minorities. Accessibility for people with limited mobility. Human capital development. Impact on the functioning of local communities. Actions for social good outside its own sphere of business.	Business ethics and organizational culture. Disclosures and reporting. Business risk control. Data protection and privacy. Employment stability. Trade unionization. Countering corruption and bribery. Diverse management. ESG clauses in existing leases. Transparency with shareholders. Standards of business partners.

Source: own elaboration based on thinkco, 2022.

Statistical analysis included: a comparison of client engagement scores in publications on key ESG areas in the real estate market, and a correlation analysis of warehouse space and social media marketing scores. The survey included companies with the largest warehouse area in Europe based on projects completed in the 2020s: from 1,394,263 to 8,043,495 sqm. These were: Panattoni, CTP, VGP Group, Segro, Prologis, GLP Europe, WDP.

Measurement of social media marketing activities is possible using internal and external tools dedicated to this. Basic monitoring of activities usually takes place within the selected site. Typically, the key results relate to company awareness, such as the number of observers and the reach and views of content and also customer engagement within the profile. In the case of this analysis, the number of observers was selected as the awareness score and engagement, which is the sum of reactions, comments and shares. Today, engagement scores are considered crucial in the world of social media marketing.

#### **4. Results and discussion**

A statistical analysis of posts communicating ESG within LinkedIn for selected companies is presented in Table 2. It was observed that in most cases, communication of ESG-related activities formed the majority of a company's total communication on its LinkedIn profile.

**Table 2.***Engagement on LinkedIn within key ESG areas*

Communicated ESG area	Number of entries	Average commitment
Environmental	74	93,202
Social	30	107,67
Corporate Governance	12	193,58
ESG in general	23	112,26

Source: own elaboration.

It proves that the most frequently communicated ESG area on LinkedIn is environmental aspects. However, they are associated with the lowest average engagement. This may be due precisely to the increasing popularity and inclusion of environmental aspects in the standards of companies in the development industry. The fewest posts on LinkedIn, on the other hand, were related to governance. This aspect, on the contrary, gained the highest average engagement from customers. Thus, the use of management area communications in social media marketing communications on LinkedIn is recommend-ed. The information gathered so far from the previous chapters and the above part of the quantitative research thereby answers the first research question.

Subsequently, Pearson's correlation coefficient has been used to examine the severity of the relation between the different variables. Once the analysis is executed, it may be concluded that there is a statistical significant correlation between the size of the warehouse and the outcome of publications communicating ESG on LinkedIn (Table 3).

**Table 3.***Evaluating the correlation between warehouse size and marketing performance on LinkedIn*

		Engagement	Followers
Size of the warehouse	Pearson's correlation coefficient	0,805**	0,760**
	Correlation strength*	Very high	Very high

P - Pearson correlation coefficient; o - correlation score.

\*\* correlation statistically significant at  $\alpha = 0.01$ .\*  $0.7 \leq \text{correlation very high} \leq 0.9$ .

Source: own elaboration.

Expressed another way, the higher a company's ranking in the Best Logistics Developers, the higher its marketing results of ESG-related entries were also. Thus, among the most engaging communications can be listed those belonging to: Panattoni, CTP and VGP Group.

A stronger correlation occurred in the analysis of engagement scores. This agrees with current trends seen in digital marketing reports. According to them, social marketing activities should first and foremost engage the audience. Therefore, it is worth creating enough valuable content that customers have a reason to interact, recommend, comment and share. The very high strength of the correlation carries a practical implication for marketing departments of warehouse logistics companies to implement continuous ESG communication within LinkedIn. Based on the literature analysis and the pilot study, it is also suggested to implement such marketing communication within other social media platforms as well. The correlation study conducted does not provide grounds to reject hypothesis H1.

## 5. Conclusions

The presented article focused on exploring the topic of ESG activities in warehouse logistics and its communication in social media. The construction sector contributes significantly to greenhouse gas emissions. This includes both the building materials used to construct buildings, as well as the operational activities of existing warehouses. The sector therefore faces a number of challenges that it is socially expected to solve. Following in the footsteps of researchers, an increasing number of institutions at both the European and national levels are introducing laws and regulations to accelerate this process. EU directives, national laws and guidelines from independent institutes are aimed at forcing the industrial sector to respond and implement solutions. The ESG revolution is gaining momentum because of this. We are currently in a transitional phase, and there is still a lot of work to be done, but change is already inevitable. ESG activities that are being implemented by companies are being communicated in parallel on social media.

The authors' research showed that the most frequently communicated ESG area on LinkedIn was environmental aspects, although it was the one associated with the lowest average engagement. The fewest posts on LinkedIn, on the contrary, were about governance. This aspect, on the other hand, gained the highest average engagement from customers. The authors thus recognize that the areas of environment and management are the most interesting from a research perspective for further exploration. This can be both quantitative and qualitative in nature.

The article also presents the results of a quantitative study involving statistical analysis of the social media marketing results of ESG-related publications. It was found that there is a very high correlation between the size of the warehouse and consequently the ranking of developers in Europe and the results of publications communicating ESG on LinkedIn (Table 3). Based on the results, it can be recommended that further research should be pursued in the direction of engaging customers in ESG marketing communications.

Every study comes with limitations. In the case of this article, attention is drawn to the choice of the number of followers as the only awareness result. Although it is one of the most commonly measured outcomes, discussions among marketers are currently taking place around the validity of including this element in the context of marketing effectiveness. Another outcome measured in this case could be reach or displays, but these are confidential data and cannot be checked without access to a company's profile statistics. However, one can try to obtain such data from companies in the future. In the context of measuring engagement, there are other directions for research as well, such as measuring only qualitative engagement or comments with positive sentiment. In this case, it is suggested to use external social media monitoring tools.

## References

1. Abbas, J., Mahmood, S., Ali, H., Ali Raza, M., Ali, G., Aman, J., Bano, S., Nurunnabi, M. (2019). The Effects of Corporate Social Responsibility Practices and Environmental Factors through a Moderating Role of Social Media Marketing on Sustainable Performance of Firms' Operating in Multan, Pakistan. *Sustainability*, Vol. 11, pp. 1-33.
2. Abratt, R., Sacks, D. (1988). The marketing challenge: Towards being profitable and socially responsible. *Journal of Business Ethics*, Vol. 7, pp. 497-507.
3. Acciaro, M., Ghiara, H. (2014). Cusano, M. Energy management in sea ports: A new role for port authorities. *Energy Policy*, Vol. 7, pp. 4-12.
4. Albrecht, G. (2011). *Chronic Environmental Change: Emerging 'Psychoterratic' Syndromes*.
5. Albuquerque, R., Koskinen, Y., Yang, S., Zhang, C. (2020), Resiliency of environmental and social stocks: An analysis of the exogenous COVID-19 market crash. *Review of Corporate Finance Studies*, Vol. 9(3), pp. 593-621.
6. Alshehhi, A., Nobanee, H., Khare, N. (2018). The impact of sustainability practices on corporate financial performance: Literature trends and future research potential. *Sustainability*, Vol. 10(2), p. 494.
7. Aluchna, M., Roszkowska-Menkes, M. (2019). Integrating corporate social responsibility and corporate governance at the company level. Towards a conceptual model. *Engineering Economics*, Vol. 30, pp. 349-361.
8. Anthony, R.N., Govindarajan, V. (2007). *Management control systems*. Boston: McGraw-Hill.
9. Appuhami, R., Tashakor, S. (2017). The impact of audit committee characteristics on CSR disclosure: An analysis of Australian firms. *Australian Accounting Review*, Vol. 27(4), pp. 400-420.
10. Araujo, T., Kollat, J. (2018). Communicating effectively about CSR on Twitter: The power of engaging strategies and storytelling elements. *Internet Research*, Vol. 28, pp. 419-431.
11. Benitez, J., Ruiz, L., Castillo, A., Llorens, J. (2020). How corporate social responsibility activities influence employer reputation: The role of social media capability. *Decision Support Systems*, Vol. 129.
12. Berman, S.L., Wicks, A.C., Kotha, S., Jones, T.M. (1999). Does stakeholder orientation matter? The relationship between stakeholder management models and firm financial performance. *Academy of Management Journal*, Vol. 42(5), pp. 488-506.
13. Brammer, S., Brooks, C., Pavelin, S. (2006). Corporate social performance and stock returns: UK evidence from disaggregate measures. *Financial Management*, Vol. 35(3), pp. 97-116.

14. Branco, M.C., Rodrigues, L.L. (2008). Factors influencing social responsibility disclosure by Portuguese companies. *Journal of Business Ethics*, Vol. 83(4), pp. 685-701.
15. Broadstock, D.C., Chan, K., Cheng, L.T.W., Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, Vol. 38, p. 101716.
16. Buchnowska, D. (2013). Analiza i ocena poziomu wykorzystania mediów społecznościowych przez największe polskie przedsiębiorstwa. *Informatyka Ekonomiczna*, Vol. 4 (30). Uniwersytet Ekonomiczny we Wrocławiu, pp. 55-69.
17. Cai, L., Cui, J., Jo, H. (2016). Corporate environmental responsibility and firm risk. *Journal of Business Ethics*, Vol. 139(3), pp. 563-594.
18. Camilleri, M.A. (2015). Environmental, social and governance disclosures in Europe. *Sustainability Accounting, Management and Policy Journal*, Vol. 6(2), pp. 224-242.
19. Cherrafi, A., Garza-Reyes, J.A., Kumar, V., Mishra, N., Ghobadian, A., Elfezazi, S. (2018). Lean, green practices and process innovation: A model for green supply chain performance. *International Journal of Production Economics*, Vol. 206, pp.79-92.
20. Cho, M., Furey, L.D., Mohr, T. (2017) Communicating Corporate Social Responsibility on Social Media: Strategies, Stakeholders, and Public Engagement on Corporate Facebook. *Business and Professional Communication Quarterly*, Vol. 80, pp. 52-69.
21. Chu, S.C., Chen, H.T., Gan, C. (2020). Consumers' engagement with corporate social responsibility (CSR) communication in social media: Evidence from China and the United States. *Journal of Business Research*, Vol. 110, pp. 260-271.
22. Cosimato, S., Troisi, O. (2015). Green supply chain management: Practices and tools for logistics competitiveness and sustainability. The DHL case study. *The TQM Journal*, Vol. 27(2), pp. 256-276.
23. COSO & WBCSD (2018). Enterprise risk management: Applying enterprise risk management to environmental, social and governance-related risks. *Committee of Sponsoring Organizations of the Treadway Commission*.
24. Daugaard, D. (2020). Emerging new themes in environmental, social and governance investing: A systematic literature review. *Accounting & Finance*, Vol. 60, pp. 1501-1530.
25. De Lucia, C., Paziienza, P., Bartlett, M. (2020). Does good ESG lead to better financial performances by firms? Machine learning and logistic regression models of public enterprises in Europe. *Sustainability*, Vol. 12, p. 5317.
26. Díaz-García, C., González-Moreno, A., Sáez-Martínez, F.J. (2015). Ecoinnovation: Insights from a literature review. *Innovation: Management, Policy and Practice*, Vol. 17(1), pp. 6-23.
27. *Digital 2023: Global Overview Report*. Retrieved from: <https://datareportal.com/reports/digital-2023-global-overview-report>, 14.06.2023.

28. Drempetic, S., Klein, C., Zwergel, B. (2020). The influence of firm size on the ESG score: Corporate sustainability ratings under review. *Journal of Business Ethics*, Vol. 167, pp. 333-360.
29. Eccles, N.S., Viviers, S. (2011). The origins and meanings of names describing investment practices that integrate a consideration of ESG issues in the academic literature. *Journal of Business Ethics*, Vol. 104, pp. 389-402.
30. Elkington, J. (1997). Cannibals with forks: The triple bottom line of 21st century business. *Capstone*.
31. Fernando, Y., Wah, W.X. (2017). The impact of eco-innovation drivers on environmental performance: Empirical results from the green technology sector in Malaysia. *Sustainable Production and Consumption*, Vol. 12, pp. 27-43.
32. Ferrell, A., Liang, H., Renneboog, L. (2016). Socially responsible firms. *Journal of Financial Economics*, Vol. 122(3), pp. 585-606.
33. Flavelle, C. (2023). *Climate change could cut world economy by \$23 trillion in 2050, insurance giant warns. The New York Times*. Retrieved from: <https://www.nytimes.com/2021/04/22/climate/climate-changeeconomy.html>, 4.06.2023.
34. Fransen, L., Kolk, A. (2019). Rivera-Santos, M. The multiplicity of international corporate social responsibility standards: Implications for global value chain governance. *Multinational Business Review*, Vol. 27(4), pp. 397-426.
35. Friede, G., Busch, T., Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, Vol. 5(4), pp. 210-233.
36. Galbreath, J. (2013). ESG in focus: The Australian evidence. *Journal of Business Ethics*, Vol. 118(3), pp. 529-541.
37. Gillan, S.L., Koch, A., Starks, L.T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance*, Vol. 66.
38. Goll, I., Rasheed, A.A. (2004). The moderating effect of environmental munificence and dynamism on the relationship between discretionary social responsibility and firm performance. *Journal of Business Ethics*, Vol. 49, pp. 41-54.
39. Green, K.W. Jr, Zelbst, P.J., Meacham, J., Bhaduria, V.S. (2012). Green supply chain management practices: Impact on performance. *Supply Chain Management: An International Journal*, Vol. 17(3), pp. 290-305.
40. Grover, P., Kar, A.K., Janssen, M., Ilavarasan, P.V. (2019). Perceived usefulness, ease of use and user acceptance of blockchain technology for digital transactions—insights from user-generated content on Twitter. *Enterprise Information Systems*, Vol. 13, pp. 771-800.
41. Gundogdu, H., Aytekin, A., Toptancı, Ş., Korucuk, S., Karamaşa, Ç. (2023). Environmental, social, and governance risks and environmentally sensitive competitive strategies: A case study of a multinational logistics company. *Business Strategy and the Environment*.

42. Ioannou, I., Serafeim, G. (2017). The consequences of mandatory corporate sustainability reporting. *Harvard Business School Research Working Paper*, pp. 11-100.
43. Jaggernath, R., Khan, Z. (2015). Green supply chain management. *World Journal of Entrepreneurship, Management and Sustainable Development*, Vol. 11(1), pp. 37-47.
44. Jha, M.K., Rangarajan, K. (2020). Analysis of corporate sustainability performance and corporate financial performance causal linkage in the Indian context. *Asian Journal of Sustainability and Social Responsibility*, Vol. 5(1), p. 10.
45. Jorgensen, A.L., Knudsen, J.S. (2006). Sustainable competitiveness in global value chains: how do small Danish firms behave? *Corporate Governance*, Vol. 6(4).
46. Kaplan, A.M., Haenlein, M. (2010). Users Of the World, Unite! The Challenges And Opportunities Of Social Media. *Business Horizons*, Vol. 53, pp. 59-68.
47. Kim, E.H., Lyon, T.P. (2015). Greenwash vs. brownwash: Exaggeration and undue modesty in corporate sustainability disclosure. *Organization Science*, Vol. 26(3), pp. 705-723.
48. Kim, K.H., Kim, M., Qian, C. (2018). Effects of corporate social responsibility on corporate financial performance: A competitive-action perspective. *Journal of Management*, Vol. 44(3), pp. 1097-1118.
49. Kotler, P., Keller, K.L. (2017). *Marketing management* (Fifteenth edition global edition Philippine). Pearson Education South Asia Pte.
50. KPMG (2023). *Sustainable investing: Fast-forwarding its evolution*. Retrieved from: <https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/02/sustainable-investing.pdf>, 5.06.2023.
51. Linton, J.D., Klassen, R., Jayaraman, V. (2007). Sustainable Supply Chains: An Introduction. *Journal of Operations Management*, Vol. 25(6), No. 8.
52. Lokuwaduge, C.S.D.S., Heenetigala, K. (2017). Integrating environmental, social and governance (ESG) disclosure for a sustainable development: An Australian study. *Business Strategy and the Environment*, Vol. 26(4), pp. 438-450.
53. Margolis, J.D., Elfenbein, H.A., Walsh, J.P. (2009). Does it pay to be good? A meta-analysis and redirection of the research on the relationship between corporate social and financial performance. *Working paper*, 1-57.
54. Miralles-Quiros, M.M., Miralles-Quiros, J.L., Valente Gonçalves, L.M. (2018). The value relevance of environmental, social, and governance performance: The Brazilian case. *Sustainability*, Vol. 10(3), pp. 574-589.
55. Moir, L. (2001). What do we mean by corporate social responsibility. *Corporate Governance*, Vol. 1(2), pp. 16-22.
56. Murphy, D., McGrath, D. (2013). ESG reporting—Class actions, deterrence, and avoidance. *Sustainability Accounting, Management and Policy Journal*, Vol. 4(2), pp. 216-235.
57. Nazari, J.A., Herremans, I.M., Warsame, H.A. (2015). Sustainability reporting: External motivators and internal facilitators. *Corporate Governance: The International Journal of Business in Society*, Vol. 15(3), pp. 375-390.



58. Newell, G., Marzuki, J. (2022). The increasing importance of environmental sustainability in global real estate investment markets. *Journal of Property Investment and Finance*, Vol. 40(4), pp. 411-429.
59. Ng, T.H., Lye, C.T., Chan, K.H., Lim, Y.Z., Lim, Y.S. (2020). Sustainability in Asia: The roles of financial development in environmental, social and governance (ESG) performance. *Social Indicators Research*, Vol. 150(1), pp. 17-44.
60. Nozari, H., Ghahremani-Nahr, J. (2023) *Smart and Sustainable Supply Chain Management*.
61. Okazaki, S., Plangger, K., West, D., Menéndez, H.D. (2020). Exploring digital corporate social responsibility communications on Twitter. *Journal of Business Research*, Vol. 117, pp. 675-682.
62. Paliszkiwicz, J. (2016). Rola mediów społecznościowych w innowacyjnym kształceniu. In: *Innowacje w zarządzaniu i inżynierii produkcji, t. II* (pp. 914-915). Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.
63. Park, S.R., Jang, J.Y. (2021). The impact of ESG management on investment decision: Institutional investors' perceptions of country-specific ESG criteria. *International Journal of Financial Studies*, Vol. 9(3), No. 48.
64. Perrini, F., Tencati, A. (2006). Sustainability and stakeholder management: The need for new corporate performance evaluation and reporting systems. *Business Strategy and the Environment*, Vol. 15(5), pp. 296-308.
65. Polańska, K. (2011). Biznesowy charakter mediów społecznościowych. *Zeszyty Naukowe Uniwersytetu Szczecińskiego*, Vol. 656, pp. 73-87.
66. Quariguasi Frota Neto, J., Bloemhof-Ruwaard, J.M., Nunen, J.A.E.E. van, Heck, H.W.G.M. van. (2008). Designing and evaluating sustainable logistics networks. *International Journal of Production Economics*, Vol. 111(2), No. 13.
67. SASB (2023). *SASB conceptual framework: Sustainability Accounting Standards Board*. San Francisco. Retrieved from: [http://www.sasb.org/wpcontent/uploads/2019/05/SASB-Conceptual-Framework.pdf?source=post\\_page](http://www.sasb.org/wpcontent/uploads/2019/05/SASB-Conceptual-Framework.pdf?source=post_page), 10.06.2023.
68. Saxton, G.D., Gomez, L.M., Ngoh, Z, Lin, Y., Dietrich, S. (2019). Do CSR Messages Resonate? Examining Public Reactions to Firms' CSR Efforts on Social Media. *Journal of Business Ethics*, Vol. 155, pp. 359-377.
69. Steiner, G., Steiner, J.F. (200). *Business, government, and society: A managerial perspective*. McGraw-Hill.
70. Stelzner, M. (2023). *Social Media Marketing Industry Report. How Marketers Are Using Social Media to Grow Their Businesses*. Retrieved from: <https://static1.squarespace.com/static/525c34f6e4b09199c2c2a427/t/6283774405877a23dd6f6be49/1652782925631/Industry-Report-2022-final.pdf>, 14.06.2023.
71. Stohl, C., Etter, M., Banghart, S., Woo, D. (2017). Social Media Policies: Implications for Contemporary Notions of Corporate Social Responsibility. *Journal of Business Ethics*, Vol. 142, pp. 413-436.

72. Tang, D.Y., Yan, J., Yao, Y. *The determinants of ESG ratings: Rater ownership matters*. Retrieved from: <https://ssrn.com/abstract=3889395>, 2.06.2023.
73. Velte, P. (2017). Does ESG performance have an impact on financial performance? Evidence from Germany. *Journal of Global Responsibility*, Vol. 80(2), pp. 169-178.
74. Whitelock, V.G. (2019). Multidimensional environmental social governance sustainability framework: Integration, using a purchasing, operations, and supply chain management context. *Sustainable Development*, Vol. 27(5), pp. 923-931.
75. Widyawati, L. (2020). A systematic literature review of socially responsible investment and environmental social governance metrics. *Business Strategy and the Environment*, Vol. 29, pp. 619-637.
76. Yoshikawa, T., Nippa, M., Chua, G. (2021). Global shift towards stakeholder-oriented corporate governance? Evidence from the scholarly literature and future research opportunities. *Multinational Business Review*, Vol. 29, pp. 321-347.
77. Zavodska, M., Rakyta, M., Binasova, V. (2015). Sustainable concept for green logistics and energy efficiency in manufacturing. *DAAAM International Scientific Book*.
78. Ziolo, M., Filipiak, B.Z., Bak, I., Cheba, K. (2019). How to design more sustainable financial systems: The roles of environmental, social, and governance factors in the decision-making process. *Sustainability*, Vol. 11, p. 5604.

## ASSESSMENT OF THE USEFULNESS OF THE IMPLEMENTATION OF THE KAIZEN METHOD IN THE CONSTRUCTION INDUSTRY

Natalia BRYCHT

Czestochowa University of Technology, Faculty of Civil Engineering; natalia.brycht@pcz.pl,  
ORCID: 0000-0002-7372-7492

**Purpose:** The aim of the article is to present and assess the usefulness of the Kaizen method in the management and organization processes of enterprises from the construction sector.

**Design/methodology/approach:** The research includes identifying tools in the area of Kaizen philosophy, assessing the possibilities of its implementation in the construction industry and identifying the most beneficial solutions. Elements of statistical and observational methods were used, as well as analyzes of literature reports. SWOT analysis was used to determine the level of suitability of the Kaizen method.

**Findings:** The conducted research showed the need to implement Lean Management tools in the structures of construction companies, in particular the Kaizen method. However, certain barriers have also been noticed, limiting their use in the Polish construction industry.

**Research limitations/implications:** The research presented is only a preliminary analysis, which is a starting point for further research on the use of the Kaizen method in construction, the method of selecting its tools and the benefits resulting from them. Due to knowledge, financial and technological deficiencies of construction companies, it is impossible to fully assess the analyzed aspect in the area of all types of enterprises.

**Practical implications:** The obtained results show the positive impact of the Lean Management method on the functioning of the enterprise. Thanks to the use of Kaizen tools, it is possible to increase the efficiency of the company and solve most problems, including the generation of large amounts of waste, insufficient financial resources for planned projects, low level of competitiveness on the market, disorganization of work and lack of timeliness of initiated implementations. The presented SWOT analysis can be successfully used as a tool supporting the decision-making process aimed at adopting an appropriate company strategy. Thanks to its simplicity and speed of execution, it allows you to save time and initially reject unfavorable solutions. Moreover, an important factor in favor of its use is the ability to adjust the criteria and weights determined by the established preferences of a given company.

**Originality/value:** The added value of the article is a practical presentation of the use of SWOT analysis to determine the most advantageous strategy necessary to be undertaken by construction companies in order to implement the principles of Lean Management.

**Keywords:** construction industry, Kaizen, Lean Construction, Lean Management, SWOT analysis.

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

## 1. Introduction

Nowadays, special emphasis is placed on personal development and continuous improvement in almost every sphere of life. This also translates into all sectors of the economy. One of them is the construction industry, which has been constantly developing in recent years, as evidenced by a large number of both volume and linear projects. However, construction faces many problems at the economic, organizational and environmental levels. According to statistical data, the construction sector contributes approximately 30% to waste generation worldwide every year. In Poland, according to estimated data from the Statistics Poland, 12 018 000 Mg of construction waste was generated in 2022, of which 49.3% is still landfilled (Statistics Poland, 2023). Moreover, insufficient financial resources to carry out renovations, failure to meet the deadlines for commenced projects, huge amounts of waste generated from demolitions, renovations and construction sites, often low quality of services provided and manufactured products, and accident rates are the main barriers preventing improvement of the efficiency of construction companies. Many of them can be solved by implementing Lean Management (LM) tools borrowed from the Japanese manufacturing industry (Aureliano et al., 2019; Babalola et al., 2019). LM principles are aimed at eliminating waste at every stage of the company's activity, which is intended to result in an increase in the quality of services provided and goods produced. At the same time, it is reflected in the overall assessment of the company's work and its place in the industry. In the era of increasing social ecological awareness, the idea of Lean Management appears as an opportunity to solve many problems at the local level, as well as in the global context. By implementing LM techniques, methods and tools in every segment of the economy, it is possible to maintain sustainable development in the construction sector at the appropriate level (Hussain et al., 2019). Such action makes it possible to realistically prevent the waste of natural resources, the accumulation of huge amounts of construction waste and environmental pollution (Dębska et al., 2020; Solaimani, Sedighi, 2020; Yücenur, Şenol, 2021). Data from 2021 indicate the consumption of natural resources at the level of over 100 billion tons globally, with the share of the construction sector amounting to approximately 50% (Brycht, 2024). The studies (Du et al., 2023; Hąbek et al., 2023; Jakubiec, 2022; Mazur, Momeni, 2018; Stronczek, 2024; Ulewicz et al., 2021) present the results of research on assessing the usefulness of applying Lean principles in the automotive industry, production, ceramics or prefabricated buildings. Another issue worth attention is the integration of Industry 4.0 with LM principles (Wolniak, Grebski, 2023a, 2023b). This approach enables increasing operational efficiency, reducing costs and minimizing waste generated.

In the aspect of the construction industry, the implementation of LM methods is called Lean Construction (LC). Introducing appropriate Lean tools into the structures of construction companies allows you to reduce waste, reduce costs, and shorten the investment implementation time. Moreover, it provides an opportunity to increase the level of efficiency by introducing

changes that streamline processes already at their initial stages (Bugdol et al., 2020; Singh, Kumar, 2021). It also reduces the impact of buildings on the natural environment already during the construction phase (Aristizábal-Monsalve et al., 2022). Proper organization and management of the enterprise, supported by appropriately selected techniques, should cover three main areas: quality, environment and safety. Maintaining these three aspects at the appropriate level can significantly contribute to solving most of the problems faced by companies in the construction sector. In the context of the quality of manufactured products, it is worth paying attention to the product production control systems discussed in (Prasalska-Nikoniuk et al., 2022) in accordance with applicable standards. It was found that both systems improve product quality, but the ISO system provides greater opportunities for efficient management of the entire organization, including: adapting to current market needs and supporting sustainable development. Among the many proposals for Lean tools, the Kaizen concept deserves special attention, the main assumption of which is continuous improvement. As part of Kaizen, it is possible to use other techniques, such as the 5S method, Poka-Yoke or the PDCA cycle. However, the introduction of Lean principles is associated with certain limitations, mainly related to the low level of knowledge of the staff, lack of financial resources, legal barriers and technological infrastructure (Ulewicz, R., Ulewicz, M., 2020; Żebrucki, Kruczek, 2018). Therefore, it is so important that when deciding to implement Lean tools, you make the right choice by conducting a detailed "pros and cons" analysis and following the practical principles of implementing the Lean concept (Dombrowski, Mielke, 2014). In order to make the right decision, scientists propose various types of algorithms and methods, as discussed in (Ansah, Sorooshian, 2017; Nowotarski et al., 2021). Due to the frequent need to make quick decisions, it is worth considering using a supporting tool such as SWOT analysis (Brycht, 2022; Brycht, Ulewicz, 2023). Easy and quick analysis allows you to save time and perform a preliminary selection of unnecessary solutions from a range of LM tools.

The aim of the article was to assess the usefulness of implementing the Kaizen concept in enterprises from the construction sector using SWOT analysis.

## **2. Kaizen concept**

The foundation of the Kaizen philosophy is the concept of continuous improvement of both the services provided, manufactured products and the skills of the staff. In the context of the construction industry, this is an important aspect due to the possibility of, for example, reducing the number of road renovations necessary (Brycht, 2021) or other defects related to incorrect production of the product, as well as reducing additional costs and saving time. Similar to other Lean Management tools, the Kaizen method involves identifying and eliminating waste and implementing activities aimed at added value in order to increase the level of company

productivity. To achieve the intended results within the Kaizen concept, various techniques are used, including: PDCA cycle, 5S method and Poka-Yoke. In the first stage of the PDCA cycle (Plan – Do – Check – Act), a plan is created that defines the goal, existing problems and ways to introduce the necessary improvements. The next step is to perform it, observe the test process and draw appropriate conclusions. The third step is to check the correctness of the plan implementation and the achieved effects by comparing the actual situation with the assumed results. The final stage is to act in accordance with the introduced improvements, provided that the expected results are achieved, while all procedures should be standardized (Obora, 2010; Starosta, 2016).

The 5S method based on 5 principles (sorting, systematics, cleaning, standardization, self-discipline) allows you to create an ergonomic workplace with little financial outlay, which increases the efficiency and productivity of the company (Veres et al., 2018). The concept requires the involvement of all company employees (Lizak, 2016). Based on eliminating waste, it is particularly important in environmental terms. The need to select waste generated at the workplace is part of the activities related to the mandatory segregation of construction waste by type according to Polish legal regulations. Creating optimal working conditions has an impact on Occupational Safety and Health (OSH) due to the possibility of reducing the level of accidents in workplaces (Ulewicz, Lazar, 2019).

Poka-Yoke is a principle of preventing errors during the implementation of a given process. It is focused on eliminating the possibility of a defective product, which is often due to the human factor (Antonelli et al., 2024). The second purpose of Poka-Yoke is to correct irregularities after identifying the defect that has occurred. Thanks to these two aspects, putting a defective product into service is minimized as much as possible, which translates into added value for the company (Saurin et al., 2012).

The essence of using the Kaizen method is to introduce small changes to improve processes, which are assumed to result in measurable benefits in the long term, which is primarily the improvement of product quality. This allows for sustainable and gradual introduction of changes using the so-called "small steps", thanks to which it is possible to constantly monitor the stages of its application. This approach, which focuses on how to achieve a result (process), not on the result itself, is called process thinking. There are two types of Kaizen: process and flow. The first one is used at individual workstations in order to introduce improvements, the second one refers to the introduction of changes in a larger area in order to achieve a more effective flow of information and materials. The practical application of the Kaizen method is based on 10 fundamental principles:

- problems create opportunities,
- ask “Why?” 5 times – 5 why? method,
- take ideas from everyone,
- think about solutions that can be implemented,
- reject the established state of affairs,

- excuses that something cannot be done are unnecessary,
- choose simple solutions, without waiting for the perfect ones,
- use your wits instead of money,
- correct mistakes on an ongoing basis,
- improvement is endless.

The presented principles can be easily introduced into the organizational structures of enterprises with low financial outlay, which is the strong point of the presented method (Gabryelewicz et al., 2015). In the face of financial problems that construction companies often struggle with, this is a chance to introduce significant changes without burdening the budget with additional costs. The need to constantly engage employees promotes their development and motivates them to continue their activities, which creates favorable conditions for improving their professional competences and allows for the acquisition of new qualified specialists. Thanks to this, the level of competitiveness of small and medium-sized enterprises on the labor market also increases (Maarof, Mahmud, 2016).

In addition to many advantages, the Kaizen method also has certain limitations, including the need for continuous involvement of employees at all levels of the plant's hierarchy. Constantly encouraging employees to continuously improve by conducting training and workshops is aimed at raising the level of awareness of the benefits of implementing its principles in the context of the entire enterprise. This is a necessary condition to achieve effectiveness and maximum efficiency and improve quality. The limited scope of application of the method is also important. If it is necessary to introduce large, one-off changes, this method will not correspond to the expected effects of work of a particularly large enterprise.

### **3. Methodology of research**

The research was conducted using the observational method and a literature review in order to identify the most frequently used Lean tools in the construction sector. On this basis, the Kaizen method was selected, the level of usefulness of its implementation in construction companies was determined using a SWOT analysis (Pickton, Wright, 1998; Piercy, Giles, 1989). Data regarding the Kaizen method obtained from literature sources were categorized and defined as the criteria for the analysis. Then they were assessed using a rating scale ranging from 1 to 3, where 1 means a low level of influence, 2 - medium level of influence, 3 - high level of influence of a given feature. In each category, three key features were defined, in accordance with the author's assumptions, to which particular weights were assigned. The sum of the weights in each category was 1. The next stage was to calculate the weighted values and add them up, which provided the basis for performing appropriate mathematical

operations and determining one of the distinguished strategies that should be adopted in a construction company:

- aggressive (maxi-maxi) – strengths and opportunities predominate,
- conservative (maxi-mini) – strengths and threats predominate,
- competitive (mini-maxi) – weaknesses and opportunities predominate,
- defensive (mini-mini) – weaknesses and threats predominate.

As part of the research, a literature review of publications from the last 10 years was also performed, based on data contained in the SCOPUS database (Scopus – Document search, 2024). The obtained results, in the form of the number of studies, were obtained by entering specific keywords: "Kaizen", "PDCA cycle", "5S tool" and "Poka-Yoke". The results of the review were presented by individual European Union member states, and a code system in accordance with the ISO 3166 standard was used to record their names: AT - Austria, BE - Belgium, HR - Croatia, CZ - The Czech Republic, DK - Denmark, EE - Estonia, FI - Finland, FR - France, DE - Germany, GR - Greece, IE - Ireland, IT - Italy, LV - Latvia, LT - Lithuania, LU - Luxembourg, NL - Netherlands, PL - Poland, PT - Portugal, RO - Romania, SK - Slovakia, SI - Slovenia, ES - Spain and SE - Sweden. Due to the lack of sufficient data in the analyzed database, countries that did not record at least 1 publication among all the selected keywords are not presented in Figure 2.

#### **4. Research results and discussion**

The research included a detailed analysis of the usefulness of the Kaizen method in construction industry enterprises. In order to determine the action strategy needed to be adopted, a SWOT analysis was used. The collected data are summarized in Table 1 and given the form of criteria assessed in terms of the impact on the economic, organizational and environmental effects of construction processes. The possibility of continuous improvement, eliminating areas of waste, simplicity of use and low implementation cost were assessed. The evaluation also took into account the need for continuous involvement of the entire staff, limitations in the scope of use and waiting time to obtain results.

The conducted research highlighted the strengths and weaknesses of the Kaizen method as well as the opportunities and threats resulting from its introduction into the organizational structures of the company. The analysis showed the strongest side of the method (simplicity and low cost of implementation) rated at 1.35, and the weakest (the need for continuous involvement of all employees) at 1.5. Among the advantages, the ability to eliminating waste was also highly rated (0.9), and the smallest negative impact among the weaknesses is the limited scope of use (0.2). According to research, the implementation of the Kaizen method will improve the quality of products and services provided (1.05), economic and ecological



savings (1.05) and improve the competitiveness of small and medium-sized enterprises (SMEs) (0.9). Unfortunately, there are also certain threats that may, to some extent, affect the final effect of the Kaizen method implementation. These are: the need to constantly monitor the progress of work (1.2), the need to periodically organize training and workshops (1.05) and the need to introduce an attractive motivation system, which was indicated as the barrier with the lowest impact (0.5).

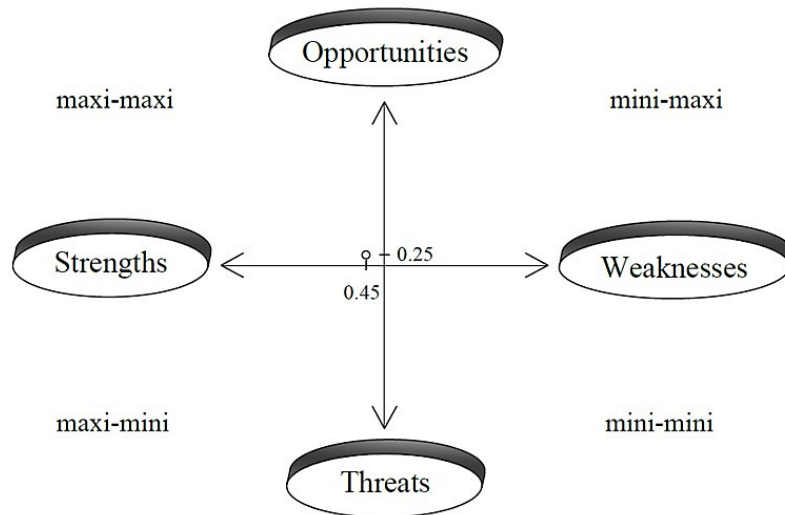
**Table 1.**

*The summary of data on the Kaizen method divided into categories with an assessment*

Strengths				Weaknesses			
Criterion	Rating	Weight	Weighted value	Criterion	Rating	Weight	Weighted value
Continuous improvement of processes and products	2	0.25	0.5	Limited scope of use	1	0.2	0.2
Eliminating waste	3	0.3	0.9	The need for continuous involvement of all employees	3	0.5	1.5
Simplicity and low cost of implementation	3	0.45	1.35	A long-term process of obtaining results	2	0.3	0.6
<b>SUM</b>		<b>1</b>	<b>2.75</b>	<b>SUM</b>		<b>1</b>	<b>2.3</b>
Opportunities				Threats			
Criterion	Rating	Weight	Weighted value	Criterion	Rating	Weight	Weighted value
Improving the quality of products and services	3	0.35	1.05	The need for continuous monitoring of work progress	3	0.4	1.2
Economic and ecological savings (natural resources, reducing the amount of waste generated and reducing costs)	3	0.35	1.05	Necessity to introduce an attractive motivational system	2	0.25	0.5
Improving the competitiveness of SMEs	3	0.3	0.9	The need to organize training and workshops periodically	3	0.35	1.05
<b>SUM</b>		<b>1</b>	<b>3</b>	<b>SUM</b>		<b>1</b>	<b>2.75</b>

Source: own study.

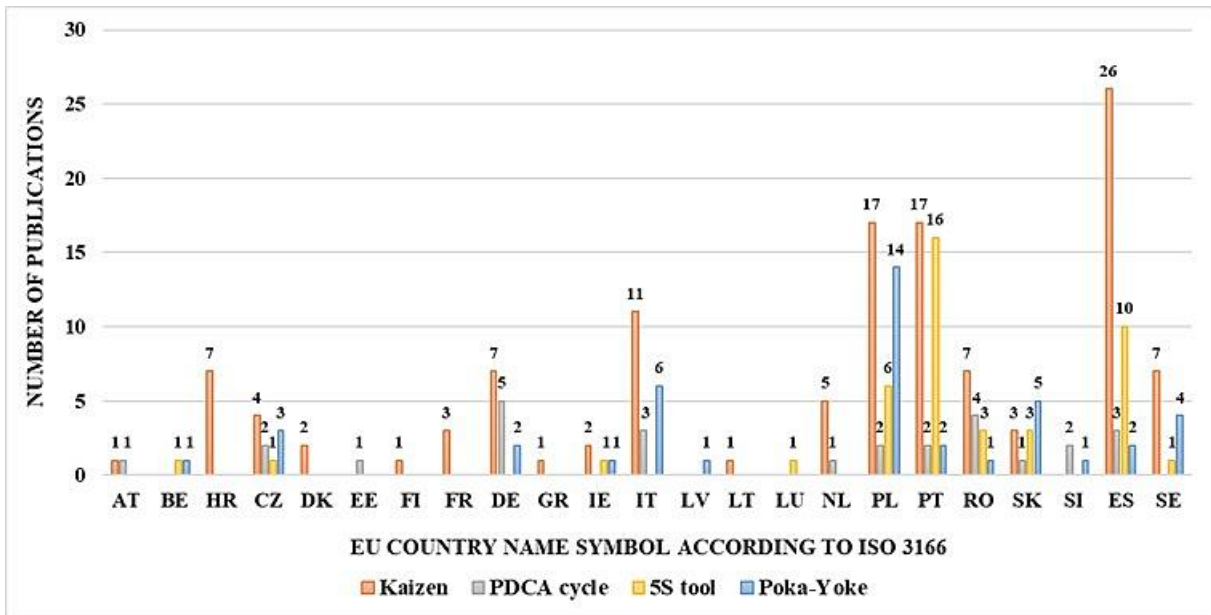
The obtained results show the dominance of the "strengths" of the method (2.75) over the "weaknesses" (2.3) and the dominance of the "opportunities" (3.0) over the "threats" (2.75). As a result, this allows you to determine the strategy of action needed by the company, as shown in Figure 1. In order to obtain the intended benefits from the implementation of the Kaizen method in the most optimal conditions, the construction company should adopt an aggressive strategy (maxi-maxi). It involves using strengths at the highest possible level, which will allow achieving maximum opportunities and strengthen the correlation between the two analyzed categories: strengths - opportunities.



**Figure 1.** Graph of the strategy for applying the Kaizen method in a construction company.

Source: own study.

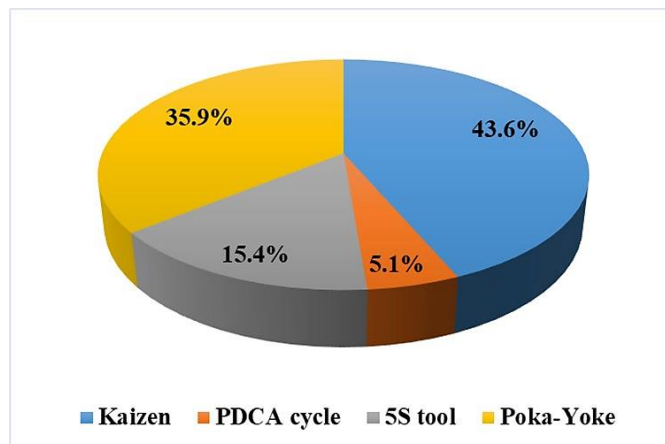
The second stage of the research was to analyze the SCOPUS database in terms of publications from the last 10 years from European Union member states. The subject of the research were works searched for the following keywords: "Kaizen" (122 publications), "PDCA cycle" (27 publications), "5S tool" (43 publications) and "Poka-Yoke" (43 publications), which was presented in Figure 2. The obtained data indicate that Poland is one of the few countries out of 27 Member States where works have been published for each defined keyword. The total number of publications is 39, which gives it second place after Spain (41 publications). The greatest interest is related to the issue of the Kaizen method (122 publications), most of which are in Spain (26 publications). The lowest number of results was obtained after searching for "PDCA cycle", with the largest number of publications recorded in Germany (5 publications). The same number of publications (43 publications) was recorded for the keywords: "5S tool" and "Poka-Yoke". The issue of 5S was most frequently discussed in Portugal (16 publications), and Poka-Yoke in Poland (14 publications).



**Figure 2.** Number of publications after keywords in European Union member states in 2014-2024.

Source: own study based on SCOPUS database.

Figure 3 shows the percentage of Polish publications in the last decade divided into defined keywords. Based on the results obtained, it was found that in Poland issues related to the Kaizen concept were most frequently analyzed (43.6%), and the fewest studies were published on the PDCA cycle (only 5.1%).



**Figure 3.** Percentage of Polish publications divided by keywords in the years 2014 - 2024.

Source: own study based on SCOPUS database.

## 5. Conclusions

The conducted research has shown that the implementation of the Kaizen concept in the organizational structures of construction companies allows for achieving measurable benefits, including time savings, cost reduction, improvement of the quality of products and services

provided, and reduction of waste, e.g. by saving natural resources and minimizing the waste generated. Therefore, the idea of Kaizen fits perfectly into the principles of sustainable development. It is an opportunity for small and medium-sized enterprises to solve problems in an uncomplicated way due to the simplicity and low financial outlays needed to implement the method. In addition to the ecological and economic aspects, the Kaizen method increases the competitiveness of the company by focusing on raising the awareness and qualifications of employees. Based on the research, it was found that in order to achieve maximum benefits resulting from the implementation of the Kaizen concept, the company should adopt an aggressive strategy (maxi-maxi), which involves using the potential of the presented method as much as possible. The weakness of the Kaizen method is the need for continuous involvement of all employees, which necessitates the need to organize regular training and introduce an attractive motivational system. The second disadvantage is the limited scope of use, especially in situations requiring radical measures to quickly achieve the required results.

The literature review indicates a growing interest in Lean in the construction sector in the European Union countries. The highest indexing of the Kaizen method was recorded in Spain (21.3%) and Poland (13.9%). However, the barrier of insufficient knowledge and too low awareness of enterprise staff is still a serious limitation to the effective implementation of Lean principles in the structures of the construction industry.

The implementation of the Kaizen method in construction companies is a real chance to solve many economic, ecological and organizational problems. However, this requires the adoption of an appropriate strategy of action, which depends on conducting a detailed analysis and selecting appropriate tools to support the decision-making process.

## References

1. Ansah, R.H., Sorooshian, S. (2017). Effect of Lean tools to control external environment risks of construction projects. *Sustainable Cities and Society*, 32, pp. 348-356. <http://dx.doi.org/10.1016/j.scs.2017.03.027>
2. Antonelli, D., Stadnicka, D., Litwin, P. (2024). Inclusive manufacturing through the application of Lean tools to sustainability issues. *Procedia CIRP*, 122, pp. 593-598, doi: 10.1016/j.procir.2024.01.085
3. Aristizábal-Monsalve, P., Vásquez-Hernández, A., Botero Botero, L.F. (2022). Perceptions on the processes of sustainable rating systems and their combined application with Lean Construction. *Journal of Building Engineering*, 46, 103627. <https://doi.org/10.1016/j.job.2021.103627>

4. Aureliano, F.d'S., Costa, A.Ap.F., Júnior, I.F., Rodrigues, R.A. (2019). Application of Lean manufacturing in construction management. *Procedia Manufacturing*, 38, pp. 241-247, doi: 10.1016/j.promfg.2020.01.032
5. Babalola, O., Ibem, E.O., Ezema, I.C. (2019). Implementation of Lean practices in the construction industry: A systematic review. *Building and Environment*, 148, pp. 34-43. <https://doi.org/10.1016/j.buildenv.2018.10.051>
6. Brycht, N. (2021). Assessment of the quality of the repair process of local roads in the rural areas of the Częstochowa and Kłobuck poviats in the context of road safety. *Production Engineering Archives*, 27(4), pp. 232-241, doi: 10.30657/pea.2021.27.31
7. Brycht, N. (2022). Ocena realizacji dróg samorządowych w technologii betonowej i asfaltowej na podstawie analizy SWOT [Evaluation of the implementation of local government roads in concrete and asphalt technology based on SWOT analysis]. *Materiały Budowlane*, 12(604), pp. 82-84, doi: 10.15199/33.2022.12
8. Brycht, N. (2024). The Problem of Recycling Construction Waste in Poland. Z. Blikharsky et al. (Eds.): CEE 2023, *LNCE 438*, pp. 42–48, doi: 10.1007/978-3-031-44955-0\_5
9. Brycht, N., Ulewicz, M. (2023). Application of the SWOT-TOWS analysis as a supporting tool when selecting a strategy for the implementation of local concrete roads. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 172, pp. 61-71. <http://dx.doi.org/10.29119/1641-3466.2023.172.4>
10. Bugdol, M., Goranczewski, B., Kądziałowski, G., Pakuła, G. (2020). Propozycja wdrożenia koncepcji „Lean Construction” opartej na znormalizowanych systemach zarządzania jakością w organizacjach branży budowlanej [The proposition of implementing the Lean Construction concept based on normalized quality management systems in the organizations operating in the construction industry]. *Cement Wapno Beton*, 25(4), pp. 261-274. <https://doi.org/10.32047/CWB.2020.25.4.1>
11. Dębska, B., Krasoń, J., Lichołai, L. (2020). Application of Taguchi method for the design of cement mortars containing waste materials. *Construction of Optimized Energy Potential*, Vol. 9, No. 1, pp. 15-26, doi: 10.17512/bozpe.2020.1.02
12. Dombrowski, U., Mielke, T. (2014). Lean Leadership – 15 Rules for a sustainable Lean Implementation. *Procedia CIRP*, 17, pp. 565-570, doi: 10.1016/j.procir.2014.01.146
13. Du, J., Zhang, J., Castro-Lacouture, D., Hu, Y. (2023). Lean manufacturing applications in prefabricated construction projects. *Automation in Construction*, 150, 104790. <https://doi.org/10.1016/j.autcon.2023.104790>
14. Gabryelewicz, I., Gawłowicz, P., Sadłowska-Wrzesińska, J. (2015). Kaizen jako skuteczna metoda wspomagająca efektywne zarządzanie przedsiębiorstwem [Kaizen as an efficient method enhancing effective company management]. *Problemy Profesjologii*, 2, pp. 139-148.
15. Hąbek, P., Lavios, J.J., Grzywa, A. (2023). Lean Manufacturing Practices Assessment Case Study of Automotive Company. *Production Engineering Archives*, 29(3), pp. 311-318, doi: 10.30657/pea.2023.29.36

16. Hussain, K., He, Z., Ahmad, N., Iqbal, M., Mumtaz, S.M.T. (2019). Green, Lean, Six Sigma barriers at a glance: A case from the construction sector of Pakistan. *Building and Environment*, 161, 106225. <https://doi.org/10.1016/j.buildenv.2019.106225>
17. Jakubiec, M. (2022). Improvement of the production process using Lean Management – case study. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 158, pp. 229-242. <http://dx.doi.org/10.29119/1641-3466.2022.158.15>
18. Lizak, M. (2016). Methods of measuring the effectiveness of Lean Management. *Production Engineering Archives*, Vol. 13, No. 4, pp. 31-34.
19. Maarof, M.G., Mahmud, F. (2016). A Review of Contributing Factors and Challenges in Implementing Kaizen in Small and Medium Enterprises. *Procedia Economics and Finance*, 35, pp. 522-531, doi: 10.1016/S2212-5671(16)00065-4
20. Mazur, M., Momeni, H. (2018). LEAN Production issues in the organization of the company – results. *Production Engineering Archives*, 22, pp. 50-53, doi: 10.30657/pea.2019.22.10
21. Nowotarski, P., Pasławski, J., Dallasega, P. (2021). Multi-criteria assessment of Lean Management tools selection in construction. *Archives of Civil Engineering*, Vol. 67, Iss. 1, pp. 711-726, doi: 10.24425/ace.2021.136498
22. Obora, H. (2010). Podejście PDCA Problem Solving w rozwiązywaniu problemów organizacji. *Acta Universitatis Lodzianis. Folia Oeconomica*, 234, pp. 323-333, doi: 11089/292
23. Pickton, D.W., Wright, S. (1998). What's swot in strategic analysis? *Strategic Change*, 7(2), pp. 101-109. [https://doi.org/10.1002/\(SICI\)1099-1697\(199803/04\)7:2<101::AID-JSC332>3.0.CO;2-6](https://doi.org/10.1002/(SICI)1099-1697(199803/04)7:2<101::AID-JSC332>3.0.CO;2-6)
24. Piercy, N., Giles, W. (1989). Making SWOT analysis work. *Marketing Intelligence & Planning*, 7(5/6), pp. 5-7. <https://doi.org/10.1108/EUM0000000001042>
25. Prasalska-Nikoniuk, J., Urbański, M., Ulewicz, R. (2022). ISO 9001:2015 vs. Factory Production Control (FPC) to ensure the quality of construction products used in road and bridge engineering. *Construction of Optimized Energy Potential*, Vol. 10, pp. 103-111, doi: 10.17512/bozpe.2022.11.12
26. Saurin, T.A., Duarte Ribeiro, J.L., Vidor, G. (2012). A framework for assessing Poka-Yoke devices. *Journal of Manufacturing Systems*, 31, pp. 358-366. <http://dx.doi.org/10.1016/j.jmsy.2012.04.001>
27. *Scopus – Document search*. Retrieved from: <https://www.scopus.com/search/form.uri?display=basic#basic>, 18.06.2024.
28. Singh, S., Kumar, K. (2021). A study of Lean Construction and visual management tools through cluster analysis. *Ain Shams Engineering Journal*, 12, pp. 1153-1162. <https://doi.org/10.1016/j.asej.2020.04.019>
29. Solaimani, S., Sedighi, M. (2020). Toward a holistic view on Lean sustainable construction: A literature review. *Journal of Cleaner Production*, 248, 119213. <https://doi.org/10.1016/j.jclepro.2019.119213>

30. Starosta, A. (2016). Cykl PDCA w zarządzaniu anty kryzysowym na przykładzie polskich przedsiębiorstw [PDCA cycle in crisis management on the example of polish enterprises]. *Nauki o Zarządzaniu. Management Sciences*, 1(26), pp. 142-151, doi: 10.15611/noz.2016.1.12
31. *Statistics Poland, Environment 2023*. Retrieved from: <https://stat.gov.pl/en/topics/environment-energy/environment/environment-2023,1,15.html>, 18.06.2024.
32. Stroncsek, A. (2024). Implementation status of Lean Management in polish manufacturing enterprises. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 191, pp. 519-540. <http://dx.doi.org/10.29119/1641-3466.2024.191.33>
33. Ulewicz, R., Kleszcz, D., Ulewicz, M. (2021). Implementation of Lean Instruments in Ceramics Industries. *Management Systems in Production Engineering*, 29(3), pp. 203-207, doi: 10.2478/mspe-2021-0025
34. Ulewicz, R., Lazar, L.V. (2019). The effect of Lean tools on the safety level in manufacturing organizations. *System Safety: Human - Technical Facility – Environment CzOTO, Vol. 1, Iss. 1*, pp. 514-521, doi: 10.2478/czoto-2019-0066
35. Ulewicz, R., Ulewicz, M. (2020). Problems in the Implementation of the Lean Concept in the Construction Industries. *Lecture Notes in Civil Engineering*, 47, pp. 495-500. [https://doi.org/10.1007/978-3-030-27011-7\\_63](https://doi.org/10.1007/978-3-030-27011-7_63)
36. Veres (Harea), C., Marian, L., Moica, S., Al-Akel, K. (2018). Case study concerning 5S method impact in an automotive company. *Procedia Manufacturing*, 22, pp. 900-905, doi: 10.1016/j.promfg.2018.03.127.
37. Wolniak, R., Grebski, W. (2023). The usage of Kaizen in industry 4.0 conditions. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 188, pp. 677-686. <http://dx.doi.org/10.29119/1641-3466.2023.188.41>
38. Wolniak, R., Grebski, W. (2023). The usage of Lean Management in industry 4.0 conditions. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 187, pp. 761-775. <http://dx.doi.org/10.29119/1641-3466.2023.187.40>
39. Yücenur, G.N., Şenol, K. (2021). Sequential SWARA and fuzzy VIKOR methods in elimination of waste and creation of Lean Construction processes. *Journal of Building Engineering*, 44, 103196. <https://doi.org/10.1016/j.jobe.2021.103196>
40. Żebrućki, Z., Kruczek, M. (2018). Uwarunkowania wdrożenia koncepcji Lean Management w sektorze MŚP [The conditions for the implementation of the Lean Management concept in the SME sector]. *Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i Zarządzanie*, 120, pp. 257-272.





## CHANGES IN TEAMWORK AND NEW LEADERSHIP CHARACTERISTICS, TRIGGERED BY THE WORK FORM CHANGES

Mateusz BYCZYK

Poznan University of Economics and Business, Department of Organisation and Management Theory;  
mateusz.bczyk@gmail.com, ORCID: 0000-0003-3188-2619

**Purpose:** This article aims to explore the evolving dynamics of teamwork and the emerging leadership characteristics that have been brought about by the shifting landscape of work. It examines how changes in work formats, such as remote and flexible arrangements, have influenced team collaboration and the qualities now crucial for effective leadership in this transformed work environment. By examining these developments, this work tries to provide insights and guidance for both organizations and supervisors to adapt and thrive in this new era of work.

**Design/methodology/approach:** This critical literature review is based on articles focused on the role of leader and manager in the context of teamwork performance, taking into account the recent work form changes, all of the reviewed papers were published between 2017 and 2022.

**Findings:** Today's teams operate differently than those from ten years ago. Newly formed groups should be led by individuals who embody leadership qualities, while also possessing some managerial traits. Leaders, utilizing new ICT tools, can influence every aspect of team management. Modern leadership now requires creativity, inclusivity, global connectivity, collaboration, technical competence, and agility. Additionally, leaders need to be adaptable, emotionally intelligent, and capable of providing moral support, especially in a remote or hybrid work setting.

**Practical/social implications:** The challenges discussed in the reviewed articles suggest that similar issues will arise in most organizations today. Supervisors can use these insights to determine whether their teams need a manager or a leader, based on team conditions. Managers ensure accountability by following established rules, while leaders in-spire and motivate through vision and personal qualities. The choice between a manager and a leader, or a combination of both, depends on the team's specific goals, the nature of the project, and the skills and qualities of the individuals involved.

**Originality/value:** This literature review emphasizes that today's employees expect supervisors to navigate and act in alignment with contemporary knowledge and technological potentials. Understanding these expectations helps organizations foster better leadership and teamwork in the modern work environment.

**Keywords:** Leader, manager, team, teamwork, remote work.

**Category of the paper:** Literature review.

**JEL codes:** J24, M12, M54, O15.

## 1. Introduction

Today's, companies expect employees to present creativity, innovative ideas and willingness to change. Additionally, while innovation creativity is based on producing the novelty (Wen, Zhou, Lu, 2017), we must remember that organization's ability of being innovative, is a key factor for long-term growth, what depends on its headmaster and his/her competences (Portnova, Peiseniece, 2017). An innovative environment allows their open use of new ideas, introduced from organizational processes, which were made from various resources (Portnova, Peiseniece, 2017). Current employees are looking for supervisors who are open to interpersonal relations, give attention to all personal needs and problems, listen carefully and frequently communicate to solve daily tasks (Vijaybaskar, 2020). The most discouraging features of supervisor, in their opinion are: bad communication behaviors, rudeness, sloth, micromanaging and meanness. As modern leaders, we should be creative, inclusive, globally connected, collaborative, challenge-seeking, technically competent and agile (Camp, Young, Bushardt, 2022). Also, "it is important for the team to understand how to communicate, when done properly, it allows them to become more productive and satisfied" (Rathod, 2022, p. 36). With the use of communication employees are able to freely and efficiently discuss, share knowledge or interact without secrets (Agbejule, Lehtineva, 2022).

The success of employees management and positive chance of increasing performance all depends on Human Resources' (HRs) practices of its supervisors (Navío-Marco, Solórzano-García, Palencia-González, 2019). One of those HR practices is communication. With the use of effective communication, it is possible to encourage teamwork, motivate employees, build confidence, manage uncertainties, avoid mistakes and reduce unproductivity (Alvarenga et al., 2020). Supervisors who present supportive attitudes and are integrated with subordinates are able to better understand their feelings which makes cooperation and work easier (Milewski, 2021). By that, they are able to motivate, direct and harmoniously guide employees by the use of the most effective communication channel. Communication affects most of the areas, such as learning, encouraging or guiding subordinates, that is why supervisor must be aware of it (Cernicova-Bucă, 2020). Thanks to improving and caring about the quality of communication, as well as the appropriate character of leadership, it is possible to have a positive impact on employees/subordinates, so that they can demonstrate their full potential.

However, recently in the work environment, there have been many changes, including those caused by the COVID-19 pandemic. It triggered the world crisis by affecting service companies, bringing market problems and disrupting well-established environments (Kashive, Khanna, Powale, 2022). One of the disadvantages of COVID-19 pandemic, was the massive inhibition in the economic activities (Hamouche, 2021). The pandemic forced many businesses to do things differently to survive, such as adapting to new circumstances, converting face-to-face approaches to virtual interactions or taking advantage of new opportunities (Johnson,

2021). In consequence, the performance was destabilized, which required time and efforts to adapt to this environment (Renkema, Bondarouk, Bos-Nehles, 2018). Teams that have traditionally worked in an on-site format have had to transition to a less familiar remote or hybrid form, thereby limiting 'live' interactions. Virtual work, for which teams were not always prepared, has shown that communication and leading virtual teams are something to which team leaders do not always know how to respond correctly. Witnessing this, we can notice that in teams working remotely or in a hybrid manner, problems related to communication are increasingly emerging. Supervisors of these teams, due to the complex environment and a vast amount of experience in almost only on-site work, often struggle to suggest ideal team-based solutions to communication problems or to select communication tools that would satisfy the entire team. Even if today's youngest employees possess a broad spectrum of skills and competencies that far outrun those of previous generations, like high proficiency with technology or strong will to learn new skills and receive knowledge while working (Baker Rosa, Hastings, 2018) it is still hard for them to communicate properly. Here, a research gap appears, emphasizing the issue of insufficient knowledge on how to manage communication in virtual teams to achieve the level of communication satisfaction that the team had during on-site work.

This article aims to investigate the changing teamwork and the evolving leadership qualities influenced by the evolving work environment. It explores the impact of contemporary work arrangements, such as remote and flexible setups, on team collaboration and the essential leadership attributes in this new work landscape. By examining these trends, this study offers insights and recommendations to help organizations and managers adapt successfully. The primary research questions can be inferred as: (1) How have recent changes in work environments affected team-work dynamics? (2) What are the evolving leadership qualities necessary for effective team management in remote and hybrid work setups? (3) How can communication in virtual teams be managed to achieve high levels of satisfaction?

The critical literature review draws on articles published from 2017 to 2022, examining the roles of leaders and managers in the context of team performance within the context of recent work environment changes. Its key contribution lies in highlighting the expectation of today's employees for leaders to navigate and act in alignment with modern knowledge and technology's potential.

The article follows a well-structured format, beginning with an Introduction to provide an overview of the topic. The Method section details the research methodology. The main body of the article is organized into several sub-sections within 'The After-effects of Changes Made to Teamwork', covering topics such as team, teamwork dynamics, the impact of changes in work formats and the evolving nature of management and leadership. Finally, the article wraps up with a Discussion and Summary section to provide insights and conclusions derived from the research.

## **2. Method**

The selected method - Critical Literature Review (CLR) is employed in academic and research settings with the purpose of summarizing the current body of research on a specific topic or issue. Moreover, through the use of CLR, papers can assess the strengths and weaknesses of prior re-search and literature within a particular field. Ultimately, this method enables the identification of gaps in existing research and the pinpointing of areas requiring further investigation.

This review used publications from databases, related to management, economy and human resource management. The selected databases were: “EBSCO”, “CAMBRIDGE JOURNALS”, “EMER-ALD” and “GOOGLE SCHOLAR”. It was decided to choose these databases because they have one of the most diverse publications from the analyzed scientific area. The search was conducted on the basis of keywords combination and those phrases included: “manager and leader” or “manager versus leader”, “leadership”, “management”, “manager and leader”, “manager vs leader” “team-work characteristics”, “remote work”, “virtual teams” and “COVID-19 pandemic work changes”.

When selecting papers related to the topic of this article, the following parameters were applied: (1) there were presented differences between manager and leader as well as management and leadership; (2) those articles presented advantages and disadvantages of the phrases mentioned above; (3) some articles presented changes caused by COVID-19 pandemic; (4) articles were supervisors’ and some of employees’ point of view; (5) all articles were not older than 5 years to address to recent work environment characteristics and also most of papers were from years 2020-2022 to include COVID-19; and (6) all articles had to be in English as it is the most popular language of scientific literature.

The conducted search resulted in 5.802 articles. A brief study of titles and abstracts resulted in the drop of 4493 papers unmatched to the research topic. The remaining 1309 results were checked for eligibility, leading to another exclusion of 1139 works, which were nonsignificant or irrelevant to primary topic. The remaining 170 articles were deeply analyzed, which resulted in the choose of 48 the most significant papers.

## **3. Literature review - The after-effects of changes made to teamwork**

### **3.1. Team**

Ciocirlan (2018, p. 29) described organization as an “association of people with shared concepts or interests, brought together in compliance with a regulation or statute, in order to perform organized activity”. Those activities can be daily, operational or strategic. While each

of those differs by time, they are all important for long-term survival. Every task conducted in organizations needs an adequate amount of assets. Recently, higher-ups began to report the increasing problem, most likely caused by pandemic, where they have to work with a limited number of resources. With them limited, to maintain in good performance level they had to make adjustments and invent new possible ways to reach imposed goals (Johnson, 2021). Following the importance of completing the daily organizational task there are many different roles to be fulfilled, which would be impossible for one person to accomplish. Long ago, to work efficiently, enterprises had to establish better solutions as opposed to one-person task completion approach.

Teams are groups of working and learning individuals inside organizations. The main purpose of the team is to achieve a goal or solve a daily work activity (Buzamãt, 2022). In a team, strategy is turned into action, that is why they must be able to grow and learn (Dixon, 2017). There are different skills needed in daily task completion, so it is obligatory to have diversified teams.

Each member of the team has the right to suggest new perspectives, styles, attitudes, ideas or intentions. These new ideas can be crucial to build a good and healthy organizational culture (Rathod, 2022). Culture is built by the whole team, with the use of their everyday interactions, introduced policies, attentional priorities and crisis solutions (Wallace et al., 2020). In organizations, it is based on the shared values, norms, beliefs and needs, which in return can trigger team-fitted behaviors (Camp, Young, Bushardt, 2022). “A key in nurturing a team culture lay in granting employees a fair amount of autonomy so they are able to make independent decisions regarding how to achieve desired outcomes” (Hess, 2018, p. 286).

Project teams characteristics, differentiate them as: cross-functional, multidisciplinary, designed for specific tasks, self-organized or hierarchically organized (Moura, Dominguez, Varajão, 2019). This division emphasizes that a project team is created for a specific purpose, important from the perspective of the organization's needs.

Each project team has its director, on his/her shoulders lies all responsibilities, restrictions, hopes and challenges to reach planned or desired result (Rathod, 2022). Teams' growth is also one of supervisor's responsibilities (Postuła, Majczyk, 2018).

### **3.2. Teamwork**

Along with the team theory, teamwork is a team activity, where people are guided or coordinated to reach a specific target. As teamwork, we can define the set of views, behaviors and attitudes that take part in task performance (Moura, Dominguez, Varajão, 2019). Thanks to teamwork it is possible to increase the quality, speed and outcomes of work, in contrast to one-person work results.

Each team is evaluated by its results and they are based on the whole team efficiency; the better it is, the better the results are. All multi-layered processes, born from team members' cooperation, with the proper engagement of everyone, is called team performance (Moura,

Dominguez, Varajão, 2019). The team, which wants to remain competitive within the enterprise, must present a high performance level, for which the supervisor is responsible (Rathod, 2022). What's more, due to knowledge shared within team members, it is possible to influence their learning efficacy and engagement, while minimizing the probability of problem occurrence (Hess, 2018).

Recently, attitudes towards work have shifted drastically and currently organizations put more emphasis on cross-cultural teamwork (Kappagomtula, 2017). Today's teams are broad, different and with specific needs (Rathod, 2022). They try to find a way to efficiently integrate and cooperate with the new environment (Zhou et al., 2021). With teamwork quality level, we can evaluate the level of actions and relations of project team members (Agbejule, Lehtineva, 2022). Interdisciplinary team projects are difficult to take care of and the complicity becomes more visible when the size of the project is vast (Kappagomtula, 2017).

### **3.3. Teamwork vs. work form changes**

The recent pandemic problems have forced supervisors and their subordinates to rethink their roles to meet the needs caused by the shift in environment (Dandalt, 2021). Pandemic started a previously known but undeveloped concept of remote work. This trend happen to achieve rapid growth due to its huge potential. Following that, by switching from stationary to virtual work, the team needed to introduce and keep a new culture, adjusted to new complicated circumstances (Camp, Young, Bushardt, 2022).

Despite many benefits, the current remote work environment influenced the increase in the level of uncertainty and instability. Virtual teams may lead to employee's isolation, arising from lack of previous daily activities conducted in stationary teams (Hamouche, 2021). However, more and more researches show that new ways of working increase work satisfaction and employee's engagement. In addition, people have a higher sense of autonomy in this work environment (Dandalt, 2021). Another research results of business complicity show the need of increasing employee well-being by the use of remote work potential (Ardebili et al., 2022). As an advantage of remote work, we need to highlight the opportunities of having the flexible work hours, time saving, better work-life balance and possibility to experience new ICT (information and communication technology) uses.

The COVID-19 crisis forced IT-enabled work introduction in some enterprises and emphasized the need for digital competences, useful for employees' daily task solving (Miszczak, 2022). Even though virtual teams are dependent on technology to do anything, they are widely used to overcome the restrictions of time and place to replace traditional teams (Kashive, Khanna, Powale, 2022).

### 3.4. Manager and leader

Most of the teams are guided by supervisors also known as managers. Managers, simply, are people taking care of management (Postuła, Majczyk, 2018). Coordinating and overseeing the work of subordinates, along the way of accomplishing the requested results, is their main responsibility (Simić, 2020). Manager is a part of a formal organizational hierarchy, with its power and authority in directing actions of subordinates.

Every manager must be aware of specific managerial practices which are stimulating subordinates and drive them to fast results accompanied by high quality (Portnova, Peiseniece, 2017). Their decisions affect the actions and behaviors of those earlier-mentioned employees. Success-seeking manager is obliged to identify the innovative solutions in the decision-making process (Iasmina et al., 2017). Today's managers are expected to be creative to bring solutions for complex and unexpected modern problems (McKeown, 2018) and thanks to understanding of other people's emotions, it is possible to know better ways to affect their actions.

Previously, in literature, leaders and managers were equated. However, as the time passed, the definition of manager has started to deteriorate in consequence of the idea:

'A good manager does things right, while leader do the right things' (Beckley, 2020). The position of the manager is based on formal authority and legitimate power, while the leader's seat is not pointed in any normative act, employment agreement or job description (Ciocirlan, 2018).

A manager is a person that holds power. On the other hand, leader is a person you want to follow without formal designation. In many articles authors presented the difference of leader and manager as the ability to influence others without the use of their authority and status (Miszczak, 2022). Leaders are tasked to lead people and guide them through the problems to increase and develop their skills (Postuła, Majczyk, 2018). In leader's hands lies the power to influence or bend the group's performance to achieve desired goals of the team (Ribeiro Cantarino, 2022). The team leader role is based on setting tasks or goals, new strategy adoption, accelerating working processes and introducing performance levels, needed or expected by the organization (Huang, Huang, Chang, 2019). In Table 1. is a comprehensive comparison of the managerial and leadership approaches to team guidance, shedding light on the distinct strategies and attributes that managers and leaders employ in order to effectively steer teams toward their objectives.

**Table 1.**  
*Manager's and leader's way of team guide*

Field	Manager	Leader
Work-style	Taking action	Use cognitive and imaginative features
	Utilizing subordinates	Inspiring subordinates
	Formal and disciplined mind	Visionaries
Employees' affection	Administration / Giving orders	Psychological influence
	Using given power to command others	Establishing social connections
	Following hierarchy	Friendly / Human oriented
	Manipulation	Motivation
Task completion	Following given goals	Creating own goals
	Achieve result no matter how	Use current assets
Main area of concern	Solving everyday problems	Taking care of strategic issues
	Running enterprise	HRM
	Managing and controlling task / people	Encouraging others

Source: Own work, based on: Ciocirlan, 2018; Postuła, Majczyk, 2018; Walsh, 2020; Lucia, 2018; Buzamăt, 2022 and Bhattacharyya, 2020

As a head of the team, the leader is in charge of making team members engaged, focused, with a solid level of understanding and knowledge (Rathod, 2022). Leaders care about team spirit that is why they must know the needs of its team members (Buzamăt, 2022). The good leader has some specific characteristics, like: honesty, inspiration, communicativeness, decisiveness, authority delegation, courage, justice, kindness, competence, creativity, optimism and intuition (Vardiashvili, 2022). With those, leaders promote respect, dignity and team acceptance, while pointing the avoidance of destructive behaviors (Wallace et al., 2020).

Newly made leaders are people deeply concerned about HR (Vardiashvili, 2022). The possibilities of modern HRs are considered to be of huge relevancy for the enterprises and it can be noticed the value of this function within employee engagement (Navío-Marco, Solórzano-García, Palencia-González, 2019). It is increasingly underlined, that as team leader, we must try to maintain the balance between control and trust (Vardiashvili, 2022), and also, we must provide constructive feedback to make our subordinates grow (Buzamăt, 2022).

### 3.5. Management and leadership

Following the description of supervising theory, two basic dimensions can be distinguished. First is task-concerned behavior, which is simply described as placing goals completion at first, without hesitation. Another one is strictly opposite, named employee-concerned behavior, and it is built around pro-human actions, relations and respect (Wen, Zhou, Lu, 2017). Those two definitions allowed us to distinguish two ways of employee guide – first is management while the second mentioned is leadership.

The foundation of a successful organization underlies in its management character (Ciocirlan, 2018). “Management is, somehow, the art of knowing what you want person to do, and then seeing that they do it in the best and cheapest way” (Simić, 2020, p. 3). As management, we can define the process of planning, directing, organizing and controlling



all resources belonging to an organization (human, informational, physical and financial) in exchange to reach desired goals (Lucia, 2018).

Constant evolution and recent economic crises made old management practices questionable enough to start the rapid growth of interest in leadership within scientific literature (Lašáková, Remišová, Kirchmayer, 2017). Most researchers, among leadership behaviors present: fairness, integrity, ethical guidance, people orientation, power sharing, role clarification and concern for sustainability (Lašáková, Remišová, Kirchmayer, 2017).

When a group of people is led towards a specific goal, under the influence, but not force, it is called leadership (Portnova, Peiseniece, 2017). The process of leadership is built thanks to relations made between leader and its followers (Chung, Navarro, 2021). By leadership, we can also define the process of creating route for others, with enough power to support their needs and goal completion (Simić, 2020). Leading a team through all challenges needs the identification of all conditions that may destroy or restrict the team's potential (Domínguez-Escrig et al., 2021). The proper leading of the group allows them to make a creative solution, without a waste of time, money or efforts (Iasmina et al., 2017).

As good leaders we are able to influence other team members, and also, those direct subordinates are able to change the leader's attitude or behaviors. Those leaders aware of its team competences can adjust tasks' requirements to fit its employees' knowledge and skills (Zheng et al., 2021). In contrary, bad leaders tend to act defensively for criticism when the job is 'heading the wrong way'; they become unmotivated to develop their skills which make them ineffective. It is highly appreciated to remember, the leader is a guardian of its subordinates, who build a relationship operating on trust (Zubek, 2020). "Trust is the intention or willingness to accept vulnerability based on positive expectations of the intentions or behaviors of others" (Dixon, 2017, p. 141). Highly competent supervisors, who have mastered certain competences are better prepared to use emerging opportunities to improve their competitive position (Stańczyk, Stańczyk, Szalonka, 2020).

### **3.6. Supervision changes in work form context**

When forms of work switched from stationary to hybrid or remote, the supervisors had to change their minds and management styles (Dandalt, 2021). The main goal of current team wardens need to be the concentration on providing moral support to avoid psychological problems. This might have forced changes from manager to leader.

The reality, shaped from 21st century's technological changes, influences almost all areas of economic and public life. Additionally, the spread of COVID-19 resulted in rapid redefinition of the work requirements. Modern leaders are in charge of guiding their subordinates under unknown circumstances, where they have to give employees the needed directions to fulfill organizational expectations (Vardiashvili, 2022). In this environment, employees are at risk, that is why they need to be strictly monitored to avoid unwanted situations (Johnson, 2021). However, the COVID-19 pandemic, as well as the fourth industrial

revolution, allowed enterprises to take part in digital changes to improve the way they operate on daily/basic tasks (Ngayo Fotso, 2021). From a business point of view, the recent pandemic was called the most important event that transformed organizational lives, needs and approaches (Camp, Young, Bushardt, 2022).

The pandemic undoubtedly shifted the way of work and team supervision (Moore, Hanson, 2022). The switch to remote work, growth of virtual teams and new information and communication technologies (Vijaybaskar, 2020) increased the need of using the new IT tools to motivate others (Miszczak, 2022). Newly created E-HRM (Electronic Human Resource Management) is able to cover all needs or requirements of the complicated, post-pandemic reality (Zhou et al., 2021). Organizations started to understand that the performance of their leaders is a major component of creating a healthy work environment (Moore, Hanson, 2022). Table 2 provides an in-depth examination of the shifts in team supervision practices brought about by changes in work environment structures, offering a detailed analysis of the evolving roles and strategies that supervisors and team leaders must adopt to effectively navigate the dynamic landscape of contemporary work arrangements.

**Table 2.**

*Changes in team supervising caused by work form environments*

Areas	Stationary team	Virtual team
<b>Integration of work with technology</b>	Low level digital competences	Daily use of ICT / IT tools
<b>Expected / Needed supervising style</b>	Bureaucratic	Psychological
<b>Management style</b>	Classic	E-HRM
<b>Focusing on:</b>	Knowledge acquisition	Skill building, mindset change, behavior growth
<b>Employees relations</b>	Daily group activities	Employees isolation
<b>Meeting ways</b>	Face-to-face approach	Virtual interactions
<b>Employees work behavior</b>	Healthy relations	Trust issues / conflicts
<b>Communication style</b>	Open	Exclusionary
<b>Team connections</b>	Homogenous	Diversified

Source: own work, based on: Miszczak, 2022; Ardebili et al., 2022; Dandalt, 2021; Ribeiro Cantarino, 2022; Hamouche, 2021; Johnson, 2021; Vardiashvili, 2022; Kashive, Khanna, Powale, 2022; Moura, Dominguez, Varajão, 2019.

Apart from challenges, the COVID-19 invoked possibilities, with which employers were able to execute their HRM actions in new, previously unknown ways. In consequence, employees received an increase in flexibility on many levels, named as: work format, timelines, dress code or role compassion. New remote work possibility gave chance disabled employees to work under friendly video conference environments. People in charge understood, the subordinates are doing their best under the complicated circumstances (Chung, Navarro, 2021).

#### 4. Discussion and summary

“Civilizations that prospered were led by great leaders while the civilizations that perished were often the victims of poor leadership. Business organizations are a part of the society and civilization” (Bhattacharyya, 2020, p. 374). Survival of the society, its dreams, crucial values and needs, are all dependent on the leaders’ competencies (Ciocirlan, 2018). Currently, we live in the age of knowledge. In this case, the major role of leadership is to establish a high level of knowledge acquisition, knowledge sharing, implementation of innovative solutions and an ability to adapt to rapid changes (Zubek, 2020). Supervisors must remember, they are responsible for the health of employees while they are at work. They have to ensure that the workplace is safe, free of any hazards that may hurt them physically or psychologically (Hamouche, 2021).

The current reality requires a modern style of management in organizations. The new type of leader should be characterized by the following: caring for employees, caring for customers and caring for the community (Vardiashvili, 2022). Additionally, thanks to leaders, it is possible to switch subordinate’s self-oriented identity into group-oriented ones (Özalp Türetgen, Unsal, Dural, 2017). The new management methods require more human-oriented way of thinking, to fully understand employees’ needs and feelings, which were placed as the most important in the new environment (Domínguez-Escrig et al., 2021).

Also, we can observe the current tendency of reducing the importance of technical skills and authority over employees. What is more, the pandemic period changed the old managerial rigorous skills to more human-oriented leader’s skills and behaviours. In previous literature we could observe the tendency to focus on the hard competencies to easily handle projects, relegating the soft skills to the end. Thanks to emotional knowledge, they will be able to convince teams and understand their true needs (Montiel, Gallo, Antolin-Lopez, 2020). Human capital is viewed as the personal attributes of a leader and their capacity to adapt and utilize these attributes (Gallego-Roquelaure, 2020) and they can use it in many beneficial ways.

Development of influential relationship between leader, direct reports, other team members and team supervisors will result in effective lead across the organization (Beckley, 2020). A communication of a good supervisor is able to influence the willingness of subordinates to share their thoughts and give comments of current good and unwanted practices (McKeown, 2018).

Sometimes, authors stated that the role of manager and leader can be occupied by the same person, but if by definition managers and leaders are different, how can one be manager and leader simultaneously? (Simić, 2020). It may be simply explained. Apart from ‘leading people’, leaders are also in charge of planning, organizing and controlling organizational resources. Similarly, managers should also try to lead people, with the use of a human-friendly approach (which is the opposite from their task-oriented minds).

Modern project managers must partially become leaders, as it is needed to combine hard skills of management with soft qualities of leadership, to deal with people and be efficient in terms of assignments, cases and targets (Alvarenga et al., 2020). To reach that point, organizations must try to motivate supervisors to learn new skills required for responsible management. Following that, managers and leaders must be ready and highly motivated to improve by learning new skills (Montiel, Gallo, Antolin-Lopez, 2020) and adapting to new environment.

## **5. Limitations**

The article's literature review from 2017 to 2022 provides valuable insights into recent developments in teamwork and leadership. However, future research could expand its scope to include a broader range of industries, enhancing the applicability of findings across various sectors. Additionally, incorporating diverse geographical contexts would offer a more comprehensive understanding of global challenges. While focusing on pandemic-related changes, exploring other disruptions could enrich the analysis. Finally, acknowledging variations in team dynamics and ICT proficiency across different teams would provide a more nuanced perspective.

## **Acknowledgements**

The purpose of this article is to open my research on leadership in a team and its changes caused by the pandemic of COVID-19. As it is the first in a series of articles during PhD studies, I would like to thank my supervisor, Prof. Elżbieta Kowalczyk, who gave me many valuable tips regarding this paper. Without her help it wouldn't be possible to finish my work.

## References

1. Agbejule, A., Lehtineva, L. (2022). The relationship between traditional project management, agile project management and teamwork quality on project success. *International Journal of Organizational Analysis*, Vol. 30 No. 7, pp. 124-136. <https://doi.org/10.1108/IJOA-02-2022-3149>
2. Alvarenga, J.C., Branco, R.R., Guedes, A.L.A., Soares, C.A.P., Silva, W.d.S.e. (2020). The project manager core competencies to project success. *International Journal of Managing Projects in Business*, Vol. 13, No. 2, pp. 277-292. <https://doi.org/10.1108/IJMPB-12-2018-0274>
3. Ardebili, A., Latifian, A., Aziz, C.F., BinSaeed, R.H., Alizadeh, S.M., Kostyrin, E.V. (2022). A comprehensive and systematic literature review on the employee attendance management systems based on cloud computing. *Journal of Management & Organization*, 1–18. <http://doi.org/10.1017/jmo.2022.63>
4. Baker Rosa, N.M., Hastings, S.O. (2018). Managing Millennials: looking beyond generational stereotypes. *Journal of Organizational Change Management*, Vol. 31, No. 4, pp. 920-930. <https://doi.org/10.1108/JOCM-10-2015-0193>
5. Beckley, J.M. (2020). Leading and Following: The Co-Construction of Leadership. *New Directions for Community Colleges*, 191, 57-66.
6. Bhattacharyya, S.S. (2020). Evolving from Manager to a Business Leader: Characteristics of 'Yogic Perspectives' & "Vedic Philosophy". *Indian Journal of Industrial Relations*, 56(2), 374-383.
7. Buzamăt, G. (2022). Implications of Leadership in Organizational and Managerial Culture in Romanian Organisations. Preliminary Study. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, 22(2), 153-158.
8. Camp, K.M., Young, M., Bushardt, S.C. (2022). A millennial manager skills model for the new remote work environment. *Management Research Review*, Vol. 45, No. 5, pp. 635-648. <https://doi.org/10.1108/MRR-01-2021-0076>
9. Cernicova-Bucă, M. (2020). Communication and Linguistic Competences for Middle Management: A Content Analysis of Job Advertisements. Scientific Bulletin of the Politehnica University of Timisoara. Transactions on Modern Languages. *Buletinul Stiintific Al Universitatii Politehnica Din Timisoara. Seria Limbi Moderne*, 19(1), 5-14.
10. Chung, J., Navarro, C.D. (2021). Leader Identity: Resisting Conformity and Reconstructing How We Define "Leader". *New Directions for Student Leadership*, 172, 35-43.
11. Ciocirlan, D. (2018). Authentic Management and Emotionally Intelligent Leaders versus Conjectural Management and Conjectural Leaders. *Management and Economics Review*, 3(1), 27-38.

12. Dandalt, E. (2021). Managers and telework in public sector organizations during a crisis. *Journal of Management & Organization*, 27(6), 1169-1182. <http://doi.org/10.1017/jmo.2022.1>
13. Dixon, N. (2017). Learning Together and Working Apart: Routines for Organizational Learning in Virtual Teams. *Learning Organization*, 24(3), 138-149. <http://dx-1doi-1org-100002bwn0952.han3.ue.poznan.pl/10.1108/TLO-12-2016-0101>
14. Domínguez-Escrig, E., Mallén Broch, F.F., Lapiedra Alcamí, R., Chiva Gómez, R. (2021). Leaders who empower: a gateway to radical innovation. *Journal of Management & Organization*, 27(5), 930-947. <http://doi.org/10.1017/jmo.2019.73>
15. Gallego-Roquelaure, V. (2020). The Emergence Process of an International Network of SMEs and the Evolution of the Leader's Role. *Journal of International Entrepreneurship*, 18(1), 44-62.
16. Hamouche, S. (2021). Human resource management and the COVID-19 crisis: implications, challenges, opportunities, and future organizational directions. *Journal of Management & Organization*, 1-16. <http://doi.org/10.1017/jmo.2021.15>
17. Hess, J.P. (2018). Autonomous team members' expectations for top-leader involvement. *Team Performance Management*, Vol. 24, No. 5/6, pp. 283-297. <https://doi.org/10.1108/TPM-10-2017-0060>
18. Huang, C.-Y., Huang, J.-C., Chang, Y. (2019). Team goal orientation composition, team efficacy, and team performance: The separate roles of team leader and members. *Journal of Management & Organization*, 25(6), 825-843. <http://doi.org/10.1017/jmo.2016.62>
19. Iasmina, I., Roxana, P., Corina, S., Gabriela, P. (2017). The Importance and the Role of Managers Regarding the Negotiation within the Group. *Agricultural Management. Lucrari Stiintifice Seria I, Management Agricol*, 19(1), 5760.
20. Johnson, J.W. (2021). Identifying the best-fit leaders for the pandemic context. *Industrial and Organizational Psychology*, 14(1-2), 123-125. <http://doi.org/10.1017/iop.2021.21>
21. Kappagomtula, C.L. (2017), Overcoming challenges in leadership roles – managing large projects with multi or cross culture teams. *European Business Review*, Vol. 29, No. 5, pp. 572-583. <https://doi.org/10.1108/EBR-12-2015-0177>
22. Kashive, N., Khanna, V.T., Powale, L. (2022), Virtual team performance: E-leadership roles in the era of COVID-19. *Journal of Management Development*, Vol. 41, No. 5, pp. 277-300. <https://doi.org/10.1108/JMD-05-2021-0151>
23. Lašáková, A., Remišová, A., Kirchmayer, Z. (2017). Are Managers in Slovakia Ethical Leaders? Key Findings on the Level of Ethical Leadership in the Slovak Business Environment. *Periodica Polytechnica: Social & Management Sciences*, 25(2), 87-96. <https://doi.org/10.3311/PPso.9758>
24. Lucia, F. (2018). Manager versus Leader. Why Are Both Roles Valuable? *Ovidius University Annals, Series Economic Sciences*, 18(2), 428-431.

25. McKeown, T. (2018). Good management is hard, but someone has to do it (and here are some suggestions). *Journal of Management & Organization*, 24(2), 163-166. <http://doi.org/10.1017/jmo.2018.16>
26. Milewski, R. (2021). Identification of Management Styles with the Use of ICT Support Instruments. *European Research Studies*, 24(1), 262-287. <https://doi.org/https://www.ersj.eu/index.php>
27. Miszczak, M. (2022). Leader's Digital Competence in Motivating Employees during the Covid-19 Pandemic – Research Findings. *Scientific Papers of Silesian University of Technology. Organization & Management [Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie]*, 159, 269-279. <https://doi.org/10.29119/1641-3466.2022.159.21>
28. Montiel, I., Gallo, P.J., Antolin-Lopez, R. (2020). What on Earth Should Managers Learn About Corporate Sustainability? A Threshold Concept Approach. *Journal of Business Ethics*, 162(4), 857-880. <https://doi.org/10.1007/s10551-019-04361-y>
29. Moore, J.R., Hanson, W. (2022), Improving leader effectiveness: impact on employee engagement and retention. *Journal of Management Development*, Vol. 41, No. 7/8, pp. 450-468. <https://doi.org/10.1108/JMD-02-2021-0041>
30. Moura, I., Dominguez, C., Varajão, J. (2019), Information systems project teams: factors for high performance. *Team Performance Management*, Vol. 25, No. 1/2, pp. 69-83. <https://doi.org/10.1108/TPM-03-2018-0022>
31. Navío-Marco, J., Solórzano-García, M., Palencia-González, F.J. (2019). Human resource management as key pillar of company strategy: Analysis of the line managers' perception. *Journal of Management & Organization*, 25(2), 175-188. <http://doi.org/10.1017/jmo.2018.49>
32. Ngayo Fotso, G.M. (2021). Leadership Competencies for the 21st Century: A Review from the Western World Literature. *European Journal of Training and Development*, 45(6-7), 566-587.
33. Özalp Türetgen, I., Unsal, P., Dural, U. (2017). The role of leadership perception as a mediator between managers' self-monitoring and subordinate attitudes. *Journal of Social Psychology*, 157(3), 295-307. <https://doi.org/10.1080/00224545.2016.1192096>
34. Portnova, I., Peiseniece, L. (2017). Leaders' Competences for Successful Leadership of Invention and Implementation of Innovation: A Conceptual Model. *Journal of Business Management*, 13, 40-55.
35. Postuła, A., Majczyk, J. (2018). Managers and Leaders in Need of Entrepreneurial Competences. *Entrepreneurial Business & Economics Review*, 6(1), 91-103. <https://doi.org/10.15678/EBER.2018.060105>
36. Rathod, S.S. (2022). Fostering Communication Skills Among Teams in Organizations. *IUP Journal of Soft Skills*, 16(3), 35-42.

37. Renkema, M., Bondarouk, T., Bos-Nehles, A. (2018) Transformation to self-managing teams: lessons learned: A look at current trends and data. *Strategic HR Review*, Vol. 17, No. 2, pp. 81-84. <https://doi.org/10.1108/SHR-10-2017-0072>
38. Ribeiro Cantarino, G.P., Oliveira de Araujo, F. (2022). Technical, behavioral and attitudinal competences of leaders/managers: practical applications based on literature exploratory study. *Brazilian Journal of Operations & Production Management*, 19(4), 1-8. <https://doi.org/10.14488/bjopm.2022.1558>
39. Simić, I. (2020). Are Managers and Leaders One and the Same? *Ekonomika*, 66(3), 1-13. <https://doi.org/10.5937/ekonomika2003001S>
40. Stańczyk, E., Stańczyk, P., Szalonka, K. (2020). The Impact of Personality and Competence of Leaders on Business Success. *European Research Studies*, 23(2), 612-623. <https://doi.org/https://www.ersj.eu/index.php>
41. Vardiashvili, N. (2022). The Impact of the Pandemic on Leadership Characteristics. *Globalization & Business*, 13, 65-70. <https://doi.org/10.35945/gb.2022.13.010>
42. Vijaybaskar, L. (2020). A New Leadership Model for Millennial Leaders in the Innovation Age. *Journal of Contemporary Management Research*, 14(1), 1-17.
43. Wallace, D.M., Raver Luning, C., Rosenstein, J.E., Ledford, A., Cyr-Roman, B. (2020). A culture of respect: Leader development and preventing destructive behavior. *Industrial and Organizational Psychology*, 13(2), 225-229. <http://doi.org/10.1017/iop.2020.46>
44. Walsh, J.P. (2020). Contextualizing the Attention to Managers and Leaders since 1890 and Our Infatuation with Leaders since 2007: A Commentary on Kniffin, Detert, and LeRoy (2020). *Academy of Management Discoveries*, 6(4), 678-688. <https://doi.org/10.5465/and.2020.0074>
45. Wen, L., Zhou, M., Lu, Q. (2017), The influence of leader's creativity on employees' and team creativity: Role of identification with leader. *Nankai Business Review International*, Vol. 8, No. 1, pp. 22-38. <https://doi.org/10.1108/NBRI-05-2016-0020>
46. Zheng, M.X., Schuh, S.C., Dijke, M., De Cremer, D. (2021). Procedural justice enactment as an instrument of position protection: The three-way interaction between leaders' power position stability, followers' warmth, and followers' competence. *Journal of Organizational Behavior (John Wiley & Sons, Inc.)*, 42(6), 785-799. <https://doi.org/10.1002/job.2493>
47. Zhou, L., Chen, Z., Li, J., Zhang, X., Tian, F. (2021). The influence of electronic human resource management on employee's proactive behavior: based on the job crafting perspective. *Journal of Management & Organization*, 1-18. <http://doi.org/10.1017/jmo.2021.33>
48. Zubek, M. (2020). Leadership and Management in Public Administration. *Education of Economists & Managers [Edukacja Ekonomistów i Menedżerów]*, 55(1), 113-126. <https://doi.org/10.33119/EEiM.2020.55.8>



## INVENTORY MANAGEMENT IN INDUSTRIAL PROCESSING ENTERPRISES IN THE CONTEXT OF CRISIS CONDITIONS

Anna CZARNY

West Pomeranian University of Technology in Szczecin, Faculty of Economics; anna.czarny@zut.edu.pl,  
ORCID: 0000-0003-2501-3871

**Purpose:** The purpose of this article was to assess changes and trends in the main parameters characterizing inventory management in industrial processing enterprises in 2006-2009, 2010-2013 and 2018-2022.

**Design/methodology/approach:** The analysis covered business entities by Divisions of Section C - "Manufacturing" in relation to four crisis situations. The research undertaken is descriptive, spatial-temporal and critical analysis - the changes and deviations of selected indicators from average values in periods of prosperity are indicated. The presentation of the research results includes descriptive form and graphical form in the form of figures. The numerical data came from the Statistics Poland website.

**Findings:** In the majority of manufacturing enterprises, all crisis situations had an adverse effect on inventory management. The exceptions were D17, D21 and D32 enterprises, which showed no negative sensitivity to crisis situations.

**Research limitations/implications:** The geopolitical and macroeconomic situation has impeded most of the favorable trends after the post-pandemic "rebound" in 2022. For this reason, it was difficult to clearly assess the impact of the energy crisis on inventory management at the surveyed companies.

**Originality/value:** The originality of the study lies in the fact that it was carried out for four different crisis situations and was concerned with assessing changes in the parameters characterizing inventory management, rather than assessing the value of indicators.

**Keywords:** Inventory management, industrial processing, crisis situation.

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

## 1. Introduction

### 1.1. Crisis situations in business operations

In an era of unpredictability, destabilization, disinformation, it is increasingly difficult to make rational decisions. This is accompanied by uncertainty, understood as “a situation in which it is impossible to predict the probability, independent of the will of the decision-maker, of future states of phenomena or the course of processes” (Redziak, 2013). On the other hand, economies seeking to raise standards of resource management and care for the environment are obliged to operate on the basis of the principles of sustainable development. This concept is defined as the ability to continuously learn, adapt to changing conditions (Grudzewski, Hejduk, Sankowska, Wańtuchowicz, 2010), in which the process of integrating political, economic and social activities takes place, with preservation of natural balance and sustainability of basic natural processes, so as to ensure the ability to meet the basic needs of the present and future generations (Siekierski, Rutkowska, 2008). In addition, global, widespread consumerism drives economic entities and entire economies, according to the statement that “man has lost the awareness that he is part of the natural environment and in his greed, fueled by the market model of the economy, in which money is the only thing that matters, he has forgotten that the overriding characteristic in his activity should be the pursuit of the common good” (Rutkowska-Podołowska, 2016).

The imbalance between expectations and the ability to meet them influences the emergence of a crisis, which, according to one definition, is defined as “a situation in which there are serious economic problems; manifested by a lack of sufficient financial resources, stunted economic development, and an insufficient amount of goods or raw materials for sale” (The Great Dictionary of the Polish Language of the Polish Academy of Sciences).

The origins of the term crisis can be traced back to the Greek language *krinein* and points to the verbs sift, separate, choose, decide, judge, while the noun derived from it *krisis* means selection, resolution (Kopaliński, 2000). In the current time, the term is conjugated by all grammatical cases and applies to almost every sphere. It is due to the complexity and severity of factors that a few years ago did not pose such a big threat, especially economically. Among the most significant are those of global scope, resulting from the geopolitical situation, the rapid spread of diseases or climate change. The current geopolitical situation, as a result of Russia's war with Ukraine, has created further adverse circumstances, including an energy crisis, waves of refugees and migrants, rising inflation, disruption of global food supply chains, or a slowdown in the energy transition and other measures designed, by design, to prevent a climate catastrophe (Soroka, Pająk, 2023). It should be borne in mind that the war involves many countries in military, financial and humanitarian aid to Ukraine, putting additional strain on their budgets. In addition, the war has “become another factor aggravating the economic downturn by triggering an energy and food crisis” (Prokopowicz, 2023). The energy crisis,

caused on the one hand by a significant reduction in the availability of energy resources, and on the other by the diversification and investment of European economies in renewable energy sources, is an additional source of the food crisis. The availability of energy is essential for the proper flow of all processes in logistics chains, from procurement through production, storage, distribution, to the sale of food products. Additional factors restricting the flow of goods, including food, were the broken logistics chains caused by the COVID-19 pandemic<sup>1</sup>.

The crisis caused by a biological agent, such as a pandemic, was a global crisis of intensified intensity, weighing down most economies and industries. In addition, it was a crisis that was sudden, unpredictable as to the direction of change and gave a sense of danger. In the literature, such a situation is referred to as a “black swan” (Wolniak, 2022; Kisielnicki, 2021), which is supposed to emphasize the exceptional unpredictability, uncertainty, even disbelief of the situation. The aforementioned crisis was characterized by many features typical of a crisis, which have been described in the literature, such as: (James, Gilliland, 2004):

- complexity caused by many interacting and intertwining factors,
- lack of panaceas and quick solutions,
- universality, expressed in the fact that under certain circumstances no one is completely immune to it and can be sure never to experience it.

Another important feature to add is the lack of a margin of time to react quickly and make the right decisions so as not to escalate the crisis.

A crisis is the culminating phase of a crisis situation. “Every crisis is a crisis situation, but not every crisis situation is a crisis phase. Every crisis situation can trigger a crisis multiple time” (Otwinowski, 2010). It is dynamic in nature and is a process indicating “a sequence of events taking place over a certain period of time, which are a threat to the existence of the company and make this existence impossible” (Zimniewicz, 1990). It should be kept in mind that “every crisis situation is different, so each should be treated individually. There are no ready-made prescriptions, but through analysis of crisis situations, simulations and experience from past crises, one can acquire skills to effectively identify the symptoms of a crisis and take effective management actions during a crisis situation” (Kaczmarek-Śliwińska, 2015). In addition, it is important to “identify problem situations, which makes it possible to avoid the surprise that a sudden crisis situation can be. This implies the need for continuous analysis of problem situations” (Ciekanowski, Stachowiak, 2011).

Crisisogenic situations are those that foster or cause crises (Dictionary of Polish Language). Virtually every organization at any time is confronted with an emergency situation, i.e., a crisisogenic situation (Gościński, 1989). The opposite of such situations is an opportunity,

---

<sup>1</sup> The COVID-19 epidemic state began on March 20, 2020 (in accordance with the Ordinance of the Minister of Health of March 20, 2020, on the declaration of an epidemic state in the area of the Republic of Poland). As of May 16, 2022, it was replaced by a state of epidemic emergency, which lasted until June 16, 2023 (in accordance with the Ordinance of the Minister of Health of June 14, 2023, on the cancellation of a state of epidemic emergency in the area of the Republic of Poland). On May 5, 2023. The World Health Organization (WHO) declared the end of the COVID-19 pandemic (End-of-epidemic-emergency-status).

which, properly exploited with favorable factors and rapid adaptation to surrounding changes, can turn into success. In an enterprise, however, “success is rarely (...) a permanent and immanent feature” (Urbanowska-Sojkin, 1999).

According to the definitions cited, the author's interests lie in the analysis of crisis situations that have occurred in recent decades, which will be developed later in this paper.

## **1.2. Inventory management as a management area**

An important area of management in a manufacturing enterprise is inventory management. In the literature, studies and definitions are mainly concerned with materials management, understood as “the process of rational circulation of materials in the enterprise related to the acquisition, transportation, receipt, transfer and release of materials needed for production” (Niziński, Żurek, 2011) or “an area of economic activity that encompasses the totality of phenomena and processes related to the management of materials at all levels of management” (Statistics Poland, Publications, 2016), and the basis of this economy is to secure the continuity of the implemented economic processes (Janik, Paździor, Paździor, 2017). Thus, inventory management is an area of activity of an economic entity in which any movement or stoppage of inventory, economically and logistically justified, is important, ultimately affecting the bottom line. With inventory management being “a process involving the allocation of disposable resources among various uses” (Dach, 2001), then inventory management can mean the disposition and allocation of inventories in accordance with the purposes of their use in a certain unit of time.

An important concept besides inventory management is efficiency, understood as efficiency, effectiveness, productivity, profitability, economy (Bielski, 2002; Kondalkar, 2010) and is among the “properties that determine the essence of the enterprise as a business entity, it conditions the functioning of the organization and determines its development” (Kulińska, Rut, 2013). In the literature, the concept of efficiency is combined with the efficiency of the production process (Koliński, 2011), logistics activities (Mesjasz-Lech, 2012) and the aforementioned inventory management, including supply, production and marketing inventories (Modi, Mishra, 2011).

Inventories are an important group of components in the assets of manufacturing enterprises<sup>2</sup>. They represent useful but idle resources with a certain economic value (Vrat, 2014). They can be considered in logistic and accounting terms. According to the logistics view, it is a certain amount of goods, located in the logistics system continuously unused, intended for later processing or sale (Klepacki, 2022). It's having something in excess, so a stockpile isn't what you absolutely need at any given time (Krawczyk, 2020). Inventories, being properly

---

<sup>2</sup> According to Statistics Poland figures, in industrial enterprises, inventories accounted for an average of 20% in total assets and nearly 40% in current assets in 2022, including about 25% in beverage enterprises and nearly 60% in tobacco enterprises (based on Statistics Poland / Subject areas / Business entities. Financial performance / Non-financial enterprises).

stored goods, are excluded from the logistics transfer, and people and appropriately adapted premises and equipment are involved in their handling and storage. It is worth noting that inventories arise as a result of two important discrepancies: the intensity of supply streams is different from the intensity of consumption streams, and/or actual consumption is different from planned or forecast consumption. According to the accounting treatment, inventories are tangible current assets - materials acquired for consumption for own use, finished products (goods and services) manufactured or processed by the entity that are fit for sale or in the course of production, semi-finished products and goods acquired for resale in an unprocessed state (Accounting Law). Information on the size of a company's inventories is located in its balance sheet (Appendix 1 to the Law), in item B.I, broken down into materials, semi-finished and work-in-progress products, finished products, goods, and advances for supplies and services.

Inventories are classified according to different areas. According to one of them, inventories can be divided into two groups (Skowronek, 2023):

- inventories in the sphere of production (stocks of materials, semi-finished products and products in the course of production processes), which serve enterprises in normal production activities and whose sales are sporadic,
- inventories in the sphere of distribution (stocks of finished products, goods), which are in the disposal phase at producers in their warehouses, logistics and distribution centers, wholesale and retail networks.

In a market economy, enterprise decision-makers are interested in proper inventory management, including efforts to maintain optimal inventory levels. The size of inventories, their structure and dynamics depend on the volume and structure of production, unit consumption of materials, seasonality, complexity of manufacturing, as well as the length of individual supply cycles. Also contributing to this is economic globalization, understood as “the process of eliminating boundary barriers to the operation of the market, the consequence of which is the integration of the world economy” (Szymański, 2004), facilitating the movement of inventory in national and international logistics chains.

Inventory management is a challenge for almost every enterprise. It should focus primarily on inventory turnover, which makes it possible to shape the level of inventory and possibly reduce it (Skowron-Grabowska, 2009). This is one of the areas affecting cost levels (Zimoń, 2015), company's result and sales profitability (Koumanakos, 2008). It is integral to consider the often mutually exclusive economic and logistical aspects. According to the economic aspect, inventory levels, both raw materials and finished products, should be kept as low as possible in order to minimize the cost of handling them (including maintenance, ordering, storage, insurance, handling, impairment). This translates into lower availability of finished products and the possibility of not meeting customer demands. Thus, the logistics aspect aims to ensure the continuity and dynamism of production, adapting to the needs of customers and maintaining a certain reserve of inventory. Customer satisfaction and minimal inventory shortages are important, while keeping inventory costs as low as possible (Reddy, 2021).

However, stock levels that are too low can “lead to inventory depletion and be a consequence of production interruption and/or loss of a customer for whom time to obtain a particular good may be the highest priority” (Gołębiowski, 2016).

According to another criterion, inventories are classified into rotating and non-rotating. The former result from synchronization of regular supplies with their current consumption and uninterrupted demand. Non-rotating inventories, on the other hand, are divided into seasonal inventories, related to the seasonality of the acquisition of raw materials or sales of finished products, promotional inventories, accumulated mostly as a marketing offer, and safety stocks. The purpose of the latter is to offset estimation error and protect the company from unexpected and unwanted inventory depletion (Priniotakis, Argyropoulos, 2019). They ensure the rhythmicity of production and reduce the risk of uncertainty about the volume and timing of deliveries. When these stocks begin to exceed the needs for hedging, they become excess stocks (Fertsch, 2008).

In the literature, the evaluation of inventory management is related to the authors' approach to the subject matter addressed, and studies have been conducted based on, among other things:

- surveys (Kolińska, Koliński, 2013),
- selected financial analysis tools (Czerwińska-Kajzer, 2014; Bieniasz, Gołaś, 2012),
- share of inventories in the structure of current assets (Comporek, 2016),
- evaluation of external and internal determinants of inventory management efficiency (Nesterak, Kołodziej-Hajdo, 2006),
- evaluation of inventory turnover (Skowron-Grabowska, 2009).

Due to the relevance of the problem of maintaining a minimum level of inventory with its constant availability, this study aims to assess the changes and trends of the main parameters characterizing inventory management in industrial processing enterprises in 2006-2009, 2010-2013 and 2018-2022. Referring to the adopted objective, the hypothesis was made that crisis situations negatively affect the proper inventory management in industrial processing enterprises. The study is an attempt to add to the literature with research on deviations of indicators depicting inventory management caused by crisis factors.

## 2. Materials and methods

The presented research is part of the author's ongoing research work. The survey covered business entities by Divisions of Section C - “Manufacturing”. In order to ensure clarity of the text and figures, the numbers of Departments were used in the designations and descriptions<sup>3</sup>:

---

<sup>3</sup> According to the Polish Classification of Business Activities PKD.

- PP - Industrial processing.
- D10 - Manufacture of food products.
- D11 - Manufacture of beverages.
- D12 - Manufacture of tobacco products.
- D13 - Manufacture of textiles.
- D14 - Manufacture of clothing.
- D15 - Manufacture of leather and leather products.
- D16 - Manufacture of wood and cork products, except furniture; manufacture of articles of straw and plaiting materials.
- D17 - Manufacture of paper and paper products.
- D18 - Printing and reproduction of recorded media.
- D19 - Manufacture and processing of coke and refined petroleum products.
- D20 - Manufacture of chemicals and chemical products.
- D21 - Manufacture of basic pharmaceutical substances and drugs and other pharmaceutical products.
- D22 - Manufacture of rubber and plastic products.
- D23 - Manufacture of other non-metallic mineral products.
- D24 - Manufacture of metals.
- D25 - Manufacture of fabricated metal products, except machinery and equipment.
- D26 - Manufacture of computers, electronic and optical products.
- D27 - Manufacture of electrical equipment.
- D28 - Manufacture of machinery and equipment not elsewhere classified.
- D29 - Manufacture of motor vehicles, trailers and semi-trailers.
- D30 - Manufacture of other transportation equipment.
- D31 - Manufacture of furniture.
- D32 - Other manufacturing of products.
- D33 - Repair, maintenance and installation of machinery and equipment.

The analysis covered the years 2006-2013 and 2018-2022, which involved four crises. The research undertaken is descriptive, spatial-temporal and critical analysis - changes and deviations from the average values during periods of prosperity are indicated. The presentation of the research results includes descriptive form and graphical form in the form of figures. The numerical data came from the Statistics Poland website. According to the author's opinion, the indicators selected for the study provide a relevant and universal basis for conducting an assessment of inventory management in manufacturing enterprises. A classification of the indicators used in the study is included in Table 1.

**Table 1.**  
*Classification of the study area*

Manufacturing enterprises by PKD	Indicators analyzed	Crisis situations/ scope of research
Scope D10-D33 and collectively all industrial processing enterprises	1. Share of inventories in current assets	The Global financial crisis 2006-2009
	2. Share of materials in inventories	The Eurozone crisis 2010-2013
	3. Share of semi-finished and work-in-progress products in inventories	The COVID-19 crisis 2018-2021
	4. Share of finished products in inventories	The COVID-19 crisis + Energy crisis 2018-2022
	5. Share of goods in inventory	
	6. Profitability of materials (1)	
	7. Profitability of semi-finished and work-in-progress products (1)	
	8. Profitability of finished products (1)	
	9. Profitability of goods (1)	
	10. Rotation of materials (2)	
	11. Rotation of semi-finished and work-in-progress products (2)	
	12. Rotation of finished products (2)	
	13. Rotation of goods (2)	
	14. Liquidity of materials	
	15. Liquidity of semi-finished and work-in-progress products	
	16. Liquidity of finished products	
	17. Liquidity of goods	
	18. Material intensity	

(1) The numerator of the formula includes the item "Financial result from sales of products, goods and materials"

(2) The denominator of the formula includes the item "Revenue from sales of products, goods and materials".

Source: own elaboration.

Inventory structure ratios provide information on the degree of immobilization of current assets in a company's inventory. The higher the proportion, the lower the elasticity of current assets. This may indicate lower asset liquidity as a result of lack of demand for inventory, or improper inventory management. The share of individual inventory items in their total value indicates the degree of the company's commitment to a particular type of inventory. Too high a share of materials relative to the share of finished goods may indicate problems with sales, or an overly conservative procurement policy.

Inventory profitability ratios indicate the efficiency of their involvement. The higher the values, the better their utilization. It is a good idea to analyze this type of indicators in relation to industry data. A dangerous situation may be indicated by negative values of the discussed group of indicators, which is the effect of generating a loss already at the stage of balancing revenues from the sale of products, goods and materials with the costs of obtaining them.

Turnover ratios in days indicate how many days elapse between the delivery of inventory to the company and its sale. A decrease in the turnover value is mostly perceived positively, as it indicates faster liquidity of inventory, its efficient management, shorter storage period, lower handling costs, and, as a result, a more favorable financial result. In addition, there is a lower demand for capital, which is "frozen" in inventory for a shorter time, and this in turn improves liquidity. An increase in inventory turnover in days can be interpreted as a deterioration in management efficiency or overstocking, the reasons for which can range from lack of demand through overproduction and seasonal sales.



Liquidity is the flexibility of converting assets into money. Inventory liquidity determines the degree to which trade payables are covered by inventory held. The higher the value of the indicator, the higher the degree of immobilization of inventories, and thus the lower their liquidity. When too low a value of the indicator takes place, the entity is obliged to settle trade payables additionally with other current assets than inventories. At the same time, this may indicate their rapid turnover or disposal of inventories due to production or sales downtime.

Material intensity indicates how much material is used to produce a unit of finished product. Too high a share or an increasing trend of this indicator is not always perceived positively and can mean a reduction in demand, production problems or downtime. Inventory intensity, on the other hand, means what proportion of inventories falls into a unit of earned income from the sale of products, goods and materials. An increasing trend may indicate a decrease in the efficiency of inventory management, its liquidity or an extended period of storage. It should be borne in mind that the magnitudes of these indicators are conditioned to a large extent by the specifics of production, the actual need for material consumption in the production process or seasonality. It should be added that the inventory intensity indicator was omitted from the final study, as it is a reflection of the inventory turnover indicator, with a difference - inventory turnover is calculated in days, while inventory intensity is calculated as a percentage.

The final part of the study presents the directions of changes in the magnitudes of the indicators studied, which took place in the analyzed companies during the two-year crisis periods in relation to the two-year period before the crises.

The general magnitudes of the indicators are presented in the figures, while the detailed ones are presented in the tables.

### 3. Results and discussion

The research conducted in this study deals with situations triggered by two financial crises, as well as pandemic and energy crises with global economic consequences. The aforementioned crises, along with the adopted research time, are illustrated in Figure 1.



**Figure 1.** Crisis situations with the adopted time ranges of the study.

Source: own study.

The end of the first decade of the 21st century saw a global financial crisis. It began in 2007 in the US, but was reflected in global markets after September 15, 2008, following the collapse of US investment bank Lehman Brothers Holding Inc. (Kołodziejczyk, 2016; Józwiakowski, 2015; Romiszewska, 2011). The relocation of the crisis to the remaining countries caused a crisis of confidence in financial institutions, exponential changes in stock prices and destabilization of stock markets, which translated into an economic slowdown in these countries, a decrease in consumption, an increase in unemployment, a halt in investment, or a collapse in global trade.

At the turn of 2009/2010, another crisis outlined itself, being the Eurozone crisis, also known as the debt crisis (Gajewski, 2013; Węc, 2020). It was the result of a number of factors, including serious problems in financing budget deficits, an increase in the public debt of some countries, inadequate supervision of the financial sector or a bad loan portfolio, especially mortgages (Poliński, 2017; Węc, 2020; Kraciuk, 2013). For the Eurozone crisis, the previous global financial crisis was the “ignition spark” (Węc, 2020), a delayed wave of its effects (Adamowicz, M., Adamowicz, T., 2018) whether the aftermath of a negative development impulse (Nazarczuk, 2013). The economic slowdown of the eurozone countries also marked the Polish economy, as evidenced by the size of the basic macroeconomic indicators.

The next of the crises discussed, was triggered by factors of biological origin and concerned the aforementioned COVID-19 pandemic. Although at the beginning its scope covered only the PRC, in a very short time it spread to almost all countries of the world, including as a result of the easy and rapid movement of the population. The effects of the crisis, in its initial phase associated with a sharp reduction in the economic activity of countries, included stunted and reduced production volumes, disruptions in the flow of goods, negative financial developments that affected households, economic entities and entire economies (Bukowski, Gawroński, Olszewska, 2023). The reduction in economic activity has also had positive consequences, related to global reductions in carbon emissions. This, in turn, has contributed to the environmental focus on decarbonizing the energy sector in line with the EU's climate goals, and the European Green Deal launched in late 2019 aimed at reducing the impact of the climate crisis<sup>4</sup> (Latest EU climate action, 2022).

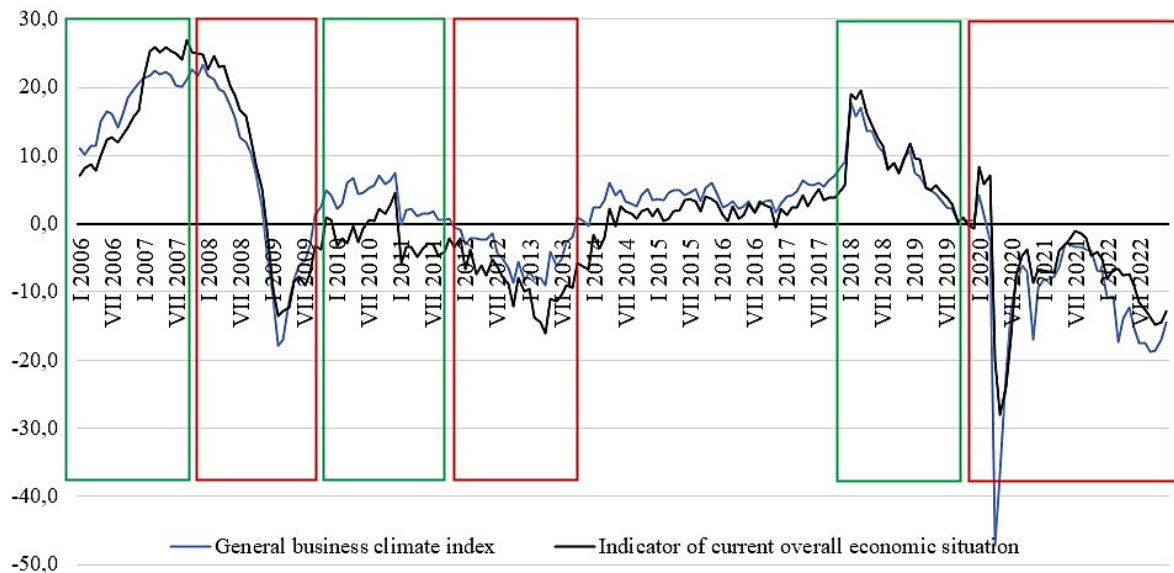
In February 2022, the still ongoing pandemic crisis was “fueled” by another militarily motivated crisis. Russia's aggression against Ukraine forced European countries to significantly reduce and become less dependent on imports of Russian fossil fuels, and thus to spread renewable energy sources, with additional financial burdens. These situations triggered the so-called “energy crisis,” which contributed, among other things, to the breaking of logistics chains, an increase in the price of goods, including energy, business disruptions and the “waiting time” of companies as to the course of the economic situation and its impact on the

---

<sup>4</sup> According to a press release dated 28/11/2019, the European Parliament has declared a climate crisis (European Parliament declares climate crisis).

conduct of business. The crisis has also adversely affected food security, global food affordability, or the increased mobility of people and goods across all modes of transportation (Market effects..., 2024).

The selection of research periods in the mentioned crises was linked to the indicator of the general business climate<sup>5</sup> industrial processing enterprises and, in addition, an indicator of the current overall economic situation of these enterprises. The development of the size of these indicators is presented in Figure 2.



**Figure 2.** The values of indicators of the general business climate and the current general economic situation of industrial processing enterprises against the background of crisis situations.

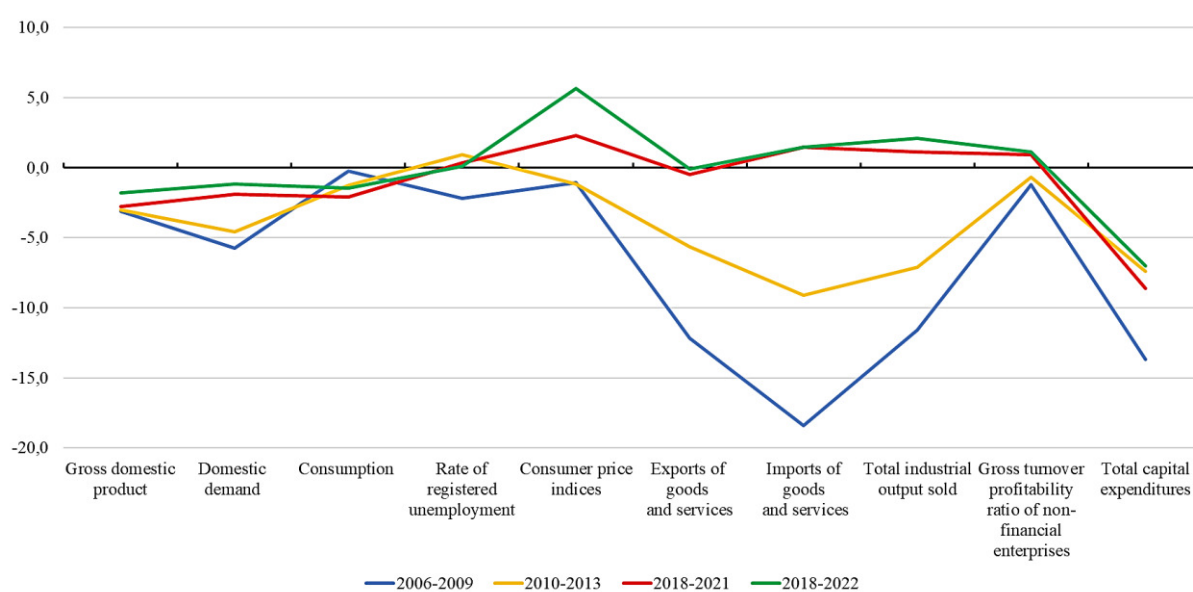
Source: own compilation based on Statistics Poland data.

The state of the economy of manufacturing enterprises during the period under review was characterized by significant dynamics. Figure 2 frames in green the years in which the economy of these enterprises was in a favorable situation, while in red are the years of bad economic conditions. The latter constituted the background of crisis conditions, which were the basis of the research conducted. The largest negative dynamics occurred in April 2020 and concerned the COVID-19 crisis. At that time, the value of the general business climate index fell to -47.2, a difference of as much as 64.9 points compared to +17.7 in January 2018. The crisis began abruptly and intensely, and the restrictions imposed by the state on the conduct of business and the functioning of society, resulted in the exclusion of most industries from normal operations. Undoubtedly, a large decrease in the index in question took place in the global financial crisis, with 41.2 points (from +23.3 in December 2007 to -17.9 in February 2009). A much milder reduction took place in the Eurozone crisis, by 16.4 points. The change in the value of the

<sup>5</sup> The general business climate index reflects the state of the economy in general or in a particular branch of the economy. It is calculated as the arithmetic average of the balances of responses to monthly survey questions on the current and expected economic situation of the enterprise. When the indicator is greater than zero, a “good” business climate is recorded. Otherwise, the climate is assessed as “bad” Statistics Poland/ Meta-information / Glossary / Terms used in official statistics.

general business climate index in the energy crisis was not easy to diagnose. Referring to the pre-pandemic period, its largest reduction was 36.5 points (from +17.7 in January 2018 to -18.8 in October 2022), while in relation to the year before the outbreak, it fell by 15.9 points (from -2.9 in May 2021 to the aforementioned level of -18.8). Given that there was still an epidemic state until May 2022, and then an epidemic emergency state, assessing the impact of the war and the related energy crisis was not possible to clearly indicate in this research. The index of the current overall economic situation, compared to the index of the general business climate, showed more optimistic figures in the financial, pandemic and energy crises, while more pessimistic figures in the eurozone crisis.

All of the aforementioned crises projected the basic macroeconomic parameters to a greater or lesser extent, as shown in Figure 3.

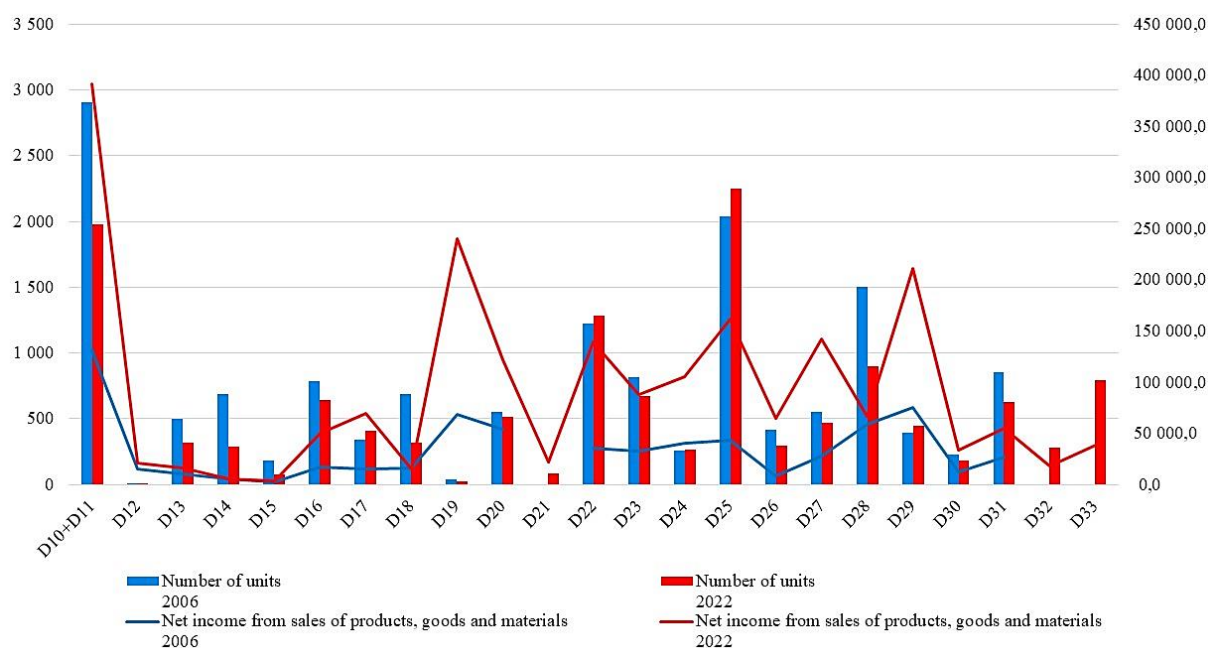


**Figure 3.** Basic macroeconomic parameters against the background of the studied crisis situations.

Source: own compilation based on Statistics Poland data.

Changes in macroeconomic parameters were calculated as the rate of dynamics of the two-year period of the crisis situation in relation to the dynamics of the two-year period before the crisis situation. As Figure 3 shows, each crisis affected the economy differently. In the global financial crisis, imports and exports of goods and services, total capital expenditures, total industrial output sold, and, to a lesser extent, domestic demand declined significantly. In the Eurozone crisis, the situation was similar, but to a lesser extent. During the last two crises, the values of the analyzed parameters were similar. In both situations, total capital expenditures decreased significantly, and to a lesser extent gross domestic product, domestic demand and consumption. In addition, the energy crisis contributed more than the COVID-19 crisis to the increase in the consumer price index.

In order to give an idea of the surveyed enterprises, Figure 4 shows their structure by the number of entities in each division of the PKD and by the revenues generated from the sale of products, goods and materials in 2006 and 2022.



**Figure 4.** Structure of enterprises of Section C - Manufacturing by number of entities (left axis) and by revenue from sales of products, goods and materials (right axis) in 2006 and 2022.

Source: own compilation based on Statistics Poland data.

The largest group of companies was in D10+D11<sup>6</sup> in 2006 and in D25 in 2022, which accounted for 19.41% and 17.11% of all manufacturing enterprises, respectively. The least numerous groups in 2022 were D12 (0.07%) and D19 (0.17%). The latter were characterized by high revenues from the sale of products, goods and materials, which accounted for 11.34% of all enterprises' revenues. Only D10+D11 enterprises had a more favorable result, whose revenue accounted for 18.44%.

The evaluation of inventory management should begin with an analysis of its share in the total assets of an enterprise or in its current assets. The latter is important from the point of view of operating activities, the size of which is determined by many factors, such as the specifics of the production cycle, the ease/difficulty of obtaining raw materials, legal regulations or the predictability of demand for manufactured products. The share of inventories in current assets in the surveyed companies for the analyzed period is shown in Table 2.

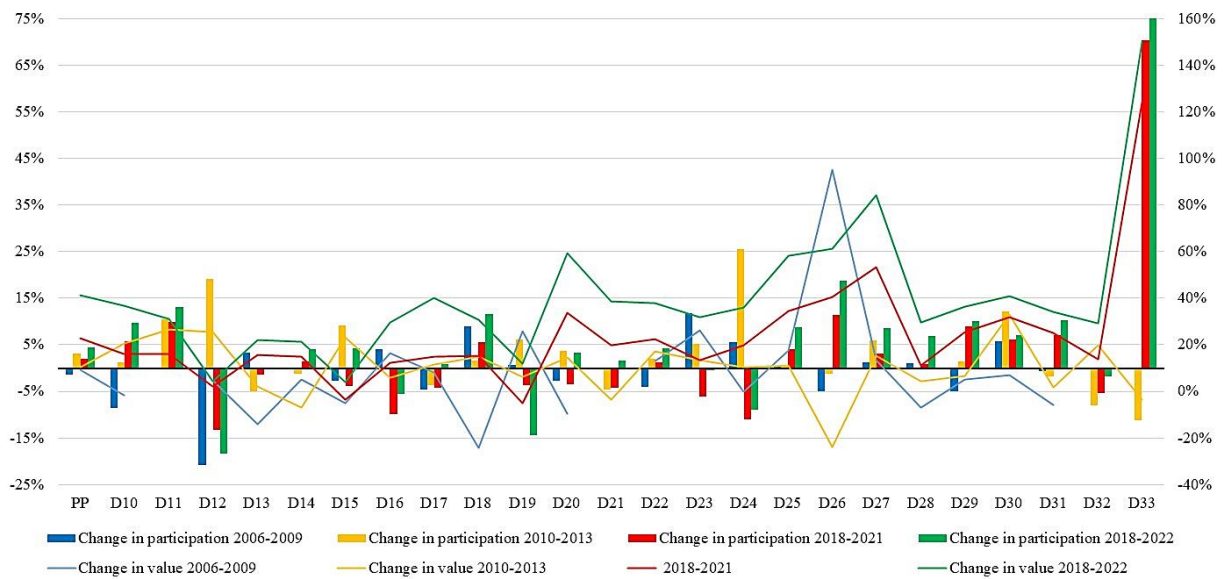
<sup>6</sup> During the period under review, enterprises were classified according to PKD 2004 and PKD 2007. Following this, some mergers of divisions take place, while others were not present in the earlier version. According to the Ordinance of the Council of Ministers of December 24, 2007, on the Polish Classification of Activities (PKD), the PKD 2004 classification was used until December 31, 2009.

**Table 2.**

*Share of inventories in current assets in the surveyed companies against the background of crisis situations*

	2006	2007	2008	2009	2010	2011	2012	2013	2018	2019	2020	2021	2022
PP	31,7%	33,1%	32,6%	31,4%	32,1%	33,1%	33,9%	33,3%	35,4%	34,9%	34,0%	37,6%	38,5%
D10	34,7%	36,6%	34,1%	31,0%	32,4%	34,0%	33,7%	33,6%	33,2%	33,7%	35,8%	34,9%	39,5%
D11				19,0%	20,4%	22,0%	24,0%	23,0%	23,2%	22,0%	24,4%	25,4%	27,0%
D12	42,4%	32,1%	24,5%	34,5%	47,0%	53,4%	56,7%	62,8%	69,5%	63,6%	61,2%	54,3%	47,4%
D13	38,6%	40,5%	39,1%	42,6%	46,4%	47,3%	45,4%	43,6%	43,0%	43,1%	39,9%	45,0%	44,0%
D14	42,6%	45,6%	42,9%	45,0%	45,0%	45,8%	45,2%	44,5%	44,1%	44,3%	44,0%	45,7%	48,3%
D15	42,5%	43,9%	44,1%	39,9%	40,5%	40,1%	43,5%	44,5%	43,2%	39,2%	35,0%	44,2%	49,6%
D16	35,5%	41,1%	42,7%	37,0%	35,3%	38,5%	35,9%	38,1%	40,3%	41,9%	36,4%	37,6%	42,3%
D17	28,9%	27,9%	28,5%	25,6%	31,3%	29,5%	29,7%	28,9%	31,9%	29,5%	27,4%	31,5%	34,0%
D18	17,2%	16,6%	18,1%	18,9%	21,6%	20,9%	21,8%	21,4%	22,1%	22,5%	21,6%	25,4%	27,5%
D19	42,4%	48,1%	45,9%	45,3%	53,2%	52,4%	57,7%	54,5%	46,5%	44,7%	46,2%	41,6%	29,4%
D20	29,4%	30,5%	30,3%	27,9%	27,5%	28,5%	29,7%	28,3%	32,8%	32,8%	29,2%	34,2%	38,4%
D21				30,3%	32,2%	38,0%	32,8%	34,1%	35,4%	29,0%	30,4%	31,2%	36,6%
D22	30,0%	32,0%	30,1%	29,3%	29,0%	30,9%	31,3%	29,8%	34,8%	34,2%	31,8%	38,0%	38,0%
D23	26,8%	28,5%	30,6%	31,2%	31,1%	30,9%	33,1%	32,1%	33,8%	34,1%	30,6%	33,1%	37,6%
D24	33,6%	30,4%	34,5%	33,1%	33,4%	38,4%	43,6%	46,6%	49,9%	44,3%	39,5%	44,3%	44,9%
D25	32,8%	34,6%	34,1%	33,5%	32,5%	31,4%	32,0%	32,2%	36,6%	36,0%	34,4%	41,1%	43,0%
D26	28,9%	27,8%	26,7%	27,1%	28,2%	26,0%	26,4%	27,2%	31,2%	28,7%	27,6%	39,2%	40,0%
D27	26,8%	28,0%	28,4%	27,1%	28,0%	28,8%	30,2%	30,1%	37,0%	39,1%	36,5%	41,9%	45,4%
D28	31,7%	34,2%	31,9%	34,7%	35,4%	35,8%	35,4%	35,5%	35,2%	33,6%	32,7%	36,7%	40,9%
D29	23,1%	23,2%	24,5%	19,5%	22,0%	21,3%	22,0%	21,9%	27,2%	27,9%	28,5%	31,6%	31,0%
D30	36,4%	35,5%	37,6%	38,5%	34,0%	34,1%	37,4%	38,9%	44,1%	41,8%	46,2%	45,0%	46,7%
D31	33,8%	36,7%	36,7%	33,3%	37,6%	36,3%	37,4%	35,2%	33,7%	37,7%	35,2%	41,3%	41,6%
D32				41,1%	41,3%	40,4%	37,3%	37,9%	45,3%	46,1%	42,2%	44,2%	48,3%
D33				23,5%	21,6%	19,3%	18,1%	18,1%	17,5%	19,4%	27,4%	35,5%	34,0%

In the surveyed companies, the level of inventories in the total value of current assets varied greatly. From 2006 to 2009, their highest share was in D19 enterprises (only in 2006 it affected D14), which was mainly due to the specifics of their operations. A characteristic change and increase in the share of inventories in current assets affected D12 enterprises, from the lowest level in 2008 (24.5%) to the highest in 2018 (69.5%). A number of factors contributed to this situation, including changing regulations, including the cyclical increase in the excise tax burden on tobacco products (Impact of Tobacco Production on the Polish Economy, 2020), the sensitivity of production to climatic conditions, and changing consumer awareness and habits. In contrast, the lowest share of inventories in current assets occurred mainly in D18 and D33 enterprises. This was mainly due to the nature of the business. It is worth noting that in most enterprises the highest share of inventories in current assets was in 2022. Thus, it can be concluded that the energy crisis was an important factor hindering proper inventory management, which was further marked by the highest inflation rate in the years under review (114.4 according to Statistics Poland sources). A broader view of the share of inventories in current assets against the background of crisis situations and, in addition, the value of inventories is illustrated in Figure 5. The calculated figures are the rate of increase in the average structure of two years in the crisis situation (in 2020-2022 it was the average structure of three years) compared to the average structure of two years before the crisis situation.



**Figure 5.** Changes in the share of inventories in current assets and the value of inventories in manufacturing companies by PKD Divisions against the background of the studied crisis situations.

Source: own compilation based on Statistics Poland data.

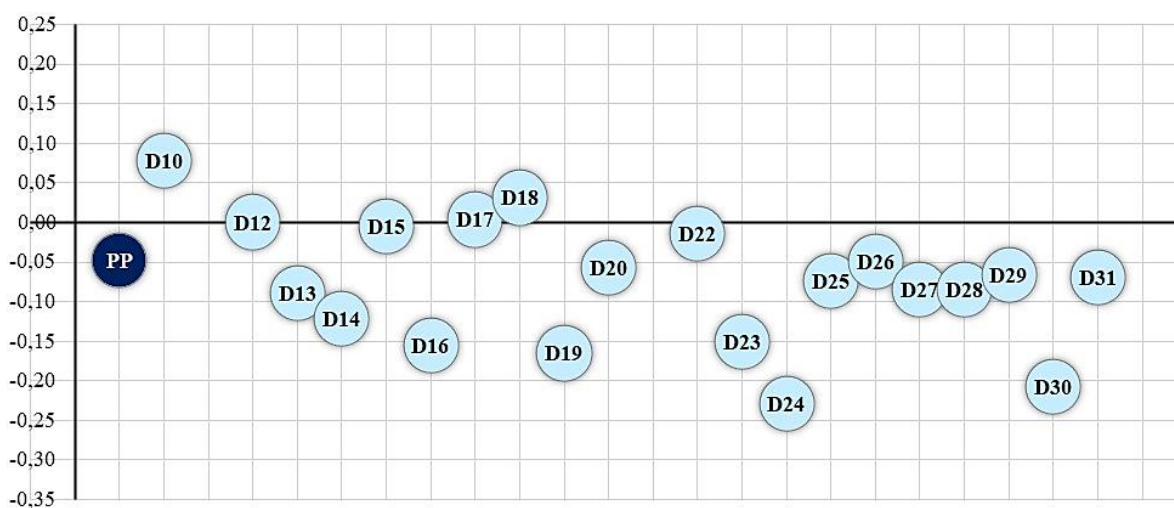
The share of inventories in the current assets of the surveyed enterprises fluctuated due to, among other things, the specifics of operations and production technology, inventory management strategy, seasonality, demand instability and crisis situations. This was particularly true for D33 enterprises, for which both the COVID-19-induced crisis and the energy crisis contributed to a significant immobilization of inventories (an assessment in 2006-2009 was not possible due to a different classification of PKD). This is evidenced by the increase in the share of inventories in current assets by 70% and 75%, respectively. In other companies, the changes were milder, mostly with an intensification in the energy crisis. In D12, D15, D19, D24 and D30, the Eurozone crisis mainly contributed to the slowdown in inventory movement, while in D23 the global financial crisis. On the other hand, however, crises may have contributed to a reduction in the share of inventories in current assets, such as in D16, D19 and D24 (pandemic crisis and energy crisis). It is worth noting that characteristic changes occurred in D12 companies. The share of inventories increased significantly in the Eurozone crisis, while it decreased in the other crises. However, it should be noted that in the pandemic and energy crises, this change was not the result of an improvement in inventory management, but only a decrease in the value of current assets. A significant increase in the value of inventories was noticeable in the last two crises in most enterprises, especially in D33, D27 or D20. In D26 companies, it was additionally noticeable in the global financial crisis, while it decreased in the Eurozone crisis.

Further research concerned the compilation of changes in the size of indicators analyzed in manufacturing enterprises separately for the adopted crisis situations, as shown in Table 1. For example, the material turnover rate in D10 enterprises in the period 2018-2021 was as follows in each year: 21.46; 21.29; 23.48; 26.69. In 2018-2019, before the crisis situation,

the average size of the index was 21.37, and in the crisis years (2020-2021) it was 25.08. The growth rate was thus 17.36%. The individual relations calculated in this way were used to select, separately for each group of companies, a synthetic indicator (conventionally SW), which is the average of the sum of all the indicators studied (listed in Table 1) according to their division into two groups:

- 1) stimulants - increasing volumes reflect a positive impact on inventory management (indicators from Table 1: Nos. 2, 3, 6, 7, 8, 9, 14, 15, 16, 17),
- 2) destimulants - decreasing magnitudes reflect a positive impact on inventory management (indicators from Table 1: Nos. 1, 4, 5, 10, 11, 12, 13, 18).

In the following figures 6-9, an attempt is made to classify the surveyed companies according to the synthetic indicator of SW, the size of which was reduced to a measurable number.

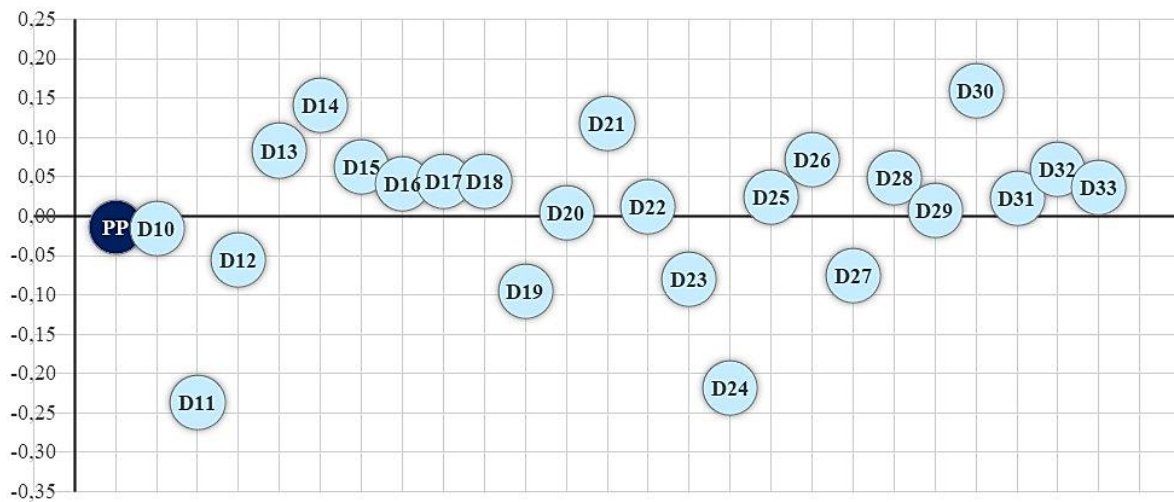


**Figure 6.** Classification of the surveyed companies in terms of the level of the synthetic SW indicator in 2006-2009 against the background of the Global financial crisis.

Source: own compilation based on Statistics Poland data.

The global financial crisis was marked by unfavorable trends in inventory management in almost all industrial processing companies, for which the synthetic SW index was at -0.05. The prevailing group of companies was in the negative zone of -0.23 to 0.0. The lowest value of the index was for D24 companies, at -0.23. This was due to a significant reduction in the profitability of all forms of inventory and an increase in its turnover in days. This, in turn, was the result of a reduction in demand for, among other things, steel and aluminum by related industries, which were also affected by the crisis. The group of enterprises that distinguished itself from the others by the positive magnitude of the index was D10 enterprises (according to the 2004 PKD classification). Their synthetic SW index was 0.08, which consisted of an improvement in profitability and a reduction in the turnover time of all forms of inventory, as well as its favorable internal structure.

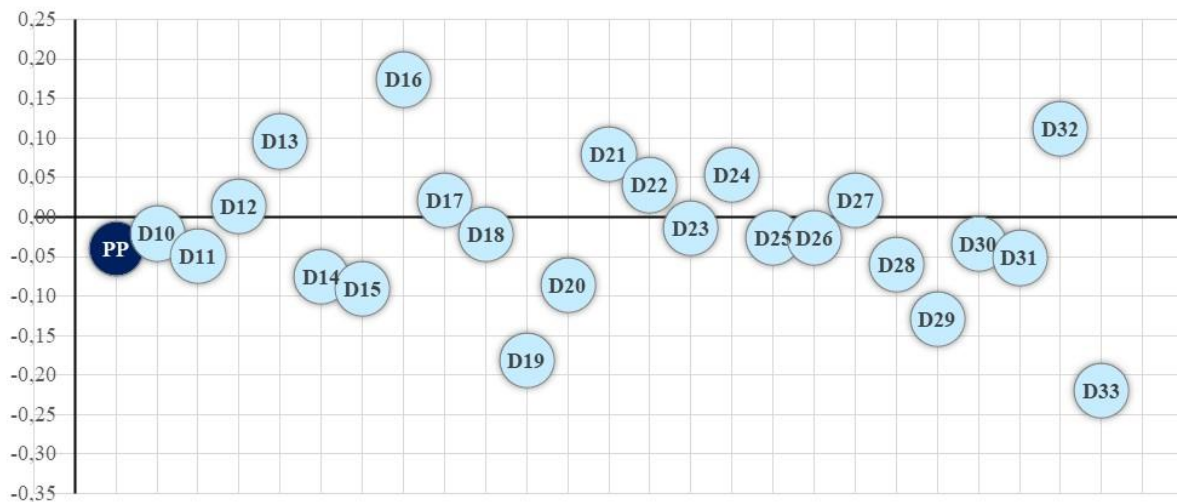




**Figure 7.** Classification of the surveyed companies in terms of the level of the synthetic SW indicator in 2010-2013 against the background of the Eurozone crisis.

Source: own compilation based on Statistics Poland data.

The subsequent Eurozone crisis in the wake of the global financial crisis brought a slight recovery in terms of inventory management. There was an improvement in the prevailing group of companies, mainly in the area of favorable inventory structure and increased liquidity. The crisis was not noticeable for all enterprises combined (PP), as the synthetic SW index was -0.01. The effects of the crisis were felt most by D11 (SW index value -0.24) and D24 (-0.22) enterprises. The latter did not rebound after the global crisis, inventory profitability continued to decline, and material intensity increased unfavorably. The situation was different for D30 companies. In the previous crisis, the synthetic SW indicator for this group was -0.21, while in the Eurozone crisis it rose to +0.16, mainly due to an increase in inventory profitability. However, it should be borne in mind that the production of other transportation equipment is also the shipbuilding industry, which collapsed in 2009 after the closure of the production shipyards in Gdynia and Szczecin (Rogala-Lewicki, 2023). With reference to D11 companies, it should be noted that all parameters building the synthetic index were unfavorable - the share of finished products and goods in total inventories increased, while the share of materials decreased, which may indicate a reduction in demand. In addition, the profitability and liquidity ratios of the various forms of inventories decreased significantly, turnover ratios in days lengthened, and the material intensity ratio increased.



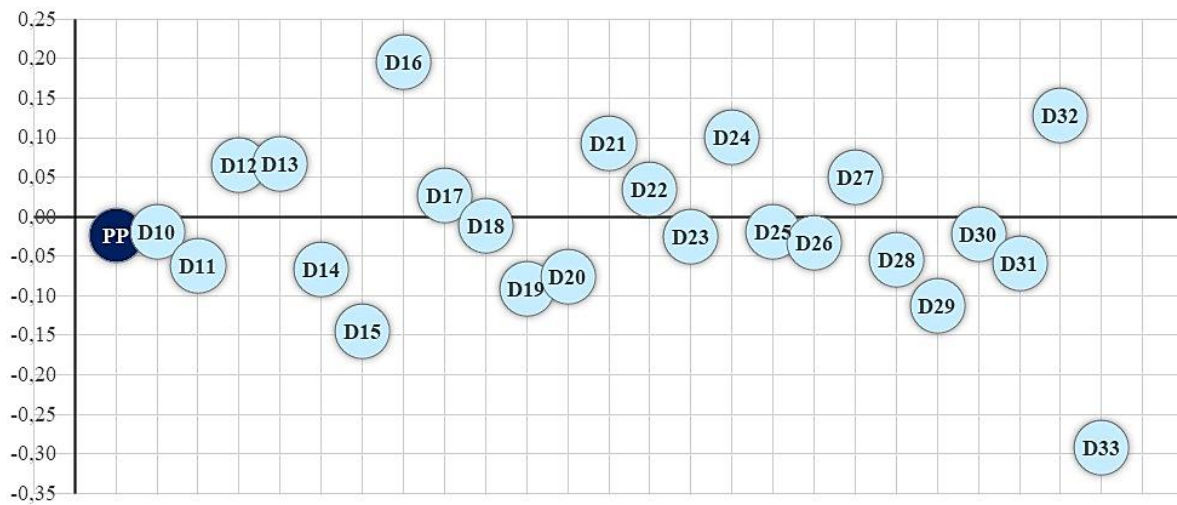
**Figure 8.** Classification of the surveyed companies in terms of the level of the synthetic SW index in 2018-2021 against the COVID-19 crisis.

Source: own compilation based on Statistics Poland data.

Over the 2018-2021 period, inventory management deteriorated in a number of enterprises, for which the SW index was in the range of -0.22 to 0.0. According to the average for all enterprises in Section C (PP), it ranked at -0.04. This situation was significantly influenced by an unfavorable increase in the turnover of mainly materials, semi-finished products and work-in-progress, as well as a reduction in the profitability of all forms of inventory and the liquidity of finished products and goods. D33 enterprises ranked the lowest (-0.22). It should be added that these enterprises are a specific group, whose business is based largely on the provision of services. The size of the index was influenced by the largest of all divisions by the reduction in inventory profitability and the increase in turnover, mainly of finished goods, semi-finished goods and work-in-progress. A large degree of deviation from other companies also affected D19 (-0.17) and D29 (-0.15). The reason for the deterioration of inventory management in these enterprises should be attributed mainly to the reduced profitability and liquidity of all forms of inventory, to which reduced demand and increased inventories contributed. It should be borne in mind that during the pandemic, especially in the initial phase, many enterprises did not operate at normal levels, hence the reduced demand for the products of these groups of enterprises.

The most favorable aggregate deviation in the COVID-19 crisis (+0.17) was for D16 enterprises. Since a broader analysis was not possible on the basis of general CSO figures limited to PKD divisions. In this situation, the author additionally used the PKO BP report (Industry Quarterly, 2023), according to which a significant improvement in the inventory management of these companies was due to a dynamic post-2020 increase in the production of wooden packaging, mainly pallets (D16.24). This situation was caused by an increase in demand for transportation services, including shipments of goods using pallets. The positive value of the SW index also occurred in enterprises D32, D13, D21, D24, D22, D27, D17 and D12. In the former (D32), the reason may have been an increase in demand for certain products,

such as sports equipment (increased physical activity), hospital beds (which was related to the construction of field hospitals for COVID-19 patients) and personal protective equipment (protective suits, masks).



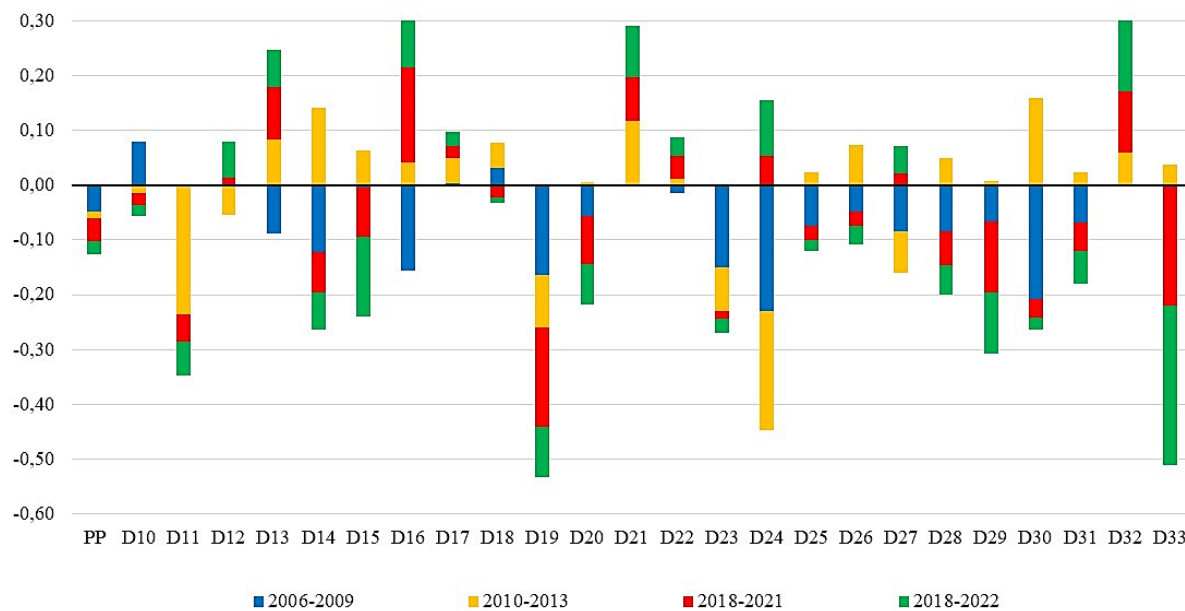
**Figure 9.** Classification of the surveyed companies in terms of the level of the synthetic SW indicator in 2018-2022 against the background of COVID-19 and the energy crisis.

Source: own compilation based on Statistics Poland data.

The extension of the COVID-19 crisis to include another energy crisis reinforced the reduced inventory management efficiency of the analyzed enterprises. Most of the enterprises were in the negative zone from -0.35 to 0.0. The lowest value of the index was for enterprises D33 - Repair, maintenance and installation of machinery and equipment (-0.35), which, as in the previous crisis, was caused by a significant increase in inventories, also in relation to current assets. This was compounded by a reduction in the profitability of inventories, an increase in material intensity and a prolongation of turnover in days, mainly of finished goods, despite an increase in the liquidity of the latter. In D19 companies, the persistently negative synthetic indicator is a derivative of a significant reduction in profitability, liquidity, as well as prolonged turnover, especially of semi-finished and work-in-progress products and goods. This situation has undoubtedly been influenced by rising prices, including fuel prices, and lower demand. In addition, it is worth mentioning that D19 enterprises are in second place in terms of the volume of carbon dioxide emissions among all manufacturing enterprises, with D23 being first (Transformation of Energy..., 2022).

Small positive values of the indicator in question occurred only in three groups of enterprises D16 (+0.07), D12 (+0.04) and D32 (+0.01). In D16 enterprises, this was a continuation of stabilized demand for palletized goods movement services. According to information in a report by the Polish Economic Institute (Impact of the war..., 2023), the war in Ukraine had a strong impact on industrial processing enterprises, regardless of size.

In order to systematize the research, a combined classification of enterprises was made in terms of the development of the synthetic SW indicator against all crisis situations, as illustrated in Figure 10.



**Figure 10.** Total classification of the surveyed enterprises in terms of the level of the synthetic SW indicator in comparison with all crisis situations

Source: own compilation based on Statistics Poland data.

In terms of inventory management, all of the crises discussed occurred in D11, D20, D23 enterprises, and the most in D19. The vast majority of enterprises were vulnerable to the global financial crisis and the COVID-19 and energy crises. Also, a significant proportion of enterprises were not much affected by the last two crises in terms of inventory management. These are enterprises D12, D16, D22, D24, D27, D17, D21 and D32. The last three enterprise divisions were not affected by any of the crises in inventory management, even there was an improvement in this regard.

## 4. Summary

Conducted research, aimed to assess changes and trends in the main parameters characterizing inventory management in industrial processing enterprises in crisis situations. The research period was divided into four areas of observation:

- 2006-2009, against the background of the Global financial crisis,
- 2010-2013, against the background of the Eurozone crisis,
- 2018-2021, against the background of the COVID-19 crisis,
- 2018-2022, against the background of the COVID-19 and Energy crises.

Analysis of the figures and selected reports made it possible to formulate basic conclusions:

1. In the majority of industrial processing companies, all crises had an adverse impact on inventory management.
2. There were unfavorable changes within the profitability indicators of the total group of manufacturing enterprises in all crises. The largest unfavorable deviation occurred in the COVID-19 crisis (close to -19%), including the profitability of materials and semi-finished and work-in-progress products, averaging -21%. The smallest negative deviation was for the profitability of materials and goods in the Eurozone crisis, about -3%.
3. inventory turnover time in days lengthened by an average of 14% in the COVID-19 and energy crises, including as much as 94% in D33 - Repair, maintenance and installation of machinery and equipment enterprises, while in the eurozone crisis it shortened by an average of less than 2%.
4. The change in inventory liquidity levels in the Eurozone, COVID-19 and energy crises was favorable, by 5-9% on average for all companies. In the global financial crisis, on the other hand, it decreased by 6%, including as much as 87% in D12 - Tobacco Manufacturing enterprises, and concerned semi-finished and work-in-progress products. This indicated a significant immobilization of this form of inventory.
5. The geopolitical and macroeconomic situation inhibited most of the favorable trends in 2022 after the “rebound” after the pandemic. For this reason, it was difficult to clearly assess the impact of the energy crisis on inventory management in the surveyed companies.
6. Each of the divisions of industrial processing enterprises has internal specifics of their operations, conditioned by a number of factors, such as the length of the production cycle, the ease/difficulty of obtaining raw materials, legal regulations or predictability of demand for manufactured products, as well as seasonality and the warehouse policy strategy adopted by the enterprise.
7. The accepted hypothesis “crisis situations negatively affect proper inventory management in industrial processing enterprises” was not fully confirmed. The exceptions were:
  - a) D17 - Manufacture of paper and paper products.
  - b) D21 - Manufacture of basic pharmaceutical substances and drugs and other pharmaceutical products, and
  - c) D32 - Other manufacturing of products.

It can be concluded that these companies did not show negative vulnerability to crisis situations.

The author realizes that the adopted research path requires further development, which will be done in future publications.

## Information

The article was written as part of the activities of the Center for Resilience and Competitiveness Research West Pomeranian University of Technology in Szczecin.

## References

1. Adamowicz, M., Adamowicz, T. (2018). Course and consequences of the global financial crisis of 2007-2011 and anti-crisis measures in Poland. *Scientific Papers UE, No. 529*, Wrocław, p. 25.
2. Bielski, M. (2002). *Fundamentals of theory, organization and management*. Warsaw: C.H. Beck, p. 54.
3. Bieniasz, A., Golaś, Z. (2012). Efficiency of inventory management in the food industry. *Issues in Agricultural Economics, No. 3*, pp. 68-88.
4. Bukowski, M., Gawroński, H., Olszewska, K. (Eds.) (2023). *Global, European and national effects of the COVID-19 pandemic on the economy. Selected problems*. Elbląg: ANS Publishing House, p. 8.
5. Ciekanski, Z., Stachowiak, Z. (2011). Decision-making in crisis situations. *Studies and Materials UW, No. 1*. Warsaw, p. 57.
6. Comporek, M. (2016). Inventory management and profitability of sales revenue in listed industrial companies listed on the Warsaw Stock Exchange. Finance, financial markets, insurance. *Scientific Publishing US, No. 4*. Szczecin, pp. 45-58.
7. Czerwińska-Kajzer, D. (2014). Efficiency of inventory management in feed mills in Poland in 2006-2011. *Scientific Yearbooks, Vol. XVI, Iss. 3*. Association of Agricultural and Agribusiness Economists, pp. 67-73.
8. Dach, Z. (Ed.) (2001). *Introduction to economics*. Cracow: AE Publishing House, p. 50.
9. *Dictionary of Polish language PWN*. Retrieved from: <https://sjp.pwn.pl/slowniki/kryzysogeny.html>, 9.04.2024.
10. *End of the epidemic emergency*. Retrieved from: <https://www.gov.pl/web/rpp/koniec-stanu-zagrozenia-epidemicznego>, 8.04.2024.
11. *European Parliament declares climate crisis* (2019). Retrieved from: <https://www.europarl.europa.eu/news/pl/press-room/20191121IPR67110/parlament-europejski-oglasza-kryzys-klimatyczny>, 11.04.2024.
12. Fertsch, M. (2008). *Fundamentals of logistics. Textbook for training in the profession of logistics technician*. Poznan: Library of Logistics, p. 131.

13. Gajewski, P. (2013). *Crisis in the Eurozone. Causes, course and prospects of its solution*. Warsaw: National Bank of Poland, p. 23.
14. Gołębiowski, G. (Ed.) (2016). *Financial analysis of the enterprise*. Difin, pp. 172-221.
15. Gościński, J. (1989). *The life cycle of an organization*. Warsaw: PWE, p. 87.
16. Grudzewski, W., Hejduk, I., Sankowska, A., Wańtuchowicz, M. (2010). *Sustainability in business, or the enterprise of the future, changes in paradigms and management concepts*. Warsaw: Poltext Publishing House, p. 27.
17. *Impact of the war in Ukraine on the activities of Polish companies (2023)*. Retrieved from: <https://pie.net.pl/wp-content/uploads/2023/02/Wplyw-wojny-na-PL-firmy.pdf>, p. 35, 22.04.2024.
18. *Impact of tobacco production on the Polish economy (2020)*. CASE - Center for Social and Economic Analysis. Retrieved from: [https://www.case-research.eu/files/?id\\_plik=6489](https://www.case-research.eu/files/?id_plik=6489), p. 47, 12.04.2024.
19. Industry Quarterly (2023). No. 1q23(221), p. 11.
20. James, R., Gilliland, B. (2004). *Crisis intervention strategies*. Warsaw, pp. 26-28.
21. Janik, W., Paździor, A., Paździor, M. (2017). *Economic analysis of the activity of the enterprise*. Lublin: PL, p. 139.
22. Józwiakowski, P. (2015). Financial crisis - the course and consequences for the economy. *Scientific Journals PTE, No. 2*. Zielona Góra, pp. 7-16.
23. Kaczmarek-Śliwińska, M. (2015). *Public relations in crisis management of organizations. The art of communication*. Warsaw: Difin, p. 16.
24. Kisielnicki, J. (2021). The “black swan” theory and the prediction of crises and disasters. *Organization Review, No. 4(975)*, pp. 23-29.
25. Klepacki, B. (2022). *Logistics*. Warsaw: CeDeWu, p. 89.
26. Kolińska, K., Koliński, A. (2013). Effectiveness of the process of spare parts inventory management in manufacturing enterprises - results of research. *Materials Management and Logistics, Vol. III*. PWE, pp. 2-6.
27. Koliński, A. (2011). Review of methods and techniques for assessing the efficiency of the production process. *Logistics, No. 5*, pp. 1083-1091.
28. Kołodziejczyk, H. (2016). The origins of the U.S. mortgage crisis from the perspective of a decade. *Legal and Sociological Movement, Iss. 4*. Poznan, pp. 213-231.
29. Kondalkar, V. (2010). *Organization Effectiveness and Change Management*. PHI Learning Pvt. Ltd, 1.
30. Kopaliński, W. (2000). *Dictionary of foreign words and foreign phrases with almanac*. Warsaw, p. 282.
31. Koumanakos, D. (2008). The Effect of Inventory Management on Firm Performance. *International Journal of Productivity and Performance Management, No. 57(5)*, p. 357.
32. Kraciuk, J. (2013). The financial crisis of the eurozone. *Optimum. Economic Studies, No. 4(64)*. Repository of the University of Białystok, pp. 126-127.

33. Krawczyk, S. (2020). *Fundamentals of logistics*. Warsaw: CeDeWu, p. 353.
34. Kulińska, E., Rut, J. (2013). Efficiency category as a key determinant of process improvement. In: Kulińska (Ed.), *Logistics in outline - selected research problems* (p. 128). Opole: Publishing House PO.
35. *Latest EU climate action, Latest EU climate action - Consilium* (2022). Retrieved from: <https://www.consilium.europa.eu/pl/policies/climate-change/eu-climate-action/> 11.04.2024.
36. *Market effects of the Russian invasion of Ukraine: the EU-Consilium response* (2024). Retrieved from: <https://www.consilium.europa.eu/pl/policies/eu-response-ukraine-invasion/impact-of-russia-s-invasion-of-ukraine-on-the-markets-eu-response/>, 11.04.2024.
37. Mesjasz-Lech, A. (2012). Selected problems of measuring the efficiency of logistics activities. *Logistics, No. 2*, pp. 901-913.
38. Modi, S., Mishra, S. (2011). What drives financial performance-resource efficiency or resource slack? *Journal of Operations Management, Vol. XXIX*, pp. 254-273.
39. Nazarczuk, J. (2013). *The impact of the global financial crisis on the economy of Poland and its regions. Selected aspects of regional development*. Olsztyn: Foundation for Support and Promotion of Entrepreneurship in Warmia and Mazury, p. 80.
40. Nesterak, J., Kołodziej-Hajdo, M. (2006). Factors determining the effectiveness of inventory management in cokeochemical enterprises. *Scientific Journals, No. 731*. Kraków: Academy of Economics, pp. 213-225.
41. Niziński, S., Żurek, J. (2011). *General logistics*. Warsaw: Communication and Communications Publishing House, pp. 152-153.
42. Ordinance of the Council of Ministers of December 24, 2007 on the Polish Classification of Activities (PKD), Dz.U.2007.251.1885.
43. Ordinance of the Minister of Health of June 14, 2023 on the cancellation of an epidemic emergency in the territory of the Republic of Poland. Dz.U.2023.1118.
44. Ordinance of the Minister of Health of March 20, 2020 on the declaration of an epidemic state in the territory of the Republic of Poland. Dz.U. 2020, item 491.
45. Otwinowski, W. (2010), *Crisis and crisis situation*. Poznan: Scientific and Methodical Review. *Education for Security, No. 2*, p. 87.
46. Polinski, R. (2017). *Eurozone - crisis and reform*. Retrieved from: [https://archiwum.pte.pl/pliki/2/12/STREFA\\_EURO\\_z\\_dn20\\_02\\_2017.pdf](https://archiwum.pte.pl/pliki/2/12/STREFA_EURO_z_dn20_02_2017.pdf), pp. 7. 18.04.2024.
47. Priniotakis, G., Argyropoulos, P. (2018). *Inventory management concepts and techniques*. Retrieved from: [https://www.researchgate.net/publication/329484998\\_Inventory\\_management\\_concepts\\_and\\_techniques](https://www.researchgate.net/publication/329484998_Inventory_management_concepts_and_techniques), p. 2.
48. Prokopovich, D. (2023). *The economic impact of the war in Ukraine*. In: Soroka, Pająk (Eds.), *Selected aspects of Russian aggression against Ukraine in the political, military and economic areas* (p. 302). Warsaw: Elipsa Publishing House.



49. Reddy, B. (2021). Inventory management concepts and technique. *Journal of Interdisciplinary Cycle Research, Vol. XIII, Iss. II*, p. 202.
50. Redziak, Z. (2013). Uncertainty in decision-making. *Scientific Journals AON, No. 2(91)*, p. 114.
51. Rogala-Lewicki, A. (2023). The situation of the Polish shipbuilding industry and the need for its consolidation. *Analyses and Materials, Geopolitical Review, No. 44*, p. 148.
52. Romiszewska, I. (2011). The state as a stabilizer of the banking market during the global financial crisis. *Scientific Journals WSB, No. 33*. Poznan, pp. 17 et al.
53. Rutkowska-Podołowska, M. (2016). The economic crisis and its impact on sustainable development. *Economics and Environment, No. 1(56)*, p. 15.
54. Siekierski, J., Rutkowska, M. (2008). Sustainable development as a concept in economic sciences. *Studies and Works of the Faculty of Economic Sciences and Management, No. 8*, p. 361.
55. Skowronek, C. (2023). Current assets and logistics processes of enterprises in 2019-2022 - basic phenomena and trends. *Materials Management and Logistics, PWE, No. 2*, p. 6.
56. Skowron-Grabowska, B. (2009). Analysis of the impact of inventory management on the financial performance of energy companies. *Acta Universitatis Lodzianis, Folia Oeconomica, Vol. 226*, p. 175.
57. Soroka, P., Pajak, K. (Eds.) (2023). *Selected aspects of Russian aggression against Ukraine in the political, military and economic areas*. Warsaw: Publishing House Elipsa, p. 7.
58. *Statistics Poland / Meta-information / Glossary of terms / Terms used in official statistics*. Retrieved from: <https://stat.gov.pl/metainformacje/slownik-pojec/pojecia-stosowane-w-statystyce-publicznej/>, 11-22.03.2024.
59. *Statistics Poland / Publications* (2016). Retrieved from: <https://new.stat.gov.pl/publikacje/gospodarka-materialowa-w-2016-r>, 11.04.2024.
60. *Statistics Poland / Subject areas / Business entities. Financial performance / Non-financial enterprises*. Retrieved from: <https://stat.gov.pl/obszary-tematyczne/podmioty-gospodarcze-wyniki-finansowe/przedsiębiorstwa-niefinansowe/>, 11-22.03.2024.
61. *Statistics Poland / Subject areas / Koniunktura*. Retrieved from: <https://stat.gov.pl/obszary-tematyczne/koniunktura/>, 11-22.03.2024.
62. *Statistics Poland / Subject areas / National accounts*. Retrieved from: <https://stat.gov.pl/obszary-tematyczne/rachunki-narodowe/>, 11-22.03.2024.
63. Szymanski, W. (2004). *The interests and contradictions of globalization. Introduction to the economics of the globalization era*. Warsaw: Difin, p. 37.
64. *The Great Dictionary of the Polish Language of the Polish Academy of Sciences*. Retrieved from: <https://wsjp.pl/haslo/podglad/11179/kryzys/4830996/w-gospodarce>, 09.04.2024.
65. The Law of September 29, 1994 on accounting, Dz.U. no. 121, item 591.
66. *Transformation of energy-intensive industries in Poland* (2022). Retrieved from: <https://klimatycznabazawiedzy.org/raport/1410/>, pp. 23-24, 12.04.2024.

67. Urbanowska-Sojkin, E. (1999). *Enterprise management. From crisis to success*. Poznań: AE Publishing House, p.15.
68. Vrat, P. (2014). Springer India 2014. *Basic Concepts in Inventory Management*, Materials Management, Springer Texts in Business and Economics, p. 21.
69. Węc, J. (2020). The Debt Crisis in the Eurozone 2010 2018: Genesis, Dynamics, and Instruments to Overcome it. *Politeja*, Vol. XVII, No. 3(66), pp. 29-52.
70. Wolniak, R. (2022). The impact of the COVID-19 pandemic on governance. *Scientific Journals WSZOP*, No. 1(18). Katowice, p. 24.
71. Zimniewicz, K. (1990). *Science of organization and management*. Warsaw: PWN, pp. 223-224.
72. Zimoń, G. (2015). The impact of inventory management strategies on the financial performance of enterprises. *Scientific Papers UE*, No. 399, Accounting and controlling. Wrocław: p. 509.

## IDENTIFYING ELEMENTS THAT CODE THE ORGANIZATION'S GENOME WITH THE SPIDER WEB MODEL TO DETERMINE BUSINESS DEVELOPMENT POTENTIAL

Magdalena GORZELANY-DZIADKOWIEC<sup>1\*</sup>, Krzysztof MACHACZKA<sup>2</sup>

<sup>1</sup> Cracow University of Economics; gorzlam@uek.krakow.pl, ORCID: 0000-0001-9062-5984

<sup>2</sup> Cracow University of Economics; machaczka@uek.krakow.pl, ORCID: 0000-0002-7345-122X

\* Correspondence author

**Purpose:** The paper aims to elaborate and discuss the spider web model and identify elements that code an organization's genome to determine its development potential and design changes.

**Design/methodology/approach:** The first step was a literature review and elaboration and discuss the spider web model. Next, a survey questionnaire with closed questions was developed and used for research. The survey was a pilot addressed to purposefully sampled organisations. Through our choice of the sample—enterprises, an NGO, and a public institution—we emphasised the tool's versatility and demonstrated that identifying elements that codify an organisation's genome to determine its development potential applies to more than just businesses. An auxiliary in-depth interview was also conducted. Responses were collected using the CAWI technique.

**Findings:** Elaboration and discuss the spider web model. It was established that all the investigated organisations have their specific genomes, sets of information, which characterise and guide their development. The case studies demonstrated that diagnosing and assessing the spider web model parameters is necessary to determine the organisation's development potential and find potential change opportunities.

**Research limitations/implications:** The research was limited by a small sample of arbitrarily selected organisations. Still, the selection of organisations for the case studies was purposeful. We demonstrated that the spider web model can diagnose and assess parameters that codify an organisation's DNA in all types of organisations, enterprises, NGOs, and public institutions. It may also help identify areas in need of change to maintain the development potential. In light of the above, future research should include a more in-depth study of selected sectors to conduct a comparative analysis and offer generalised conclusions.

**Practical implications:** The use of a questionnaire to diagnose the parameters of the spider web model in the design of changes within organizations.

**Social implications:** Increase awareness among managers and people in organizations of the impact of DNA genome on organizational development.

**Originality/value:** Discussing of the spider web model, indication of the parameters that build the DNA genome. Indication of integration and reconfiguration mechanisms in management systems consisting in the development and implementation of model solutions facilitating adaptation to dynamic exogenous and endogenous conditions.

**Keywords:** spider web model, organisation's DNA, change management, organisation development, development potential.

**Category of the paper:** Research paper, Case study.

## 1. Introduction

Organisation management concepts have been changing since the turn of the twenty-first century. One reason is certainly the dynamism of developmental challenges organisations face from exogenous and endogenous factors combined with their qualitative weight. The challenges are generated by factors of local or national scale but also those affecting the international or even global environment. Hence, there is a necessity to adapt management concepts to these factors. The concepts have to respond by design to the architecture of new trends on the one hand and the need to anticipate adjustments to the operating conditions of organisations on the other hand. They even have to be capable of designing suitable management models to rise to the challenges.

Therefore, the article aims to discuss the spider web model and identify elements that code an organization's genome to determine its development potential and design changes that ensure its further operational potential.

The first research step was a literature review. We then verified the proposed theses with original research using a diagnostic survey. The research tool is an original questionnaire with close-ended questions followed by an in-depth interview. Responses were collected using the CAWI technique. The primary research conclusion is that diagnosing and assessing the spider web model parameters (that codify an organisation's genome) is useful for determining the organisation's development potential and designing changes. The selection of organisations for case studies was purposeful. We demonstrated that the spider web model can be used to diagnose and assess parameters that codify an organisation's DNA in all types of organisations, enterprises, NGOs, and public institutions.

## 2. Spider web model. A literature review

A genome is a set of all genes and other DNA sequences. It is the entire genetic material in an organism. Each genome contains the information necessary to build, grow, and develop the organism. The human genome consists of three billion DNA letters that codify genes, which are critical to making people the way they are. This is why it is sometimes referred to as the 'book of life'. It can also be used as a metaphor to describe organisations. For an organisation to grow and develop, it is necessary to identify its unique DNA. An organisational genome is

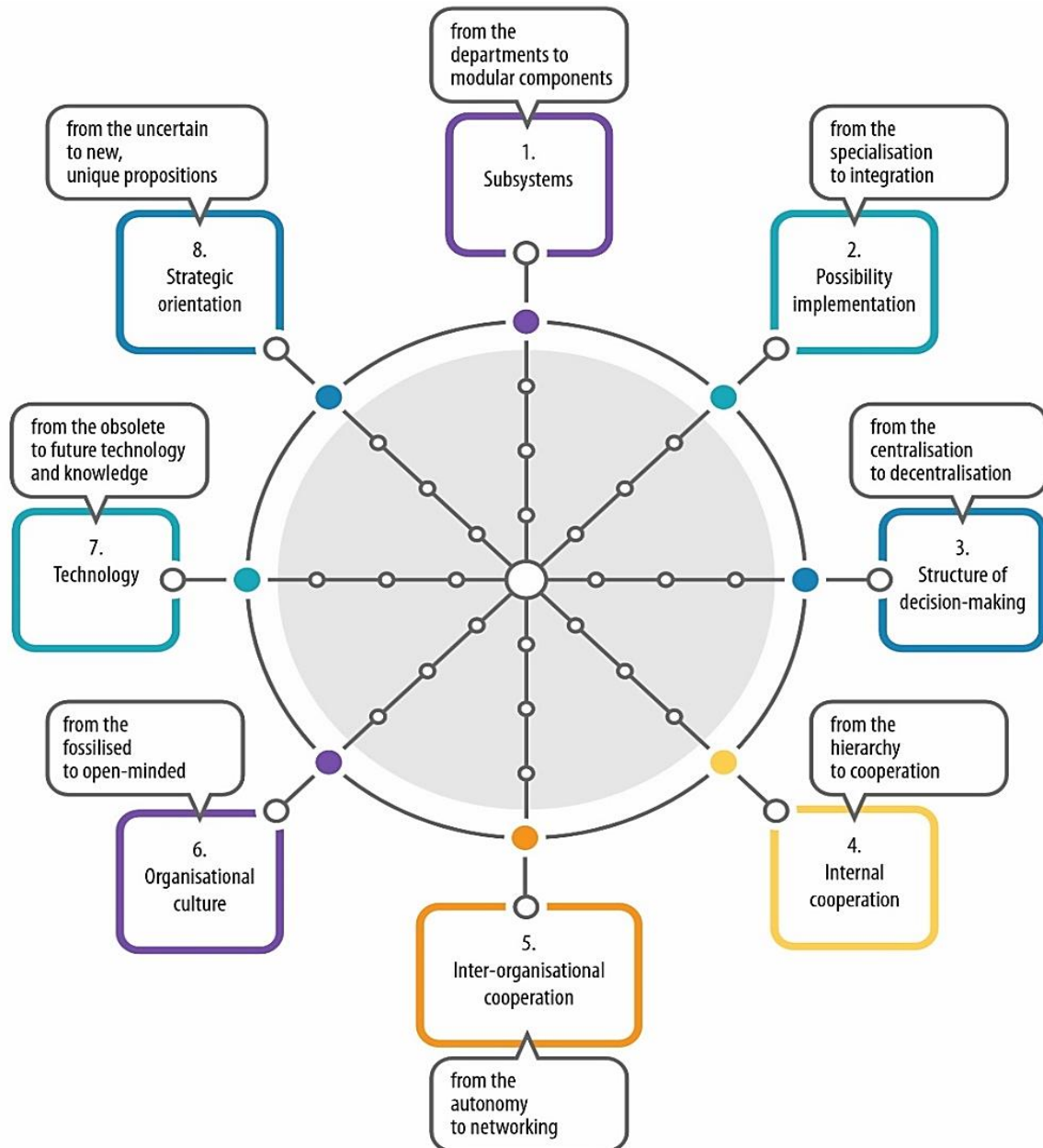
conceived as a complete set of 'genetic' material, an array of its typical defining elements and characteristics. One popular model conceptualising the construction of an integrated model of an organisation's development is founded on the organisation's DNA. Its premise is that an organisation has a unique DNA, just like any living creature. The difference is that there is no limit to how an organisation's DNA can be modified.

Organisations fail to use or describe their behaviour with simple action maps in their day-to-day operations. This deficiency might be a source of multiple developmental problems. Such maps should contain structural parameters and other elements such as culture, technology, communication, or cooperation. Note that such a map of entwined elements would help identify elements that codify the organisation's genome, guiding the effective growth of the enterprise.

The concept of an organisation's spider web visualises a spider in the diagram, which can be holistically developed to conceptualise business models of brick-and-mortar or online enterprises. The diagram is modified by selecting and combining eight parameters visualised in Figure 1 [the spider web model by Krüger, Bach, 2000].

When appropriately guided, the model's parameters are important for creating the organisation's autonomy or its organisational DNA. Additionally, each element is an area of change in the organisation. The organisational spider web model consists of 32 points, forming a business model (eight parameters of four points each). Five parameters contain structural variables (subsystems, possibility of implementation, decision-making structure, internal cooperation, and inter-organisational cooperation). The other three are strategic orientation, culture, and technology (Krüger, Bach, 2000).

The first discussed parameter is **subsystems**, linked to the second parameter in the web, the possibility of implementation. Subsystems defines the surface of the formal structure. In traditional organisations, structure is linked to subsystems emerging over years of growth. Modern organisations have to navigate towards smaller autonomous units (such as business units or autonomous workgroups). The idea is to model an organisational structure by delegating formal power towards lower tiers. The creation of autonomous units should aim to remove hierarchical lines, and subsystem modelling should indicate a clear transition from power on various management tiers to a more transparent and flexible structure. The traditional approach satisfies lazy and tardy organisations because it calls for no change. In contrast, modern subsystem modelling requires creative patterns and is typical of agile organisations.



**Figure 1.** Organisation spider web model.

Source: original work based on: Krüger, Buchholz, 2000; Gouillart, Kelly, 1996; Neilson, Pasternack, 2005. The internal organisational structure and its subsystems can be described in work schedules, but the **possibility of implementation** depends on specialisation and integration. The organisation and management theory points out the advantage of specialisation over integration (although not always and not in every dimension). Business activity in a dynamic environment with constant high uncertainty and risk requires managers to reorient their mental framework and decision-making. Modern enterprises operating in variable environments must constantly look for effective product and service portfolios. Decision-making in this area ranges from a monostructure (a single strategic segment) to a multistructure (multiple segments).

The focus on specialisation, diversification, and integration strategies should be constantly

analysed and assessed, mainly regarding efficiency and risk levels. Specialisation should be pursued as long as the enterprise achieves a clear and sustainable advantage over its competition. The decisive factor for pursuing either specialisation or diversification is the optimum allocation of corporate assets to reach the highest possible return. Many enterprises sit on the fence, trying to decide whether to invest in specialisation and improve their market position or diversify, hoping for higher returns.

Note that specialisation has its drawbacks. Beyond any doubt, specialisation comes with alienation, work fatigue, work dissatisfaction, increased fluctuation, and problems finding work or filling a position. According to F.W. Taylor, the specialisation of tasks and duties can give an advantage if adapted to the organisation's subsystems. When building organisational structure and creating interdependencies, one has to focus on various domains, customers, or projects useful for specific integration types. Moreover, integration has to ensure adequate integrity of the strategy with tactical and operational management. The role of system integration is relevant to organisations. It is a challenge for enterprises and employees to ensure that an integrated system reflects the needs of all stakeholders: employees, customers, and the public. Therefore, it must strive to entwine three management levels: strategic, tactical, and operational. Other important issues include a coherent strategy for the entire management area, integrity of objectives and efforts improving individual management areas, avoidance of task, authority, and responsibility overlapping, reduction of document and record volume, and cost reduction (Ejdys, Kobylińska, Lulewicz-Sas, 2012). An integrated system facilitates a comprehensive approach to all problems in the organisation. The primary objective of system integration should be the pursuit of improvement of all corporate processes and areas (Harmon, 2018). Therefore, structure building must mean more than just the creation of autonomous units. It should also ensure sufficient integration and cooperation through a certain degree of freedom to individuals or project teams (such as in a virtual organisation).

Another critical component of every organisation is the **allocation of power and decision-making**. Concepts of centralisation and decentralisation are paramount here. Centralization is connected with amassing power and control at the very top of the organization. Decentralization, on the other hand, involves moving decision-making to various tiers of management. Centralisation vs decentralisation is a matter of self-reliance in task performance and use of competencies available in the organisational structure (Habuda, 2017). The organisation is highly centralised when the top management only emanates orders downwards. When an organisation is not strictly centralised, it can be said to undergo certain decentralisation, although perhaps only in some domains. Centralisation and decentralisation are not a zero-sum game. They coexist and dominate different areas of organisational activities. Therefore, organisations should move from centralisation towards decentralisation. This may be achieved through **internal cooperation** (another parameter in the spider web model). Internal cooperation should consist in departing from hierarchy, from using power *ex officio* towards an authority based on expertise, for example.

Today's business model is based largely on **inter-organisational cooperation**, which is the next structural parameter in the spider web model. Separate autonomous units need a different organisation with which they can cooperate as a single organisation. The proposed approach suggests moving from autonomous units to the network structure. An organisation's architecture emerges from its network of internal and external connections. External connections can be weak or strong. Strong connections are usually asset and capital-related. Weak connections include vertical partnerships when suppliers and customers are considered partners through inclusion in corporate production process preparation. Corporate architecture is also built from internal connections, which come as strong connections, such as structure, and weak connections, such as autonomous groups, quality circles, personal contacts, etc. Cooperation and collaboration of economic agents have been uninterrupted since the exchange economy emerged. Still, their scope, intensity, and forms vary as economic development progresses from exchange to trade and commodity transactions to partnership and integration of activities to specialist services and supplies to franchising and joint endeavours and projects. The needs for joint effort are mostly similar in different domains of economic life, but they are also specific. They result from business methods and relevant conditions (Bochenek, 2017). Each organisation has a certain ability to cooperate with which it can achieve its goals more effectively and economically. The goals would be beyond its reach or require much greater effort if faced independently. Modern organisations are involved in various interactions with components of their environments. The components are considered to exert either direct or indirect impact and involve competition, neutrality, or cooperation (Kozuch, Sienkiewicz-Małyjurek, 2013). Causes for inter-organisational cooperation include a high level of interdependence, risk sharing, insufficient resources, experience with previous joint projects, and problem complexity.

**Organisational culture** is a separate parameter in the model. Organisational culture has been discussed broadly in the literature of the last decades of the twentieth century. Barney (1986) and Slater, Olson, and Finnegan (2011) explained that not only does organisational culture reflect who the employees, customers, suppliers, and competitors are but it also defines how the company will work with key stakeholders. The right organisational culture helps employees comprehend the business strategy. It motivates and nourishes human relationships. Moreover, organisational culture has become a means for realising the organisation's mission over the ages.

The multitude of investigated variables relevant to organisational culture led to the emergence of the notion of innovation-friendly culture. It should be taken into consideration in management theory. (Buschgens, Bausch, Balkin, 2013). Considering the views of Fralinger and Olson (2007) that organisational culture is the primary decision factor in organisations, it appears as an inherent component of the existence and growth of any organisation. Whether and how it can promote development is a completely different matter.



Although it is generally believed that it was Pettigrew (1979) who introduced the notion of culture to organisation theory, it was present in social sciences—sociology and anthropology in particular—nearly from their beginnings. Issues related to organisational culture are interdisciplinary. Not only does organisational culture reflect who the employees, customers, suppliers, and competitors are, but it also defines how the organisation will work with them. A strong culture helps employees understand the business strategy, motivates, and improves human relations between organisation members. Therefore, if the success of a business strategy depends on its implementation and realisation, the organisation needs cultural support (Gorzelany, Gorzelany-Dziadkowiec et al., 2021). Moreover, culture determines the types of people attracted to the organisation and who can succeed in its structure. This approach is reflected in a definition by Hofstede (1998), who perceives organisational culture as ‘the collective programming of the mind’. Shared values and the degree to which organisation members share them are the basis for any effort to build organisational culture. The internalisation of an organisation's values should lead to the consistency of goals among managers and individual employees (Sánchez-Cañizares, Munoz, López-Guzmán, 2007).

This is how Quinn and Rohrbaugh (1983) devised the competing values framework. The concept postulates that managers have to make choices reflecting two types of tensions within the organisation stemming from internal and external factors and challenges related to control vs flexibility. This two-dimensional representation yields four types of culture. Although all organisations exhibit some features of each type of culture, one usually dominates. In the spider web model, cultural changes should move from a fossilised formula towards an open-minded and innovative culture. Innovation culture is the *sine qua non* of organisation growth. It improves entrepreneurship level and boosts financial results (Storey, Kahn, 2010), according to Hogan and Coote (2014). Innovation culture improves company results by promoting innovative and creative behaviour, helping develop innovative products and services, and generating innovative solutions. As opposed to some management theorists, Kirby and Ibrahim (2011) believe that when directed towards entrepreneurship, organisational culture should not be understood as ‘more business-like’ but must strongly promote innovation and creativity. Therefore, employees should be encouraged to take initiative and be active, which improves sharing and cooperation in business organisations and public administration alike. Over the last decade, researchers and managers identified concepts of organisational culture in various environments to improve functional and work cohesion and productivity in organisations.

Another parameter of the spider web model is **technology**, which is a critical change area in any organisation. With new smart technologies approaching, the business has to manage the implementation of Industry 4.0 and smart principles (Pfeifer, 2021). To be able to cope with technology trends, employees need to adjust to new expectations because—apparently—contributors to intellectual capital benefit the most from the Fourth Industrial Revolution. Implementing digital technologies in the industry and institutions, which need to keep up with

changes, builds up new expectations for employee qualifications. Undoubtedly, 'new technologies will radically change the nature of work in all industries and professions. The primary uncertainty stems from the questions: to what degree automation and artificial intelligence (AI) will replace workforce, how long it will take, and how far it will go. Innovation gained momentum in the late twentieth century. Many believe we live in the time of Industry 4.0, and the changes we go through can be perceived as a revolution in the labour market. Still, the term 'Industry 5.0' emerges in the literature (Mohd, Abid, 2020). It refers to a new type of society where scientific and technological innovations are important for balancing social problems that must be resolved while sustaining economic growth (Salgues). Society 5.0 is also defined as 'Imagination Society', where digital transformation is combined with creativity and values to create a sustainable society (Guevara, Terra, 2020). The pace of changes in technology and engineering requires that to be effective, enterprises need to introduce innovation. They also have to choose a specific innovation strategy, which defines the degree and manner of innovation used to achieve strategic advantage. It covers R&D and technology strategies but also transcends them. Depending on the attitude towards innovation originality, one can speak of (I) innovation leadership, where the organisation aims to be a technology leader by developing new technologies and marketing new products and (II) innovation followership, where an enterprise markets new products by imitating and learning from technology leaders (Zakrzewska-Bielawska, 2010). Technology changes promote the development of organisations. Organisations should transition from obsolete technologies to strategic technology orientation, founded mainly on knowledge.

The last component of the spider web model is **strategic orientation**. Although strategy is listed last, it is the starting point for any action. Note that a strategy should be able to identify differences among team strategies. The organisational spider web includes unique and exceptional propositions. Hence, the most effective means should be identified as the most valuable parts of a business model. It can be done not through acceptable solutions that improved the effectiveness of actions but by answering why customers choose a specific enterprise's offering, for example, or how employees coordinate their efforts. This is why a unique (exceptional) strategy is the cornerstone of the entire organisational design. When formulating a strategy, one has to analyse vague, ambiguous environments and create unique propositions.

### 3. Novelty and aim of the article

The need to assimilate indication integration and reconfiguration mechanisms in management systems—mechanisms based on devising and implementing model solutions that facilitate adaptation to dynamic exogenous and endogenous conditions—is a critical factor for

realising the vision of the future and survival of the organisation. Therefore, the article aims to elaborate and discuss the spider web model and identify elements that code an organization's genome to determine its development potential. Specific goals follow from that aim:

1. to define the organisation's DNA,
2. to identify spider web model parameters,
3. to discuss relationships between spider web model parameters and identification of the organisation's genome,
4. to improve the state of the art regarding the use of spider web model parameters in identifying the development potential of enterprises (through an original diagnostic questionnaire).

The aim is pursued with the following theses:

T1: Parameters in the spider web model codify the organisation's genome.

T2: Identifying components that codify the organisation's genome is necessary to determine its development potential.

T3: A diagnosis and assessment of spider web model parameters for an organisation determines the codification of its genome.

#### **4. Material and methods (area, design, and execution of the study)**

The first step of the research process was a bibliometric analysis and systemic literature review using the Scopus and Google Scholar databases. The articles were filtered by research aim. They were searched using the following keywords: subsystems, systems, centralisation, decentralisation, possibility of implementation, intra-organisational cooperation, networking, hierarchy, authority, organisational culture, innovation culture, technologies, strategic technologies, Industry 4.0, and Industry 5.0. The literature analysis was conducted from January 2024 to 10 February 2024. It provided grounds for discussing the spider web model and identifying elements that code an organization's genome to determine its development potential. The analysis further identified a knowledge gap: the need for a tool for diagnosing and assessing how spider web model parameters are shaped in organisations. Such a tool would enable managers to determine their organisation's development potential and codify its individual genome.

Therefore, the next stage was to devise a questionnaire for diagnosing and assessing how spider web model parameters are shaped in organisations. The questionnaire questions concerned the eight parameters from the spider web model. The answers were given on a five-point Likert scale. The Likert scale (1932) allows researchers to detect even relatively subtle differences in attitudes. The advantage of this scale over simple scales is apparent also in the

fact that individual points cannot significantly affect the final result. They are meant to be balanced within the scale, while the specificity of a simple scale can affect research conclusions to a large degree. Normalisation in ranking methods consists in ordering objects according to the ordering criterion for the given variable. Next, variants of the variable are assigned ranks, conventional numeric values that are most often ordinals of positions of the objects in an ordered sequence. Hence, for the present research, 1 means ‘to a very little degree’, and 5 means ‘substantially’.

Our original research was a diagnostic survey using an original questionnaire with eight close-ended questions. As we sought to answer whether the spider web model parameters codify the organisational genome, we asked about any needs for change related to each parameter. The questionnaire for the research was validated with a pilot survey, where respondents were asked about their understanding of the questions in the questionnaire and the correctness of their content. Responses were collected using the CAWI technique. The questionnaire was loaded to Google Drive, and the link to it was sent to people in the research sample. The survey was a pilot addressed to purposefully sampled organisations. Through our choice of the sample—enterprises, an NGO, and a public institution—we emphasised the tool's versatility and demonstrated that identifying elements that codify an organisation's genome to determine its development potential applies to more than just businesses. The investigated organisations have a solid competitive position, regularly introduce changes to drive development, and are open to cooperation. The selected organisations are a micro-enterprise (Cyfrowa Królowa, a private tuition provider), a small enterprise (Cukiernia Magdalenka confectionary), an association (LKS Respekt sports club), and the University of Economics in Kraków as a public institution.

Cyfrowa Królowa was established in 2021. Its core business is innovative mathematics tuition. In the words of the owners, ‘we teach maths and get wild with numbers, but no child is just another number or statistic to us. We believe the key to success in educating young people is to offer them the right environment founded on good vibes, acceptance, and a sense of safety. We are human. Both us, teachers, and the children we teach. We have the right to make mistakes. We believe in relationships.

The Cukiernia Magdalenka confectionary was established in Myślenice, Poland in 1957. Its craft products are made based on recipes over 60 years old. The confectionery has ten employees and a simple organisational structure where the owners own all processes. It is a family business handed down from the previous generation. The third generation of the family is stepping in now. The owner's children have completed confectionary education, earning both apprentice and then master craftsman certificates. In addition to confectionary-focused training, they completed higher education. The son graduated from the AGH University of Technology, and the daughter completed studies at the University of Physical Education in Kraków. Still, they are committed to the confectionery business.

The LKS Respekt sports club is located in Myślenice at 20a Zielona Street. It was registered with the District Starost in July 2013 (statutes of such organisations do not provide for economic activity). The club is registered as a physical culture association with a legal personality and one section: female football. It has 80 active players, all registered on the official extranet. The girls participate in national-level matches, while young players compete at regional and local tiers.

The link to the questionnaire was sent by e-mail to owners and employees of the selected enterprises, board, officials and of-age players of LKS Respekt and students of the University of Economics in Kraków who discussed the spider web model during lectures and classes. The total number of correctly completed and returned questionnaires was 2 from Cyfrowa Królowa, 10 from Cukiernia Magdalenka, 20 from LKS Respekt, and 32 from the University of Economics.

The data and relationships were analysed using Spearman's rank correlation coefficient. Spearman defined his coefficient as a regular Pearson correlation coefficient for ranks of variables (hence the name rank correlation coefficient). It describes the strength of the correlation of two measurable and qualitative features when the population is small and the features can be ordered. The measure values lie in the interval of  $[-1, +1]$ . The closer it is to one, the stronger the correlation between the variables (Aczel, Sounderpandian, 2018).

## 5. Results and discussion

Considering that Spearman's correlation coefficient did not identify statistical significance among the answers given by the owners of Cukiernia Magdalenka, vs its employees, the board and officials of LKS Respekt vs the players and answers by the students (UEK), the results are presented in aggregate.

The first question concerned subsystems. The respondents described to what extent their respective organisations implemented specific activities. The results for the four organisations are summarised in Table 1.

**Table 1.**  
*Subsystems. Results of original research*

Subsystems	Response scale									
	1	2	3	4	5	1	2	3	4	5
smaller, independent units are created										
UEK/LKS Respekt	12%	34%	25%	25%	3%	40%	0	40%	0	20%
CM/CK	0	0	0	50%	50%	0	0	0	50%	50%
autonomous project (work) teams are created										
UEK/LKS Respekt	6%	23%	25%	28%	18%	20%	20%	20%	20%	20%
CM/CK	0	0	0	0	100%	0	0	0	0	100%

Cont. table 1.

authority is delegated to lower tiers										
UEK/LKS Respekt	28%	28%	34%	9%	0	60%	20%	20%	0	0
CM/CK	0	0	0	0	100%	0	0	0	0	100%
drive towards the removal of hierarchical dependencies										
UEK/LKS Respekt	12%	38%	38%	12%	0	0	0	40%	40%	20%
CM/CK	0	0	0	0	100%	0	0	0	0	100%
autonomous, independent units are needed										
UEK/LKS Respekt	6%	34%	22%	31%	6%	40%	20%	40%	0	0
CM/CK	100%	0	0	0	0	100%	0	0	0	0

Source: original work based on research.

The data in Table 1 shows that the spider web model parameters related to subsystems are used and realised to a substantial degree in Cukiernia Magdalena and Cyfrowa Królowa. The enterprises are founded on independent units, project teams are created, authority is delegated, and the organisations progress towards the removal of hierarchical dependencies. LKS Respekt does not create independent units or delegate authority but has no hierarchical dependencies. The results are linked to the characteristics of the organisation. Respekt is a sports club, a team that operates within a defined structure of distinct groups of players. Notably, the respondents from these organisations do not feel the need to create autonomous units. Therefore, subsystems can be considered as DNA components there. The results are slightly different for the University of Economics. The answers are significantly scattered, with 37% of the respondents needing independent units. It suggests that the parameter requires refinement, and smaller, independent units should be considered in the university structure.

The next diagnosed and assessed spider web parameter is the possibility of implementation. The results are presented in Table 2.

**Table 2.**  
*Possibility of implementation. Results of original research*

Possibility of implementation	Response scale									
	1	2	3	4	5	1	2	3	4	5
human potential is employed										
UEK/LKS Respekt	6%	16%	25%	44%	9%	0	20%	0	60%	20%
CM/CK	0	0	0	70%	30%	0	0	0	0	100%
opportunities of external cooperation are utilised										
UEK/LKS Respekt	9%	22%	3%	47%	18%	0	20%	0	80%	0
CM/CK	0	0	0	20%	80%	0	0	0	100%	0
specialisation occurs										
UEK/LKS Respekt	18%	22%	38%	22%	0	0	20%	20%	60%	0
CM/CK	0	0	0	0	100%	0	0	0	0	100%
cooperation occurs										
UEK/LKS Respekt	6%	3%	18%	31%	34%	0	20%	0	20%	60%
CM/CK	0	0	0	0	100%	0	0	0	0	100%
integration occurs										
UEK/LKS Respekt	3%	6%	18%	50%	22%	0	20%	0	80%	0
CM/CK	0	0	0	0	100%	0	0	0	0	100%
individuals and teams are given freedom to act										
UEK/LKS Respekt	3%	28%	28%	34%	6%	0	20%	20%	40%	20%
CM/CK	0	0	20%	40%	40%	0	0	0	0	100%

there is a need for more cooperation, integration, and freedom to act										
UEK/LKS Respekt	6%	18%	31%	38%	6%	20%	20%	40%	0	20%
CM/CK	100%	0	0	0	0	0	50%	0	0	50%

Source: original work based on research.

The results in Table 2 suggest that regarding the possibility of implementation, LKS Respekt, Cukiernia Magdalena, and Cyfrowa Królowa make significant use of the spider web model parameters and realise them. The organisations tap into human potential, practice internal cooperation, sometimes to a great extent, and cooperate with third parties. Integration occurs, and people are given substantial freedom to act. Respondents from Cukiernia Magdalena do not feel the need to increase cooperation, integration, or more freedom to act. Participants from LKS Respekt and Cyfrowa Królowa indicated some needs in this regard. Results for the university demonstrate a need for more operational freedom for teams and individuals. Therefore, the possibility of implementation is an element of the spider web model that builds the genome of Cukiernia Magdalena and shapes its development potential.

The next diagnostic and assessment step involved the decision-making structure in the organisations. The results are summarised in Table 3.

**Table 3.**

*Decision-making structure. Results of original research*

Decision-making structure	Response scale									
	1	2	3	4	5	1	2	3	4	5
power is concentrated at the top tier										
UEK/LKS Respekt	0	3%	38%	38%	16%	0	20%	40%	40%	0
CM/CK	50%	50%	0	0	0	0	100%	0	0	0
power is distributed among various management levels										
UEK/LKS Respekt	6%	22%	22%	44%	6%	20%	40%	20%	20%	0
CM/CK	0	0	0	80%	20%	0	0	0	100%	0
decision-making is delegated to lower tiers										
UEK/LKS Respekt	12%	12%	47%	25%	3%	40%	60%	0	0	0
CM/CK	0	0	0	30%	70%	0	0	0	0	100%
there is a need to delegate decision-making										
UEK/LKS Respekt	6%	22%	25%	38%	9%	40%	40%	20%	0	0
CM/CK	50%	50%	0	0	0	100%	0	0	0	0

Source: original work based on research.

The summary in Table 3 shows that at the University of Economics in Kraków, power is partially or completely concentrated at the top tier. The respondents from LKS Respekt also noted a partial concentration of power at the top tier. Cukiernia Magdalena and Cyfrowa Królowa do not focus power at the very top. It is distributed among various tiers of management. Decision-making is delegated to lower tiers, and there is no need to delegate authority. The survey revealed that decision-making power is concentrated at the very top at LKS Respekt due to the characteristics of the organisation. There is no need to delegate decision-making there. Therefore, the decision-making structure at Cukiernia Magdalena, Cyfrowa Królowa, and LKS Respekt codifies their genomes. Answers from the students are scattered and suggest a need to delegate decision-making to lower tiers. This particular element of the spider web model for the University of Economics in Kraków may require changes.

Internal cooperation is the next spider web model parameter analysed in the organisations. The results are presented in Table 4.

**Table 4.**  
*Internal cooperation. Results of original research*

Internal cooperation	Response scale									
	1	2	3	4	5	1	2	3	4	5
managers employ authority										
UEK/LKS Respekt	3%	9%	31%	31%	25%	0	20%	60%	0	20%
CM/CK	0	0	0	80%	20%	0	100%	0	0	0
power is used										
UEK/LKS Respekt	0	22%	28%	38%	12%	20%	40%	0	20%	20%
CM/CK	70%	30%	0	0	0	50%	50%	0	0	0
expertise is used										
UEK/LKS Respekt	0	12%	18%	56%	13%	0	0	40%	20%	40%
CM/CK	0	0	30%	40%	30%	0	0	0	0	
organisation members share knowledge										
UEK/LKS Respekt	3%	12%	18%	41%	25%	0	20%	0	40%	40%
CM/CK	0	0	0	60%	40%	0	0	50%	50%	0
Cyfrowa Królowa	0	0	50%	50%	0					
there is a need for more internal cooperation										
UEK	3%	18%	28%	34%	16%	20%	20%	20%	40%	0
CM/CK	100%	0	0	0	0	0	50%	0	50%	0

Source: original work based on research.

The summary in Table 4 demonstrates that although the selected parameters (authority, expertise, knowledge sharing) were assessed as present or present to a significant degree in all the organisations by over half of the respondents, this domain needs change. Only respondents from Cukiernia Magdalenka believed these parameters did not need to change. Therefore, internal cooperation codifies the genome of the confectionery. The other respondents pointed to some need for more internal cooperation.

The fifth diagnosed and assessed element was inter-organisational cooperation. The results are presented in Table 5.

**Table 5.**  
*Inter-organisational cooperation. Results of original research*

Inter-organisational cooperation	Response scale									
	1	2	3	4	5	1	2	3	4	5
cooperates with other organisations (businesses, institutions)										
UEK/LKS Respekt	9%	12%	28%	31%	12%	20%	0	20%	20%	40%
CM/CK	0	0	50%	50%	0	0	0	100%	0	0
moves towards networking										
UEK/LKS Respekt	9%	18%	31%	31%	9%	0	60%	20%	20%	0
CM/CK	100%	0	0	0	0	0	100%	0	0	0
cooperates with international organisations										
UEK/LKS Respekt	12%	16%	25%	34%	12%	60%	40%	0	0	0
CM/CK	100%	0	0	0	0	100%	0	0	0	0
cooperates with organisations from various regions										
UEK/LKS Respekt	12%	16%	16%	41%	16%	0	20%	80%	0	0
CM/CK	100%	0	0	0	0	100%	0	0	0	0



Cont. table 1.

inter-organisational cooperation should be intensified										
UEK/LKS Respekt	6%	22%	28%	28%	16%	20%	20%	20%	40%	0
CM/CK	0	100%	0	0	0	0	0	0	0	100%

Source: original work based on research.

Regarding inter-organisational cooperation, the university cooperates with other organisations and regions. It moves towards networking. The other organisations cooperate externally to a small or very small extent. The scope of cooperation in Cyfrowa Królowa should clearly grow. The conclusion is that inter-organisational cooperation requires changes. It does not determine the development potential of the investigated organisations because it is not shaped properly.

Organisational culture is another analysed element of the organisations. The results are presented in Table 6.

**Table 6.**  
*Organisational culture. Results of original research*

Organisational culture	Response scale									
	1	2	3	4	5	1	2	3	4	5
family atmosphere; the organisation is a place of personal encounter; people commit strongly										
UEK/LKS Respekt	6%	22%	28%	31%	12%	20%	0	0	0	80%
CM/CK	0	0	0	0	100%	0	0	0	50%	50%
energy, entrepreneurship, risk-taking, etc. are present										
UEK/LKS Respekt	6%	18%	31%	25%	18%	0	20%	0	20%	60%
CM/CK	0	0	30%	70%	0	0	0	0	50%	50%
primarily deliverables matter; the best performance is the paramount focus; employees are ambitious and set to achieve										
UEK/LKS Respekt	3%	9%	34%	38%	16%	0	0	40%	20%	40%
CM/CK	50%	50%	0	0	0	0	0	100%	0	0
strict hierarchy and control; actions usually governed by formal procedures										
UEK/LKS Respekt	3%	9%	34%	38%	16%	40%	0	20%	20%	20%
CM/CK	50%	50%	0	0	0	50%	50%	0	0	0
leadership is associated with advice, help, and attention; teamwork is preferred; complete consensus and participation are the goal										
UEK/LKS Respekt	12%	9%	18%	54%	6%	0	0	20%	40%	40%
CM/CK	0	0	0	50%	50%	0	0	0	0	100%
leadership is associated with entrepreneurship and innovation; individual risk-taking, freedom, and originality are preferred										
UEK/LKS Respekt	12%	28%	25%	25%	9%	0	40%	20%	40%	0
CM/CK	0	0	20%	40%	40%	0	0	100%	0	0
leadership is associated with resolve, expansiveness, and performance orientation; fierce competition is preferred; high requirements are posed; focus on achieving										
UEK/LKS Respekt	16%	34%	9%	31%	9%	40%	20%	20%	0	20%
CM/CK	100%	0	0	0	0	0	100%	0	0	0
leadership is associated with coordination, efficient organisation, and provision of harmonious conditions for good performance; employment security, subordination, predictability, and constant relationships are preferred										
UEK/LKS Respekt	3%	9%	38%	38%	12%	0	0	40%	60%	0
CM/CK	100%	0	0	0	0	0	50%	50%	0	0
changes in this domain are necessary										
UEK/LKS Respekt	18%	18%	31%	18%	12%	0	40%	0	60%	0
CM/CK	50%	50%	0	0	0	50%	50%	0	0	0

Source: original work based on research.

The summary in Table 6 shows that the organisations are dominated by clan and adhocracy cultures. LKS Respekt demonstrates some signs of a hierarchy culture. Respondents from Cukiernia Magdalena and Cyfrowa Królowa do not feel the need for change in their cultures. Therefore, organisational cultures code their DNAs. The domain is in need of redesigning in LKS Respekt and at the university.

The penultimate parameter of the investigated organisations is technology. The results are presented in Table 7.

**Table 7.**  
*Technology. Results of original research*

Technology	Response scale									
	1	2	3	4	5	1	2	3	4	5
new technologies are used in production (services)										
UEK/LKS Respekt	6%	16%	18%	47%	12%	0	20%	80%	0	0
CM/CK	40%	60%	0	0	0	0	0	0	0	100%
new technologies are used in marketing (such as social media)										
UEK/LKS Respekt	3%	12%	22%	41%	22%	0	0	20%	40%	40%
CM/CK	0	0	0	70%	30%	0	0	0	0	100%
knowledge capital is used										
UEK/LKS Respekt	0	9%	18%	38%	34%	0	20%	20%	40%	20%
CM/CK	0	0	20%	40%	40%	0	0	0	0	100%
strategic technologies have been identified (providing long-term competitive advantage)										
UEK/LKS Respekt	12%	16%	31%	31%	9%	20%	0	60%	0	20%
CM/CK	0	0	30%	50%	20%	0	0	100%	0	0
old technologies are used that need to be replaced										
UEK/LKS Respekt	12%	22%	38%	25%	3%	40%	40%	20%	0	0
CM/CK	100%	0	0	0	0	100%	0	0	0	0

Source: original work based on research.

It is evident from the data in Table 7 that technology codifies the DNAs of the confectionery, Cyfrowa Królowa, and LKS Respekt. These organisations use new technologies and knowledge and identify strategic technologies. The University of Economics in Kraków is the only organisation in the study where respondents feel the need for change.

The last diagnosed and assessed parameter is strategic orientation. The results are presented in Table 8.

**Table 8.**  
*Strategic orientation. Results of original research*

Strategic orientation	Response scale									
	1	2	3	4	5	1	2	3	4	5
only tested and reliable solutions										
UEK/LKS Respekt	0	0	31%	44%	25%	0	0	60%	40%	0
CM/CK	0	0	0	70%	30%	0	0	50%	50%	0
new, unique solutions acceptable										
UEK/LKS Respekt	3%	22%	41%	31%	3%	0	0	40%	60%	0
CM/CK	0	60%	40%	0	0	0	0	50%	50%	0
long-term plans drawn										
UEK/LKS Respekt	3%	9%	25%	31%	31%	0	20%	20%	60%	0
CM/CK	30%	40%	30%	0	0	0	0	100%	0	0

Cont. table 8.

strategy-based business model										
UEK/LKS Respekt	6%	6%	18%	47%	22%	0	40%	20%	40%	0
CM/CK	30%	40%	30%	0	0	0	0	0	50%	50%
strategic advantages constantly identified										
UEK/LKS Respekt	9%	12%	16%	50%	12%	20%	0	40%	40%	0
CM/CK	0	0	20%	60%	20%	0	0	0	0	100%
the most effective actions chosen										
UEK/LKS Respekt	0	9%	16%	53%	22%	0	20%	0	20%	60%
CM/CK	20%	50%	30%	0	0	0	0	0	50%	50%
changes in this domain are necessary										
UEK/LKS Respekt	9%	33%	31%	25%	0	80%	0	20%	0	0
CM/CK	60%	40%	0	0	0	0	100%	0	0	0

Source: original work based on research.

Strategic orientation codifies the genomes of all the investigated organisations. They adopt new, unique solutions, opt for effective actions, and their business models are largely based on a strategy.

The discussed parameters are entwined. One has to decide how to act and link these elements. The scale ordering rank ranges from 1 to 5 for each parameter and is determined by achievements in each cluster. The comparison scale and clusters for comparing the parameters are visualised in Figure 2, taking into account scores in Tables 1–8 and answers to the question of whether a parameter needed change. If the respondents pointed out the need for change, the score is below 5.

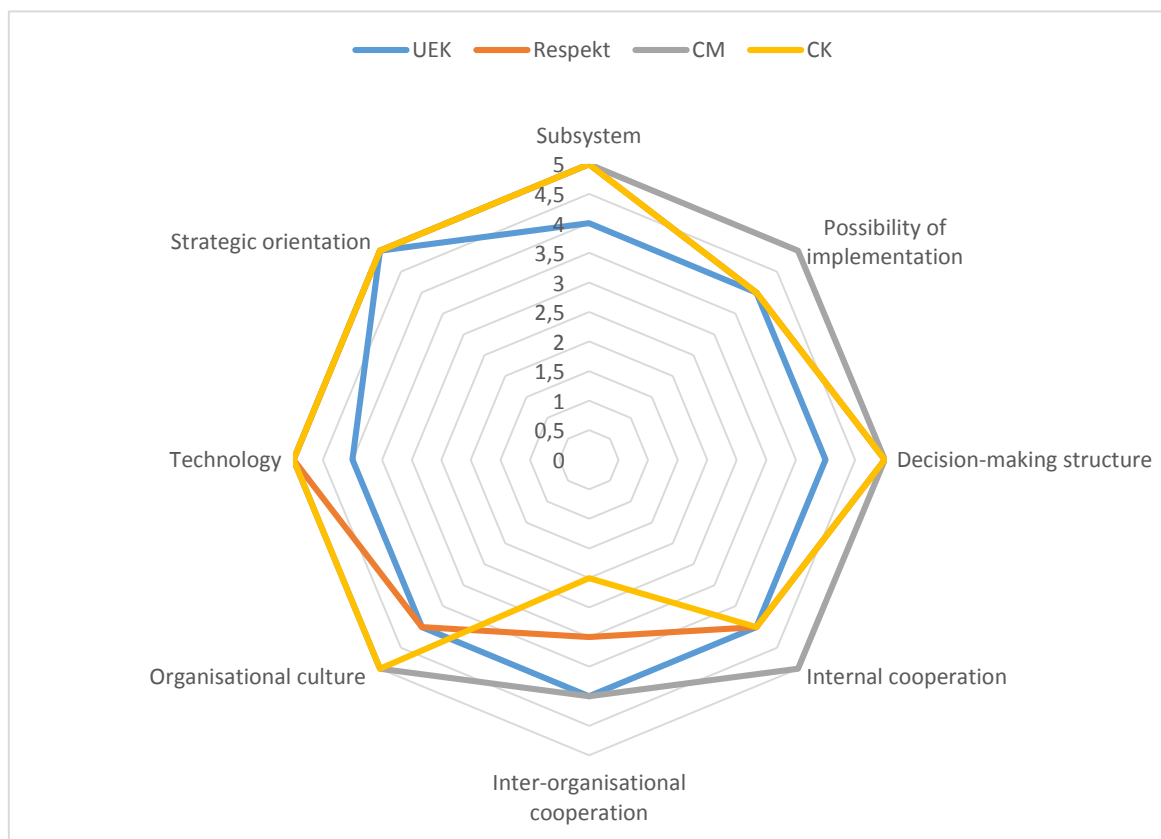


Figure 2. Organisation spider web model of the analyzed organizations.

Source: original work based on research. Using the spider web model to identify elements codifying an organisation's genome to determine enterprise development potential in Figure 2, we conclude that Cukiernia Magdalenka has the clearest organisational genome determining its development. All the parameters, apart from inter-organisational cooperation, were rated 5 points. This means that the enterprise keeps up with changes in its environment, creates autonomous, independent units, has authority as its foundation, and improves internal cooperation. The alignment of the parameters supports the continuous development of the confectionery even though it operates in a local market and is a small enterprise. The owners can stimulate inter-organisational cooperation to reinforce their genome.

The elements identified for other organisations codify their organisational genomes and determine their development potential. The respondents from Cyfrowa Królowa gave the possibility of implementation and internal cooperation four points. Therefore, their development potential may be determined by enhancing these areas. The owners should work on inter-organisational cooperation, which received two points.

Subsystems, the structure of decision-making, technology, and strategic orientation of LKS Respekt were given five points, which shows that these parameters are distinguishing features of the individual DNA of the club. Club managers should appreciate the development potential of the possibility of implementation, which can be a foundation of the team's strength if combined with individual player skill sets. Other noteworthy parameters are cooperation and organisational culture, each with four points. Just like in the case of Cyfrowa Królowa, inter-organisational cooperation currently does not contribute to the development potential of the club. An interview with club officials revealed that the domain is, indeed, neglected as conditions for external cooperation, for example, with other clubs, are challenging. Regrettably, football circles in Lesser Poland are peculiar, and any cooperation during sports or other events results in other clubs poaching exceptional players who are critical for LKS Respekt.

The last analysed organisation was the University of Economics in Kraków. The identified elements can be considered to codify its organisational genome. All the parameters were given four points except for strategic orientation, which had five points. This shows the development potential of the university. It is a large organisation, which makes management more complex than in a sports club, confectionery, or mathematics tuition provider.

All investigated organizations have their specific genomes, sets of information that characterize and guide their development. The aim was achieved in the work: elaboration and discussion of the spider web model and identification of elements that encode an organization's genome to determine its development potential and design changes. The reports confirmed that every company has a personality. Just as you can understand an individual's personality, you can also understand a company's type—what makes it tick, what's good and bad about it. (Gouillart, Kelly, 1996; Neilson, Pasternack, 2005; Harrison, Frakes, 2005)

The following specific objectives were achieved in the work:

- The genome of organizational DNA was defined.
- The parameters of the spider web model were identified.
- The relationship between the parameters of the spider web model and the identification of the organization's genome was discussed.
- Knowledge of the use of the parameters of the spider web model in recognizing the company's development potential was expanded (a diagnostic questionnaire was developed).

The following theses were also verified:

- Parameters in the spider web model codify the organization's genome.
- Identifying components that codify the organization's genome is necessary to determine its development potential.
- A diagnosis and assessment of spider web model parameters for an organization determine the codification of its genome.

The article has achieved its research objective. We discussed the spider web model in detail and identified elements that codify organisations' genomes, which helps determine their developmental potential. We defined the organisational DNA and discussed relationships between spider web model elements and possibilities of identifying the organisational genome. The case studies demonstrated that diagnosing and assessing the spider web model parameters (that codify an organisation's genome) is necessary to determine the organisation's development potential and find potential change opportunities.

The research was limited by a small sample of arbitrarily selected organisations. Still, the selection of organisations for the case studies was purposeful. We demonstrated that the spider web model can diagnose and assess parameters that codify an organisation's DNA in all types of organisations, enterprises, NGOs, and public institutions. It may also help identify areas in need of change to maintain the development potential. In light of the above, future research should include a more in-depth study of selected sectors to conduct a comparative analysis and offer generalised conclusions.

## References

1. Barney, J. (1986). Organizational culture: Can it be a source of sustained competitive advantage? *Academy of Management Review*, 11(3), 656-665, <https://doi.org/10.2307/258317>
2. Bochenek, M. (2017). Znaczenie współpracy międzyorganizacyjnej w sektorze publicznym. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, Nr 341, 21-34.

3. Buschgens, T., Bausch, A., Balkin, D.B. (2013). Organizational Culture and Innovation: A Meta-Analytic Review. *Journal of Product Innovation Management*, 30, 763-78. <https://doi.org/10.1111/jpim.12021>
4. Ejdys, J., Kobylińska, U., Lulewicz-Sas, A. (2012). *Zintegrowane systemy zarządzania jakością, środowiskiem i bezpieczeństwem pracy*. Białystok: Oficyna Wydawnicza Politechniki Białostockiej.
5. Fralinger, B., Olson, V. (2007). Organizational culture at the university level: A study using the OCAI instrument. *Journal of College Teaching & Learning (TLC)*, 4(11), 85-97. <https://doi.org/10.19030/tlc.v4i11.1528>
6. Gorzelany, J., Gorzelany-Dziadkowiec, M., Luty, L., Firlej, K., Gaisch, M., Dudziak, O., et al. (2021). Finding links between organisation's culture and innovation. The impact of organisational culture on university innovativeness. *PLoS ONE* 16(10), e57962. <https://doi.org/10.1371/journal.pone.0257962>
7. Gouillart, F.J., Kelly, J.N. (1996). *Transforming the Organization*. McGraw-Hill.
8. Guevara, A.J.H., Terra D.M., Portes, J.H., Silva, J.D.A., Magalhães, K.E. (2020). A ranking of countries concerning progress towards a Society 5.0. *Risus. Journal on Innovation and Sustainability*, vol. 11, 4, <https://doi.org/10.23925/2179-3565.2020v11i4p188-199>
9. Habuda, L. (2017). Centralizacja vs decentralizacja w hierarchicznej, spiętrzonej strukturze państwowej administracji. *Chorzowskie Studia Polityczne*, nr 13, 177-195.
10. Harmon, P. (2018). *The State of Business Process Management*. <http://www.bp-trends.com>, 2019.10.1.
11. Harrison, T.L., Frakes, M.H. (2005). *Instinct: Tapping Your Entrepreneurial DNA to Achieve Your Business Goals Hardcover*. Grand Central Pub.
12. Hofstede, G. (1998). Attitudes, Values and Organizational Culture: Disentangling the Concepts. *Organization Studies*, 19, 477-492.
13. Hogan, S.J., Coote, L.V. (2014). Organisational culture, innovation, and performance: a test of Schein's model. *Journal of Business Research*, 67, 1609-1621. <https://psycnet.apa.org/doi/10.1016/j.jbusres.2013.09.007>
14. Kirby, D.A., Ibrahim, N. (2011). Entrepreneurship education and the creation of an enterprise culture: provisional results from an experiment in Egypt. *International Entrepreneurship and Management Journal*, 7, 181-193. <http://dx.doi.org/10.1007/s11365-010-0153-0>
15. Kożuch, B., Sienkiewicz-Małyjurek, K. (2013). Mierzenie skuteczności współpracy międzyorganizacyjnej w zarządzaniu bezpieczeństwem publicznym. *Studia Ekonomiczne. Zeszyty Naukowe Wydziałowe Uniwersytetu Ekonomicznego w Katowicach*, nr 168, 82-95.
16. Kruger, W., Buchholz, W., Bach, N. (2000). Organizing for the future – Conceptual Framework and Empirical Evidence. *Arbeitspapier*, 2, 72-86.

17. Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, 140, 5-55.
18. Machaczka, K. (2011). Rozwój organizacji opartych na wiedzy w aspekcie zmian systemów zarządzania. *Ekonomiczne Problemy Usług*, 68, 387-395.
19. Mohd, J., Abid, H. (2020). Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing. *Journal of Industrial Integration and Management*, Vol. 5, 3, 327-348. <https://doi.org/10.1142/S2424862220500141>
20. Neilson, G.L., Pasternack, B.A. (2005). *Results: Keep What's Good, Fix What's Wrong, and Unlock Great Performance Hardcover*. Crown Business.
21. Pettigrew, A.M. (1979). On studying organizational cultures. *Administrative Science Quarterly*, 24, 570-581.
22. Pfeifer, M.R. (2021). Development of a Smart Manufacturing Execution System Architecture for SMEs: A Czech Case Study. *Sustainability*, 13, 10181. <https://doi.org/10.3390/su131810181>
23. Quinn, R.E., Rohrbaugh, J. (1983). A spatial model of effectiveness criteria: Towards a competing values approach to organizational analysis. *Management Science*, 29(3), 363-377. <https://doi.org/10.1287/mnsc.29.3.363>
24. Salgues, B. (2018). *Society 5.0: Industry of the Future*. Technologies, Methods and Tools [M]. ISTE ltd. and John Wiley & Sons, Inc.
25. Sánchez-Cañizares, S.M., Munoz, M.A.A., López-Guzmán, T. (2007). Organizational culture and intellectual capital: a new model. *Journal of intellectual capital*, 8(3), 409-430. <http://dx.doi.org/10.1108/14691930710774849>
26. Slater, S.F., Olson, E.M. (2011). Finnegan C. Business strategy, marketing organization culture, and performance. *Marketing Letters*, 22(3), 227-242. <http://www.jstor.org/stable/41488535>
27. Storey, C., Kahn, K.B. (2010). The role of knowledge management strategies and task knowledge in stimulating service innovation. *Journal of Service Research*, 13(4), 397-410. <https://doi.org/10.1177/1094670510370988>
28. Zakrzewska-Bielawska, A. (2010). *Technologia, innowacje i wiedza a strategia przedsiębiorstw high tech*. In: A. Kaleta, K. Moszkowicz (eds.), *Zarządzanie strategiczne w praktyce i teorii*. *Prace Naukowe UE we Wrocławiu, nr 116*. Wrocław: Wydawnictwo UE we Wrocławiu.





## DETERMINANTS INFLUENCING THE IMAGE OF BANKS IN THE POLISH BANKING SYSTEM AMONG GENERATION Z MEMBERS

Marta GRZYB

Jan Dlugosz University, Faculty of Law and Economics; m.grzyb@ujd.edu.pl, ORCID: 0000-0002-2537-2084

**Purpose:** The purpose of this paper is to identify the factors that influence the image of banks in the Polish banking sector among members of Generation Z (Gen Zers) and assess the strength of their impact.

**Design/methodology/approach:** The methods used to achieve this purpose included a literature review and a diagnostic survey with an original questionnaire. The study employed PAPI and CAWI techniques and targeted Gen Zers with accounts at commercial and/or cooperative banks in Poland.

**Findings:** The study identified the determinants influencing the image of banks and assessed their impact on how Gen Zers perceive banks in Poland. The findings indicate that the factors with the greatest impact on the image of banks in the Polish banking sector are security, convenience and accessibility, and technologies and innovations.

**Research limitations/implications:** Since the research part of the paper is based on a survey study, the findings are somewhat superficial. A significant limitation preventing these findings from being generalized globally is the scope of the study, which was conducted solely among customers of the Polish banking sector. Therefore, it would be beneficial to expand the research by conducting a qualitative study, and by including it customers of banks from other countries.

**Practical implications:** By understanding the impact of the determinants influencing the perception of banks in the Polish banking sector among Gen Zers, those responsible for managing the bank's image will be better equipped to understand the needs and expectations of the youngest generation of banking service users. This, in turn, should lead to more effective management of the bank's image among a generation that currently makes up almost one-fourth of the Polish population.

**Originality/value:** The paper is primarily aimed at individuals in managerial positions in commercial and cooperative banks within the Polish banking sector, as well as bank image specialists. The ranking of the determinants influencing the image of banks among Gen Zers, presented in the paper, partially fills the research gap by revealing the real needs and expectations of the youngest generation of bank customers.

**Keywords:** bank image determinants, Generation Z, bank image.

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

## 1. Introduction

Present-day banks operate in a highly turbulent environment. In addition to fulfilling their inherent tasks and objectives, they constantly face numerous challenges. How they cope with these challenges impacts not only a range of their economic indicators but also their perception among individuals, i.e., their image. This image represents significant value for banks, contributing to their security, building, and maintaining public trust, and providing various other benefits. Therefore, it is imperative that banks undertake managerial activities aimed at building a strong and positive image of the banking sector among the public.

Skillful management of a bank's image requires an understanding of how this construct is shaped among the different stakeholders of the organization. This step can be seen as the prelude to the entire managerial process. In this context, it is important to know the factors that impact a bank's image among individuals. While the literature on the subject offers many publications on image, only a small proportion are concerned with the issue of bank image. Of the titles that address this subject, only a tiny percentage focus on exploring the issues connected with bank image management and the determinants influencing this construct. According to the author, this represents a significant research gap in the field.

Taking the above into account, this paper focuses on examining the determinants influencing the formation of banks' images among Gen Z bank customers from both theoretical and empirical perspectives. This is the youngest generation with full access to bank products and services, typically defined as individuals born between 1995 and 2009. The importance of this group to banks is underscored by the fact that it constitutes around one-fourth of the world's population. However, banking institutions still do not fully understand the preferences or needs of Gen Z customers, making it more difficult for them to serve this demographic group (Wenalyze, 2023) and communicate effectively. This lack of understanding simultaneously disrupts image management among this significant group of bank stakeholders.

The focus of this paper is to at least partially close the research gap recognized in the literature. Its aim is to identify and assess the impact of the factors influencing the image of banks in the Polish banking sector among Gen Zers. The achievement of this goal is a valuable source of information for individuals in managerial positions within the Polish banking sector, bank image specialists, as well as theoreticians exploring issues in this area. So far, no similar research has been carried out in Polish doctrine.

## 2. Literature review

Banks operate within an oligopolistic structure (Altermatt, Wang, 2024; Dong et al., 2021). Due to the significant similarity among the products and services offered by entities in the banking sectors of different countries, these institutions find it extremely challenging to differentiate themselves from competitors in the market. Consequently, they are compelled to explore alternative methods to achieve this objective. One such strategy is cultivating a strong and positive image, which is considered essential (Malara, Sobol-Wojciechowska, 2011) and consistently emphasized value for banks (Grzybowska-Brzezińska, Rudzewicz, 2016).

How should one understand the concept of bank image and why is such importance attributed to it in the context of banking operations? The literature on this subject offers numerous definitions of this concept. Depending on the research context, authors highlight various aspects of the construct. Thus, a bank image can be defined, among other things, as "a set of customers' interactions, beliefs, ideas, feelings, and impressions by which the bank is known and through which customers describe, remember, and refer to it" (Verma, Kaur, 2023, p. 110); "the way that a customer perceives the products and services offered by a bank" (Nur et al., 2023, p. 7); or "the perception of a bank by an individual resulting from direct interaction with the assessed bank, enabling the bank to gain broadly understood benefits" (Grzyb, 2022, p. 42). The primary and essential role of a bank's image is widely recognized as providing security and building and maintaining public trust (Gray, 1986). Researchers also point out various other benefits associated with a bank's image. Most commonly, it is emphasized that a bank's image (Grzyb, 2022; Omoregie et al., 2019; Kaakeh et al., 2019; Akhgari et al., 2018; Saleh et al., 2017; Akbari et al., 2017; Świeszczak, 2016; Marinkovic, Obradovic, 2015; Perek, Pawlonka, 2014; Glabiszewski, 2013; Khvtisiashvili, 2012; Stolarska, 2011; Prokopowicz, 2011; Szlis, 2010; Strycharczyk, 2009; Bravo et al., 2009; Flavián et al., 2005; Nikodemska-Wołowik, 2004; van Heerden, 1999; Nguyen, LeBlanc, 1998):

- Is the essential source of competitive advantage.
- Allows banks to distinguish themselves in the market.
- Contributes to banks' increased credibility.
- Impacts customers' attitudes, loyalty, and approach to banks.
- Constitutes a significant criterion for choosing a bank.
- Implies the degree of a bank's recognizability.
- Reflects a bank's market position.
- Helps a bank to attract and retain customers as well as highly qualified staff.
- Determines the quality of a bank's relationships with its stakeholders.
- Helps a bank to fulfill its goals and reach the desired level of numerous economic indicators.
- Is a key success factor for a bank.

The benefits listed above, which a bank's image helps achieve, underscore the significant importance of this construct in today's banking operations. Therefore, it is crucial for banks to take steps to build a strong and positive public image. In this context, understanding the factors that influence customers' perception of banks is of fundamental importance (Table 1).

**Table 1.**

*Factors influencing the formation of the image of banks*

<b>Category of the factors influencing the formation of the image of banks</b>	<b>Category description</b>
Bank identity	It includes, among other things, visual identification elements, the bank's behaviors, its personality, experience, espoused values, size, decor, aesthetics, appearance, policies, philosophy, and organizational functioning.
Products and services	This category includes, among other things, quality, costs, level of complexity, reliability, and functionality of products and/or services.
Staff	This category encompasses various aspects related to a bank's staff, including their experience, knowledge, competences, attitude towards customers, engagement, ethical conduct, openness, customer-orientation, dress code, and appearance.
Communication	It includes, among other things, marketing and promotional materials, social media activity, the bank's relationships with others, advertisements, and online presence.
Social engagement	It involves, among other things, environmentally-friendly actions, promotion of culture, sponsoring, charitable, educational and philanthropic activities, patronage.
Security	This category includes, among other things, a sense of privacy and confidentiality, customer protection systems, data security, ATM security, branch security, and electronic banking security.
Bank reputation	It refers to, among other things, bank leadership and management style, the bank's market position, overall local reputation, and trust in the bank's honesty and good intentions.
Technologies and innovations	This category includes, among other things, the bank's level of innovation, access to ATMs and cash deposit machines, ease of use of innovative solutions, product innovations, and openness to change.
Transparency	It refers to, among other things, the way financial reporting is conducted, the bank's competitive position, its capital structure, economic results, and operational transparency.
Convenience and accessibility	This category involves aspects connected with banks' accessibility to customers and related convenience. It includes, among other things, the number of bank branches, their opening hours, density of ATM networks, bank locations, access to a mobile application, waiting times, and speed of service.
Emotional factors	This category includes, among other things, trust in a bank, stakeholders' personal beliefs, their attitudes, satisfaction, contentment, feelings, loyalty, and bond with the bank.
Individual characteristics of the person assessing the bank	This category consists, among other things, of factors such as sex, age, education, social status, religion, health condition, or the personality of the person assessing the bank.
Other factors	This category includes any factors that do not fit into the groups described above.

Source: Grzyb, 2023.

For bank managers to successfully undertake activities aimed at building a strong and positive bank image among stakeholders, it is essential to understand the factors influencing this construct. The categories of these determinants, as indicated in Table 1, should not be considered exhaustive but rather a condensed presentation of factors impacting the image of

banks identified in national and international literature on the subject (Grzyb, 2023). As noted earlier, the image itself has a significant impact on the operations of banks.

It should be noted that modern banks have diverse groups of stakeholders (Marcinkowska, 2012), which include entities affected or potentially affected by the organization, as well as those that exert or may exert an impact on its functioning (Marcinkowska, 2013; Kościelniak, 2010). Undoubtedly, banks' customers constitute one of their most important interest groups, categorized by various criteria, including the generation to which they belong. The generations currently active as bank customers in 2024 and fully capable of managing their bank accounts are (Ławińska, Korombel, 2023b):

- The Silent Generation (individuals born between 1922 and 1944, known as the architects of modern Europe).
- Baby Boomers (individuals born between 1945 and 1964, representing the generation of demographic and economic boom).
- Generation X (individuals born between 1965 and 1980, who grew up during the economic crises of the 1970s).
- Generation Y (Millennials; individuals born between 1981 and 1994, raised in the era of globalization and widespread access to the Internet).
- Generation Z (individuals born between 1995 and 2009, the youngest generation with full access to banking products and services).

Each of these generations has unique characteristics that distinguish it from others and reflect socio-economic changes. Given the focus of this paper, it is particularly important to highlight the main attributes of Generation Z, which currently constitutes approximately 25% of the global population (Patel, Morrison, 2019) and around 23% of Poland's population (Ławińska, Korombel, 2023b).

One of the fundamental characteristics of Gen Zers is their high digital and technological orientation, which manifests as a core part of their identity (Ławińska, Korombel, 2023a) and enables them to perceive themselves as tech-savvy and highly self-sufficient (EY & JA Worldwide, 2021). Individuals born between 1995 and 2009 view education not merely as a stage in life but as an ongoing process (Korombel, Ławińska, 2023), fostering not only financial awareness among Gen Zers (Ławińska, Korombel, 2023b) but also their creativity, curiosity, and agility (Oxford Economics, 2021). Gen Zers place significant emphasis on self-development and independence (Cpl, 2022), demonstrating a strong desire for continuous learning according to the principle of "just in time" (Wiktorowicz et al., 2016). Moreover, their orientation is global, and they typically embrace innovations, often shaping them, feeling at ease in the digital world. They place great importance on the visual presentation of information and value the social aspect of human relationships. Simultaneously, due to their young age, they have limited or no work experience (Korombel, Ławińska, 2023; Ławińska, Korombel, 2023a, Ławińska, Korombel, 2023b). However, from the perspective of this paper,

the crucial issue is to determine which factors, and to what extent, influence Gen Zers' perceptions of banks. This question will be addressed in the next section of the paper.

### 3. Methods

Despite being research-oriented, this paper's structure can be divided into two parts: theoretical and empirical. The theoretical part employs a literature review method and draws from numerous Polish and foreign publications on the subject of bank image and its influencing factors. It also characterizes Generation Z, a significant group of bank stakeholders constituting around 25% of the global population and 23% of the Polish population. The literature review revealed that no studies had been conducted to investigate the determinants influencing the image of banks from the Polish banking sector among Gen Zers. The author considers this a research gap.

To begin closing this gap, the author formulated her research purpose as identifying and assessing the factors influencing the image of banks in the Polish banking sector among Gen Zers. The determinants were identified through a literature review, while their actual impact on the formation of banks' image among Gen Zers was determined through empirical research. In this stage of the study, a quantitative research method in the form of a diagnostic survey was employed (Apanowicz, 2000). The research tool was an original survey questionnaire aimed at Gen Zer customers of Polish commercial or cooperative banks. This study was conducted from February to May 2023 using both PAPI (Paper and Pencil Interview) and CAWI (Computer-Assisted Web Interview) techniques.

The data collected through the survey study were analyzed using Microsoft Excel spreadsheets and Statistica software. To analyze responses to the survey questionnaire, basic descriptive statistics were employed. Frequency measures were used to describe qualitative variables: N for the size of the research group, n for subgroup size, and percentages (%) of the research group. Quantitative variables were described using basic descriptive statistics: M for mean, Med. for median, SD for standard deviation, Q1 for the first quartile, Q3 for the third quartile, Min. for minimum value, and Max. for maximum value. Following processing and analysis, the primary data were compared with secondary data from national and international reports and publications. This allowed the obtained results to gain deeper insights and be interpreted in the context of global attitudes and international realities concerning the youngest generation using banking services. This approach provided a more comprehensive understanding of how specific determinants impact the perception of Polish banks among Gen Zers.

## 4. Results and discussion

A total of 675 Gen Zers participated in the study, with 298 correctly filled forms collected using the PAPI technique and 377 using the CAWI technique. The participants were diverse. As shown in the Table 2, the group consisted of 53.78% of females and 46.22% of males. It is noteworthy that the percentage of females closely mirrors their share in the overall population of Poland. According to Statistics Poland, this share was nearly 52% at the end of 2022 (Główny Urząd Statystyczny, 2023).

**Table 2.**

*Structure of the respondents by the examined characteristics*

Analyzed characteristic		Number of responses N = 675	Percentage of respondents
Sex	females	363	53.78%
	males	312	46.22%
Education	below high school	5	0.74%
	high school	395	58.52%
	higher education	275	40.74%
Place of residence	village	230	34.07%
	small town (less than 20,000 residents)	58	8.59%
	medium-sized city (between 20,000 and 100,000 residents)	111	16.44%
	large city (over 100,000 residents)	276	40.89%
Average monthly gross salary	up to PLN 2500	212	31.41%
	between PLN 2501 and 5000	206	30.52%
	between PLN 5001 and 7500	82	12.15%
	between PLN 7501 and 10,000	23	3.41%
	over PLN 10,000	9	1.33%
	refusal to answer	143	21.19%
Bank type*	commercial bank	607	89.93%
	cooperative bank	44	6.52%
	commercial and cooperative bank	24	3.56%

\* Type of bank used by the respondent.

Source: own elaboration.

Among the respondents, city dwellers predominated, comprising almost 66% of the sample, with residents of large cities constituting under 41% of the respondents. This corresponds with data published by Statistics Poland (Główny Urząd Statystyczny, 2023). The dominant presence of city dwellers, particularly from large cities, among the research participants is linked to the greater opportunities available in such areas, including more job opportunities, better pay conditions, and access to academic institutions, which are especially important for Generation Z.

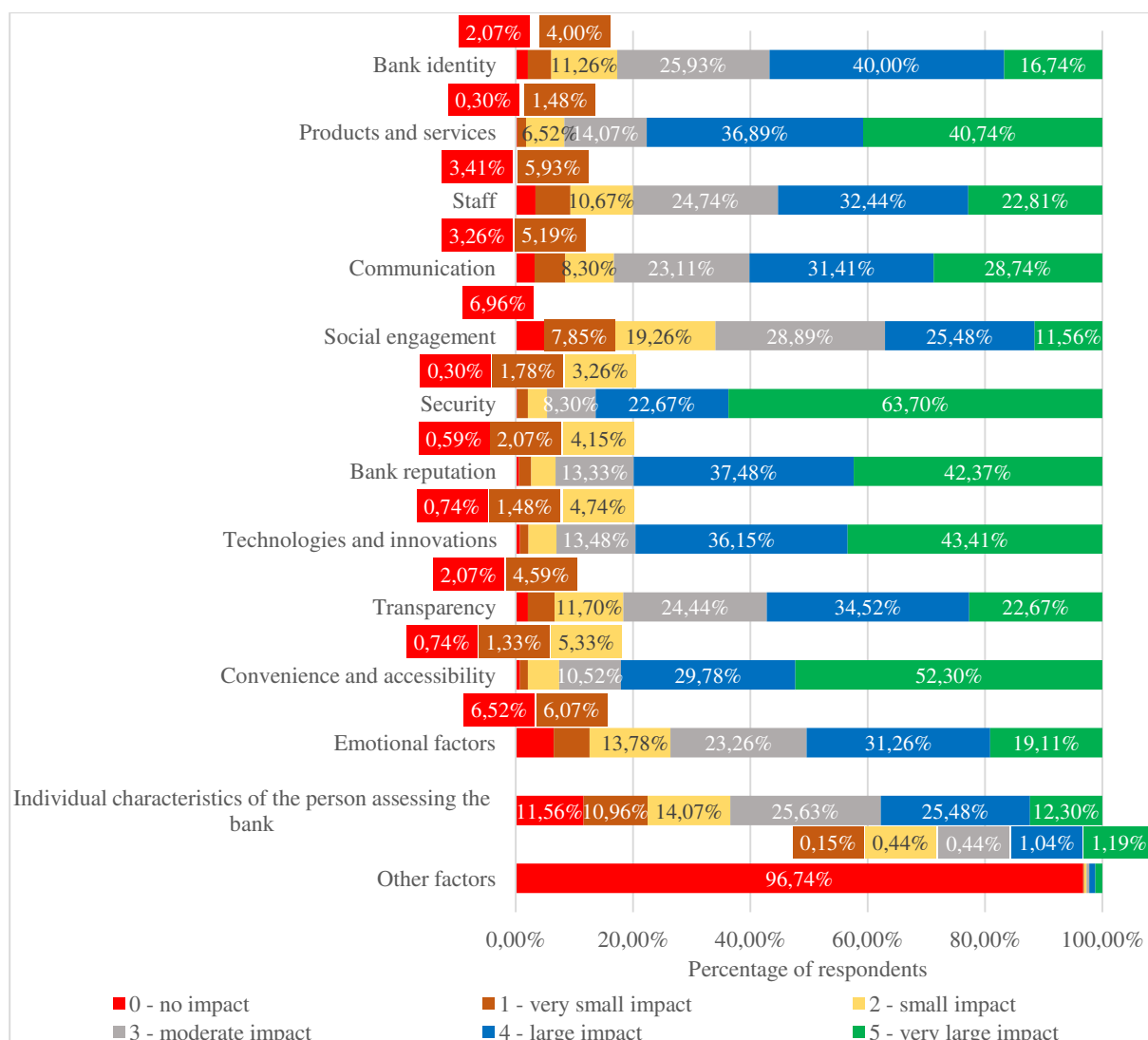
Given the young age of the respondents and their limited work experience, it is unsurprising that the salary of the overwhelming majority of Gen Zers (almost 62%) does not exceed the threshold of PLN 5,000. Only 1.33% of the respondents earn a monthly salary of over PLN 10,000. It should also be noted that over 21% of the respondents chose not to respond to the question about their salary.

Gen Zers exhibit traits such as a strong drive for self-development, a constant pursuit of knowledge, and a view of learning as a lifelong process, as reflected in the educational backgrounds of the respondents. Among the 675 respondents, only 5 individuals had education below the high school level. Over 99% of the respondents reported having at least a high school education, with almost 41% of those surveyed having completed higher education.

Since the survey questionnaire was distributed among Gen Zers with bank accounts in Poland, it was relevant to inquire about the type of bank they use. As shown in Table 2, almost 90% of the respondents have accounts exclusively with commercial banks. It is noteworthy that these institutions operate on a much larger scale (nationwide or even globally) and possess significantly greater financial resources compared to cooperative banks, which primarily serve local markets with a different operational profile. Gen Zers' strong orientation towards globalization and their willingness to move to larger cities resulted in only 6.52% of respondents having accounts exclusively with local cooperative banks. Slightly over 3.5% reported having accounts with both types of banks (i.e., cooperative and commercial).

In the context of the research, it was crucial to determine whether the factors outlined in the theoretical part of the paper (Table 1) indeed influence the perception of banks among Gen Zers in Poland, and to assess the strength of this influence. Therefore, participants were asked to rate on a scale of 0 to 5 the impact of these factors on their perception of the banks they use. The scale values were interpreted as follows: "0" – no impact, "1" – very small impact, "2" – small impact, "3" – moderate impact, "4" – large impact, and "5" – very large impact. The survey questionnaire included the following categories: bank identity, products and services, staff, communication, social engagement, security, bank reputation, technology and innovations, transparency, convenience and accessibility, emotional factors, and individual characteristics of the person assessing the bank. Each category was described succinctly to facilitate understanding and differentiation. Respondents were also given the opportunity to suggest additional factors they consider when assessing a bank, which did not fit into any of the listed categories. These responses were analyzed both qualitatively and quantitatively. For each category of factors, the mean score assigned by participants was calculated, along with standard deviation, median, first and third quartiles, and minimum and maximum values (Table 3).





**Figure 1.** Distribution of responses to the question regarding the impact of factors influencing the perception of Polish banks by Gen Zer customers.

Source: own elaboration.

The information presented in Figure 1 clearly indicates that the twelve categories outlined in the theoretical part of the paper (namely: bank identity, products and services, staff, communication, social engagement, security, bank reputation, technologies and innovations, transparency, convenience and accessibility, emotional factors, and individual characteristics of the person assessing the bank) impact the perception of banks among the overwhelming majority of Gen Zers. While the strength of this impact varies, it typically ranges between large and very large. It is also noteworthy that nearly 97% of the respondents indicated that other factors not fitting into these categories did not influence their perception of the banks they use. However, some participants in the study provided their own suggestions regarding factors that influence this process. The factors proposed by the respondents were as follows:

- a) Factors with a large impact (value “4”):
  - Recommendations from others, opinions (1 response).
  - Bank's participation in the deposit guarantee scheme (1 response).

- Notifications in the system: information about maintenance breaks, education about security and scams, messages about upcoming changes in the rules, "not spamming the e-mail box" (1 response).

b) Factors with a very large impact (value "5"):

- Family's opinions (2 responses).
- Offering for businesses, fee for conducting the account (1 response).

The full distribution of responses to the question regarding the impact of specific categories of factors on the perception of banks among Gen Zers is presented in Figure 1. Basic descriptive statistics were also computed for each factor category. Table 3 presents aggregate data, revealing that individual characteristics of the person assessing the bank exhibited the highest variability in respondents' responses. On average, responses for this factor deviated from the arithmetic mean by 1.53 points. Among the twelve defined categories, security showed the least variability, with a standard deviation of 0.94,<sup>1</sup> indicating high consistency in responses across all Gen Zers in the study. For each category, the median ranged from 2 to 4, and the third quartile<sup>2</sup> was either 4 or 5. Only for the other factors did these statistics equal 0. Regarding minimal and maximal values, each category ranged from 0 to 5.

**Table 3.**

*Basic descriptive statistics for the individual factors influencing the perception of banks in Poland by Gen Zer customers*

Factor category	N	M	SD	Med.	Q1	Q3	Min.	Max.
Bank identity	675	3.48	1.14	4.00	3.00	4.00	0.00	5.00
Products and services	675	4.08	0.99	4.00	4.00	5.00	0.00	5.00
Staff	675	3.45	1.30	4.00	3.00	4.00	0.00	5.00
Communication	675	3.60	1.30	4.00	3.00	5.00	0.00	5.00
Social engagement	675	2.93	1.36	3.00	2.00	4.00	0.00	5.00
Security	675	4.42	0.94	5.00	4.00	5.00	0.00	5.00
Bank reputation	675	4.12	1.00	4.00	4.00	5.00	0.00	5.00
Technologies and innovations	675	4.13	1.00	4.00	4.00	5.00	0.00	5.00
Transparency	675	3.53	1.21	4.00	3.00	4.00	0.00	5.00
Convenience and accessibility	675	4.24	1.01	5.00	4.00	5.00	0.00	5.00
Emotional factors	675	3.24	1.41	4.00	2.00	4.00	0.00	5.00
Individual characteristics of the person assessing the bank	675	2.79	1.53	3.00	2.00	4.00	0.00	5.00
Other factors not fitting into the categories above	675	0.12	0.71	0.00	0.00	0.00	0.00	5.00

N – number of observations, M – arithmetic mean, SD – standard deviation, Med. – median, Q1 – first quartile, Q3 – third quartile, Min. – minimum, Max. – maximum.

Source: own elaboration.

<sup>1</sup>Smaller standard deviation was only recorded for other factors not fitting into the twelve 'named categories'.

<sup>2</sup>Median (Med.) indicates that 50% of the respondents provided responses with values not exceeding Med., with the other half of the group providing responses with values not less than Med.

The first quartile (Q1) informs that one-fourth of respondents provided responses with values not exceeding Q1, with the remaining 75% indicating answers with values not less than Q1.

The third quartile (Q3) informs that 75% of the respondents participating in the study provided responses with values not exceeding Q3, with 25% indicating responses with values not less than Q3 (Zob. Ręklawski, 2020).

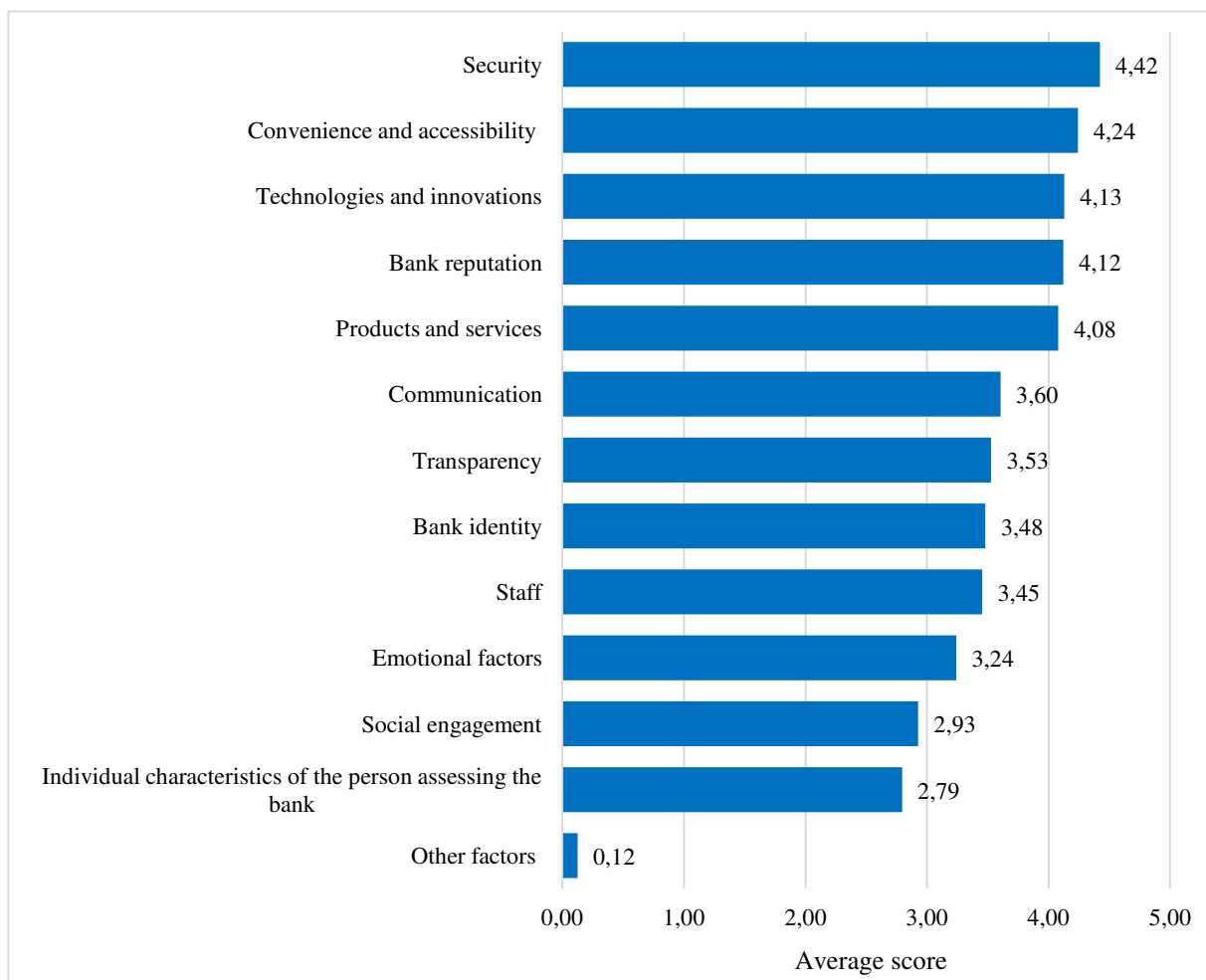
Based on the research, among the analyzed factors, security has the greatest impact on the perception of banks by Gen Z customers, as evidenced by its average score of 4.42. This result suggests that despite ongoing societal changes and shifting values, security remains one of the most highly valued attributes in the modern world. This finding aligns with conclusions from other widely available reports, which indicate that Gen Zers prioritize security highly and perceive their current economic security negatively, contributing to their overall mental stress—a characteristic often associated with this generation (Błaszczak, 2024). Ensuring data security is viewed as a paramount consideration for GenZers when selecting and evaluating banks. For comparison, Millennials, Baby Boomers, and Generation X members prioritize straightforward and simple principles to avoid account and card usage fees (Minds & Roses, 2023).

Second place in terms of its impact on the image of banks among Gen Zers was occupied by the factor of convenience and accessibility, with an average score of 4.24. For some customers, this category equates to the availability of bank branches and their operating hours, while others prioritize continuous access to electronic banking. Particularly noteworthy are research findings (Wigley, Kantaria, 2023) indicating that 43% of Gen Zers, despite their affinity for the digital world and technology, still value brick-and-mortar banks for the "peace of mind" they provide. Therefore, the category of convenience and accessibility should be understood broadly, considering it as one of the fundamental factors influencing the perception of banks among Gen Zers (Wenalyze, 2023).

Having high digital and technological literacy, Gen Zers place great importance on technologies and innovations when evaluating banks. This is evidenced by the fact that this factor achieved an average score of 4.13, ranking third among all the examined categories. The significance of this category is also emphasized by international experts who highlight the digital nature of interactions between Zoomers and financial institutions. They underscore that Generation Z views technologies as tools that facilitate problem-solving (Fagan, 2024; Mondres, 2019). However, they also note that meeting the requirements and expectations of Generation Z necessitates continuous improvement of existing technologies and the implementation of new and more advanced innovations. This aspect is crucial in shaping the bank's image not only among Generation Z but also among future generations (Karmakar, 2021).

As depicted in Figure 2, in addition to security, convenience and accessibility, and technologies and innovations, other determinants with a significant impact on the image of banks in Poland among Gen Z customers include bank reputation, products and services, communication, and transparency. According to the research findings, these factors ranked fourth, fifth, sixth, and seventh respectively. This underscores the importance of bank reputation and public perception among the young generation as they navigate their initial interactions with banks. Products and services themselves are slightly less crucial but must be highly personalized, with Generation Z placing a strong emphasis on mobile accessibility for

using these offerings (Webster, 2024). The interconnectedness of products and services with technologies and innovations is intrinsic, given Generation Z's upbringing in a fully digitalized world. This demographic's reliance on technology also extends to communication with banks, with nearly 48.5% preferring mobile applications for interactions, as reported by PYMNTS Intelligence & i2c (2024). Other less favored communication methods include email (28% of responses), in-person visits to bank branches (nearly 13% of responses), and traditional mail (slightly over 10% of responses). Transparency, which encompasses operational transparency and information policy, holds a slightly lower average score of 3.53 but still exerts a significant influence on GenZers' perceptions of banks. Therefore, maintaining continuous access to information, coupled with honesty and transparency in operations, remains critical for these individuals when evaluating financial institutions (Minds & Roses, 2023; Hackiewicz, 2024).



**Figure 2.** Average strength of impact of the different factors influencing the perception of banks in Poland by Gen Z customers.

Source: own elaboration.

The findings from the research indicate that the remaining "named categories of factors" (specifically, bank identity, staff, emotional factors, social engagement, and the individual characteristics of the person assessing the bank) have a moderate impact on the perception of banks in Poland among Gen Zer customers, ranking from 8th to 12th place. Given Gen Zers'

strong emphasis on visual communication (Korombel, Ławińska, 2023), a key component of bank identity, which includes the bank's personality and presentation, it is surprising that bank identity ranks relatively low in the compiled ranking (eighth position, average score of 3.48). Similarly, despite 43% of Gen Zers preferring in-person bank visits and nearly 60% valuing remote advisory services (Oliver Wyman and The News Movement), it is unexpected that bank staff have only a moderate impact on the image of banks among Zoomers (average score of 3.45). However, this finding aligns with Gen Zers' preference for technology and innovation over direct interpersonal interactions, including with bank staff. Factors with emotional dimensions, such as trust in the bank, personal beliefs, and loyalty, as well as the bank's social engagement activities (e.g., environmental initiatives, charitable efforts, cultural promotion), and individual characteristics of the person assessing the bank (such as age, education, work experience, residence, social status, and principles of faith), are even less significant in shaping the perception of banks among the youngest generation of banking service users. This does not imply that these categories are irrelevant to the perception of banks among Gen Zers; rather, their impact on the bank's image is comparatively weaker than the previously mentioned categories. Therefore, these findings are influenced by both the individual characteristics and experiences of the research participants and the broader tendencies observed among Gen Zers involved in the study.

## 5. Conclusion

The operation of modern banks is influenced by a variety of factors, both internal and external. Some factors may be within the control of banks (either partially or fully), while others are not. Additionally, the functioning of banks is shaped by their stakeholders, with customers being one of the most vital groups impacting the viability of banks. The perception that customers hold of a particular bank—referred to as the bank's image—significantly affects not only the overall quality of the bank's operations but also plays a crucial role in enhancing security and fostering public trust. Consequently, it is essential for banking institutions to engage in managerial activities aimed at cultivating a robust and positive bank image within the public sphere.

In this context, the starting point is the identification of factors significant to different groups of stakeholders involved in the assessment of banks. If bank managers and other responsible individuals within banks are unaware of the preferences of these groups, how can they determine which actions to take and what tools to utilize to strengthen the bank's image and mold it in a favorable manner? Therefore, based on a literature review, the author distinguished twelve categories of factors influencing customers' perception of banks. These categories are: bank identity, products and services, staff, communication, social

engagement, security, bank reputation, technologies and innovations, transparency, convenience and accessibility, emotional factors, and individual characteristics of the person assessing the bank. Other factors that do not fit into these categories were grouped into a thirteenth category labeled "other factors not fitting into the other categories."

Bank customers encompass a diverse group of stakeholders, among whom Generation Z—the youngest generation using banking services—is gaining significance. This generation, born between 1995 and 2009, is characterized by a strong technological orientation, emphasis on self-development, financial awareness, and a global lifestyle. Despite being born into the digital age, the factor that most profoundly influences the perception of banks among Gen Zers is not "technology and innovations" (which ranked third with an average score of 4.13 on a scale of 0 to 5), but the enduring and universally appreciated value of security (average score of 4.42). Following closely are convenience and accessibility (average score of 4.24). In addition to these primary factors, other significant contributors to the image of banks in Poland among Gen Zers include bank reputation (average score of 4.12), products and services (average score of 4.08), communication (average score of 3.60), and transparency (average score of 3.53). Despite Gen Zers placing great importance on visual aspects, bank identity—encompassing visual identification elements—only moderately impacts their perception of banks, with an average score of 3.48. While many Gen Zers express a desire for personal contact with bank staff, this factor has a lesser impact on their overall perception of banks, with an average score of 3.45. Less significant in their assessment of banks are emotional factors (average score of 3.24), social engagement (average score of 2.93), individual characteristics of the person assessing the bank (average score of 2.79), and other factors not fitting into the listed categories (average score of 0.12).

The author acknowledges that her findings should not be regarded as definitive or exhaustive. To enhance their credibility and facilitate global generalization of the conclusions, future studies should expand both in terms of participant numbers and national diversity. Ideally, these studies should also incorporate qualitative research. Such a complementary approach would bolster the scientific and research value, particularly given the underexplored nature of the research area addressed in this paper. Nonetheless, the author believes that the research presented here has managed to partially address the existing research gap in the field and its findings will be applied by bank managers, thereby encouraging further investigation into this subject matter.

## References

1. Akbari, R., Dadras, A., Beheshti, S.J. (2017). Prioritizing the Factors Affecting the Image of Mel-lat Bank Customers on Their Satisfaction in The Process of Selecting Branch. *International Journal of Management Sciences and Business Research*, Vol. 6, No. 6, pp. 112-121, doi: 10.5281/zenodo.3472248
2. Akhgari, M., Bruning, E.R., Finlay, J., Bruning, N.S. (2018). Image, Performance, Attitudes, Trust, and Loyalty in Financial Services. *International Journal of Bank Marketing*, Vol. 36, No. 4, pp. 744-763, doi: 10.1108/ijbm-06-2017-0118
3. Altermatt, L., Wang, Z. (2024). Oligopoly banking, risky investment, and monetary policy. *European Economic Review*, Vol. 164, pp. 1-40, doi: 10.1016/j.eurocorev.2024.104704
4. Apanowicz, J. (2000). *Metodologiczne element procesu poznania naukowego w teorii organizacji i zarządzania*. Gdynia: Wyższa Szkoła Administracji i Biznesu.
5. Błaszczak, Z. (2024). *Pokolenie Z nie czuje się bezpiecznie. Nie chcą podejmować ryzyka*. Retrieved from: <https://www.rp.pl/rynek-pracy/art39711361-pokolenie-z-nie-czuje-sie-beezpiecznie-nie-chca-podejmowac-ryzyka>, 15.06.2024.
6. Bravo, R., Montaner, T., Pina, J.M. (2009). The Role of Bank Image for Customers versus Non-Customers. *International Journal of Bank Marketing*, Vol. 27, No. 4, pp. 315-334, doi: 10.1108/02652320910968377
7. Cpl (2022). *Zoomersi w pracy – czyli jak pokolenie Z podbija rynek pracy w Polsce*. Retrieved from: [https://www.cpl.com/rails/active\\_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBd2FDTFE9PSIsImV4cCI6bnVsbCwicHVyJoiYmxvYl9pZCJ9fQ==--a977e9349b5af438d8679ae0ffcdbdf6fcbd0c33f/Raport%20Gen%20Z.pdf](https://www.cpl.com/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBd2FDTFE9PSIsImV4cCI6bnVsbCwicHVyJoiYmxvYl9pZCJ9fQ==--a977e9349b5af438d8679ae0ffcdbdf6fcbd0c33f/Raport%20Gen%20Z.pdf), 10.06.2024.
8. Dong, M., Huangfu, S., Sun, H., Zhou, C. (2021). A macroeconomic theory of banking oligopoly. *European Economic Review*, Vol. 138, doi: 10.1016/j.eurocorev.2021.103864
9. EY & JA Worldwide (2021). *Gen Z is poised to reframe the future, but are business and education ready?* Retrieved from: [https://www.ey.com/en\\_it/corporate-responsibility/how-business-and-education-can-help-gen-z-reframe-the-future](https://www.ey.com/en_it/corporate-responsibility/how-business-and-education-can-help-gen-z-reframe-the-future), 10.06.2024.
10. Fagan, E. (2024). *Winning with Gen Z: Navigating the Future of Digital Banking Solutions*. Retrieved from: <https://www.alkami.com/blog/strategies/winning-with-gen-z-navigating-the-future-of-digital-banking-solutions/>, 16.06.2024.
11. Flavián, C., Guinalú, M., Torres E. (2005). The Influence of Corporate Image on Consumer Trust: A Comparative Analysis in Traditional versus Internet Banking. *Internet Research*, Vol. 15, No. 4, pp. 447-470, doi: 10.1108/10662240510615191
12. Glabiszewski, W. (2013). Kreowanie wizerunku przedsiębiorstwa usługowego na rzecz budowania relacji w transferze technologii. *Polityki Europejskie. Finanse i Marketing*, Vol. 58, No. 9, pp. 161-173.

13. Główny Urząd Statystyczny (2023). *Ludność. Stan i struktura oraz ruch naturalny w przekroju terytorialnym w 2022 r. Stan w dniu 31 grudnia*. Retrieved from: [https://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5468/6/33/1/ludnosc\\_stan\\_i\\_struktura\\_oraz\\_ruch\\_naturalny\\_w\\_przekroju\\_terytorialnym\\_na\\_30.06.2022.pdf](https://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5468/6/33/1/ludnosc_stan_i_struktura_oraz_ruch_naturalny_w_przekroju_terytorialnym_na_30.06.2022.pdf), 15.06.2024.
14. Gray. J.G. (1986). *Managing the Corporate Image: The Key to Public Trust*. Westport: Quorum Books.
15. Grzyb, M. (2022). Wpływ pandemii covid-19 na wizerunek banków w Polsce. *Zeszyty Naukowe Politechniki Częstochowskiej. Zarządzanie, No. 48*, pp. 39-52, doi: 10.17512/znpcz.2022.4.04
16. Grzyb, M. (2023). *Zarządzanie wizerunkiem banków w kontekście współczesnych wyzwań [Management of bank image in the context of contemporary challenges]*, Doctoral dissertation. Częstochowa: Czestochowa University of Technology, Faculty of Management.
17. Grzybowska-Brzezińska, M., Rudzewicz, A. (2016). Instrumenty merchandisingu w bankowych placówkach detalicznych. *Marketing i Zarządzanie, Vol. 45, No. 4*, pp. 301-311, doi: 10.18276/miz.2016.45-27
18. Hackiewicz, M. (2024). *Top 5 Digital Banking Features for Generation Z*. Retrieved from: <https://www.netguru.com/blog/top-banking-features-genz>, 16.06.2024.
19. Kaakeh, A., Hassan, M.K., van Hemmen Almazor, S.F. (2019). Factors Affecting Customers' Attitude Towards Islamic Banking in UAE. *International Journal of Emerging Markets, Vol. 14, No. 4*, pp. 668-688, doi: 10.1108/ijoem-11-2017-0502
20. Karmakar, A. (2021). Generation-Z Banking Trends – A Study based on Kolkata. *IBMRD's Journal of Management & Research, Vol. 10, Iss. 2*, pp. 52-61, doi: 10.17697/ibmrd/2021/v10i2/166805
21. Khvtisiashvili, I. (2012). How does Corporate Image Affects the Competitive Advantage of Georgian Banking Segment. *Journal of Business, Vol. 1, No. 1*, pp. 35-44.
22. Korombel, A., Ławińska, O. (2023). Expectations of Generation Z Representatives towards the Features and Competencies of their Direct Supervisors (Managers) – Results of Own Study. *Scientific Papers of Silesian University of Technology. Organization and Management Series, No. 185*, pp. 187-212, doi: 10.29119/1641-3466.2023.185.11
23. Kościelniak, H. (2010). Analiza grup interesu w zarządzaniu wartością przedsiębiorstwa. *Zeszyty Naukowe Instytutu Zarządzania i Marketingu Akademii im. Jana Długosza w Częstochowie. Pragmata Tes Oikonomias, No. 4*, pp. 147-157.
24. Ławińska, O., Korombel, A. (2023b). *Pokolenie Z jako wyzwanie współczesnego zarządzania przedsiębiorstwem. Relacje, media społecznościowe i crowdsourcing*. Częstochowa: Wydawnictwo Politechniki Częstochowskiej.
25. Ławińska, O., Korombel, A. (2023a). Activity of Generation Z on Social Media as the Basis of Marketing Orientation of Enterprises – Comparison of Poland and Great Britain.



- Scientific Papers of Silesian University of Technology. Organization and Management Series, No. 185*, pp. 259-284, doi: 10.29119/1641-3466.2023.185.15
26. Malara, Z., Sobol-Wojciechowska, J. (2011). Wizerunek przedsiębiorstwa oraz mechanizmy jego kreowania na potrzeby kształtowania potencjału rozwojowego. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No. 218*, pp. 154-164.
  27. Marcinkowska, M. (2012). Wymogi stawiane bankom przez ich otoczenie. *Studia Ekonomiczne. Zeszyty Naukowe Wydziałowe Uniwersytetu Ekonomicznego w Katowicach, No. 105*, pp. 165-172.
  28. Marcinkowska, M. (2013). *Kapitał relacyjny banku. Tom 1. Kształtowanie relacji banku z otoczeniem*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
  29. Marinkovic, V., Obradovic, V. (2015). Customers' Emotional Reactions in the Banking Industry. *International Journal of Bank Marketing, Vol. 33, No. 3*, pp. 243-260, doi: 10.1108/ijbm-09-2013-0107
  30. Minds & Roses (2023). *Generacje 2023: Największe porównawcze badanie konsumentów w Polsce*. Retrieved from: <https://www.mindsandroses.com/blog/generacje-2023-najwieksze-porownawcze-badanie-konsumentow-w-polsce>, 15.06.2024.
  31. Mondres, T. (2019). *How Generation Z Is Changing Financial Services*. Retrieved from: <https://bankingjournal.aba.com/2019/01/how-generation-z-is-changing-financial-services/>, 16.06.2024.
  32. Nguyen, N., LeBlanc, G. (1998). The Mediating Role of Corporate Image on Customer's Retention Decisions: An Investigation in Financial Services. *International Journal of Bank Marketing, Vol. 16, No. 2*, pp. 52-65, doi: 10.1108/02652329810206707
  33. Nikodemska-Wołowik, A.M. (2004). Rola badań marketingowych w programie całościowej identyfikacji. *Acta Universitatis Lodzianis. Folia Oeconomica, No. 179*, pp. 285-293.
  34. Nur, Y., Basalamah, S., Semmail, B., Hasan, S. (2023). The Influence of Bank Image, Accessibility, and Customer Relationship Management on Customer Satisfaction and Loyalty at Islamic Banks in Makassar City. *International Journal of Professional Business Review, Vol. 8, No. 9*, pp. 1-34, doi: 10.26668/businessreview/2023.v8i9.3640
  35. Oliver Wyman and The News Movement (2023). *A-Gen-Z Report. What Business Needs To Know About The Generation Changing Everything*. Retrieved From: <https://www.oliverwymanforum.com/content/dam/oliver-wyman/ow-forum/template-scripts/a-gen-z/pdf/A-Gen-Z-Report.pdf>, 16.06.2024.
  36. Omoregie, O.K., Addae, J.A., Coffie, S., Ampong, G.O.A., Ofori, K.S. (2019). Factors Influencing Consumer Loyalty: Evidence from the Ghanaian Retail Banking Industry. *International Journal of Bank Marketing, Vol. 37, No. 3*, pp. 798-820, doi: 10.1108/ijbm-04-2018-0099

37. Oxford Economics (2021). *Gen Z's role in shaping the digital economy*. Retrieved from: <https://www.oxfordeconomics.com/resource/gen-z-role-in-shaping-the-digital-economy/>, 10.06.2024.
38. Patel, H., Morrison, E. (2019). *Generation Z: Step aside Millennials*. Retrieved from: [https://www.ib.barclays/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/gen-z/Leaflet%20Generation\\_Z.pdf](https://www.ib.barclays/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/gen-z/Leaflet%20Generation_Z.pdf), 10.06.2024.
39. Perek, A., Pawlonka, T. (2014). Rozpoznawalność banków spółdzielczych w segmencie młodych konsumentów. *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego, No. 106*, pp. 71-83, doi: 10.22630/eiogz.2014.106.16
40. Prokopowicz, M. (2011). Wizerunek banku i lojalność nabywców. *Nauki o Zarządzaniu, No. 9*, pp. 50-68.
41. PYMNTS Intelligence & i2c (2024). *The Credit Economy: The Role of Reward Programs in Consumer Credit Usage*. Retrieved from: <https://www.pymnts.com/study/credit-economy-gen-z-personalized-credit-cards-rewards-program/>, 16.06.2024.
42. Ręklawski, M. (2020). *Statystyka opisowa. Teoria i przykłady*. Włocławek: Wydawnictwo Państwowej Uczelni Zawodowej we Włocławku.
43. Saleh, M.A., Quazi, A., Keating, B., Gaur, S.S. (2017). Quality and Image of Banking Services: A Comparative Study of Conventional and Islamic Banks. *International Journal of Bank Marketing, Vol. 35, No. 6*, pp. 878-902, doi: 10.1108/ijbm-08-2016-0111
44. Stolarska, A. (2011). Kształtowanie wizerunku instytucji finansowych na przykładzie banków. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Poznaniu, No. 209*, pp. 254-264.
45. Strycharczyk, A. (2009). Wiarygodność ekonomiczna: newralgiczny element budowy relacji biznesowych w czasie kryzysu. *Ekonomiczne Problemy Usług, No. 46*, pp. 311-320.
46. Świeszczak, K. (2016). Programy etyczne wybranych banków należących do polskiego sektora bankowego. In: D. Czechowska (Ed.), *Etyka w relacjach instytucji finansowych z gospodarstwami domowym* (pp. 139-154). Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
47. Szlis, I. (2010). Źródła przewagi konkurencyjnej w bankowości detalicznej w świetle badań. *Ekonomiczne Problemy Usług, No. 55*, pp. 105-115.
48. van Heerden, C.H. (1999). Developing a Corporate Image Model. *South African Journal of Economic and Management Sciences (SAJEMS), Vol. 2, No. 3*, pp. 492-508, doi: 10.4102/sajems.v2i3.2593
49. Verma, N., Kaur, M. (2023). Examining the Relationship Among Customer Experience, Bank Image, and Trust: A Multichannel Banking Perspective. *Journal of Global Marketing, Vol. 36, No. 2*, pp. 141-164, doi: 10.1080/08911762.2023.2188508
50. Webster, K. (2024). *What Generation Z Wants From Their Bank*. Retrieved from: <https://www.pymnts.com/news/banking/2024/what-generation-z-wants-from-their-bank/>, 16.06.2024.

51. Wenaryze (2023). *The Gen Z and the banking sector*. Retrieved from: <https://www.wenaryze.com/what-is-generation-z-looking-for-in-banking/>, 15.06.2024.
52. Wigley, B., Kantaria, R. (2023). *Speaking Gen Z: How banks can attract your customers*. Retrieved from: <https://www.weforum.org/agenda/2023/11/gen-z-banking-finance-money-trends/>, 15.06.2024.
53. Wiktorowicz, J., Warwas, I., Kuba, M., Staszewska, E., Woszczyk, P., Stankiewicz, A., Kliombka-Jarzyna, J. (2016). *Pokolenia – co się zmienia? Kompendium zarządzania multigeneracyjnego*. Warszawa: Wolters Kluwer.



## CHANGES IN COMPANIES' PERSONNEL POLICIES – TOWARDS OPTIMISING THE MANAGEMENT OF KEY EMPLOYEES (CASE STUDY)

Michał IGIELSKI

Gdynia Maritime University; m.igielski@wznj.umg.edu.pl, ORCID: 0000-0003-4680-3733

**Purpose:** The aim of this article is to analyse the actions taken by companies to create optimal working conditions for their main stakeholders - their key employees.

**Design/methodology/approach:** In order to achieve the research objective, the author used a critical analysis with reference to the collected literature; an observational method (which made it possible to obtain and use a number of scientific insights into the behaviour of business actors in changing external and internal conditions); an intuitive method (which involves considering a number of concepts, problems and terms in the area of employee management and governance); and a method based on individual case studies in 10 companies, which made it possible to explore the use of tools to manage identified key employees.

**Findings:** Companies are aware of the challenges they are facing due to the new determinants of the economy and are striving to move towards developing their employees and providing them with the right working conditions that influence the results they achieve.

**Practical implications:** What we can say for sure is that the core competencies of the employees employed will remain a permanent feature of management, just as physical assets, organisational structures, strategies, processes, systems, financial or information resources have become.

**Social implications:** For employees, intelligently organised work can be lighter, more useful, more satisfying and allow a wider range of needs to be met.

**Originality/value:** Thanks to the research process carried out in 10 large enterprises from various countries in Europe, the author believes that the main objective of the prepared material has been developed and realised. In turn, the conclusions obtained may find theoretical and practical application, in building competitive advantage of enterprises on the market, with the use of competences of key employees.

**Keywords:** key personnel, human capital management, key competences.

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

## 1. Introduction

Globalisation, technological innovation and the rapid development of knowledge and information have forced changes in the structure of employment and a change in the approach to the competences needed to perform a specific job. In today's world, without knowledge we will not build an optimal competitive model and we will not be able to manage a company. It is human capital that has become the most valuable resource in a company. It is the only capital that can acquire, collect and select the necessary information. It has the knowledge that we use to make decisions and solve problems at every level of management.

Therefore, according to the author, nowadays the most important and valuable strategic resource of any organisation is knowledge, which is an attribute of the staff employed. Why? Because it is thanks to the employees, consciously acquired knowledge (sometimes also created), adapted to the needs of the organisation and properly disseminated (used), with the help of developed methods and available information technology tools, that is the key attribute in building a sustainable competitive advantage. In the 21st century, in the era of turbulent conditions in the environment - technological, social, political and economic changes - it is no longer possible to compete effectively on the market based on investments in traditionally understood material resources - the global economy has been redirected in a new direction. Gone to the "pool of ancient times" is not only the economy in which agriculture dominated and the quality of the soil determined a country's wealth, but also the era of mechanical production based on a predatory policy of environmental exploitation and unlimited investment in technological processes. We are slowly entering an era in which "greatness" is determined primarily by the ability and aptitude to acquire, process and use information (knowledge), which is the basis for gaining market and thus economic success.

According to the author, the findings obtained through the research process (in 10 large companies from different countries in Europe), can find theoretical and practical application in building the competitive advantage of companies in the market, using the competences of key employees.

## 2. Literature Review

The most important value for companies is starting to be the knowledge possessed by people - it is this group that is becoming particularly important to them and it is to this group that all activities associated with changing management systems will be adapted. The emerging new economy is forcing the creation of new organisations, and is even creating new organisations

itself, in which new employees with hitherto unheard-of (or unnoticed and so far unneeded) competences are “coming to the fore”.

**Table 1.**

*Determinants of human capital management in the 21st century*

New economy	New organisation	New employee
<ul style="list-style-type: none"> <li>– globalization</li> <li>– tough competition</li> <li>– constant innovation</li> <li>– breaking up of monopolies</li> <li>– technological progress</li> <li>– computerization</li> <li>– cultural diversity</li> <li>– customer orientation</li> <li>– changes on the labour market</li> </ul>	<ul style="list-style-type: none"> <li>– intellectual capital</li> <li>– core competences</li> <li>– reduction of hierarchies</li> <li>– project management</li> <li>– network organisations</li> <li>– virtualisation of activities</li> <li>– management of professionals</li> <li>– talent acquisition</li> </ul>	<ul style="list-style-type: none"> <li>– knowledge worker</li> <li>– lifelong learning</li> <li>– changes in occupations and functions</li> <li>– less job stability</li> <li>– work as a task, not as a place to do things</li> <li>– creative thinking</li> <li>– working as part of a team</li> <li>– managing one's own time and career</li> </ul>

Source: Own study based on Poczowski (2007).

Increasingly, so-called ‘intelligent organisations’ are appearing on the market, i.e. organisations that develop their capacity to continuously adapt to a changing and unpredictable environment. They also acquire, create and store knowledge to improve their productivity and efficiency or to create innovative products. An intelligent organisation is also often referred to as a learning organisation and in this context is defined as one that continuously learns and practices to achieve mastery in self-improvement (Senge, 2014).

Already these two cited definitions, clearly indicate the very important role of employees who, while working in an organisation, demonstrate their knowledge, skills and experience. It is today's economic realities that force managements to recruit and retain (this seems to be an even more complicated process than recruitment itself) people with high potential. The 21st century, therefore, requires organisations to continuously improve and innovate - these activities are determined precisely by the potential of the organisation's key people, created by a group of interrelational factors between the organisation and the staff employed.

This leads to the conclusion that, in the 21st century, the competences of key human capital are a strategic element in the fight against competition, which makes it possible to create the expected advantage on the market. Of course, the success of this process is determined by the people employed in the organisation. Therefore, it is very important not only to attract people with promising potential, but also to create working conditions for them that are conducive to their development, motivation and commitment. This is possible primarily by supporting and encouraging employees to behave in a pro-innovative manner, creating a climate conducive to innovation and shaping the right organisational culture. In the face of today's challenges, the comprehensive management of high-potential employees, the so-called key employees, is of particular importance here (Król, 2017).

But on the other hand, we must remember that different employees, just like different people, have different qualities, skills or talents. The problem is to identify those who are the most talented, the most ambitious and the most motivated to work. This skill, is undoubtedly crucial to the success of any organisation operating in today's market. However, many entities have a problem with this - they don't quite know how to do it. Why is this the case? What are the characteristics of key employees? What characteristics make them unique? Analysing the definitions of this group of employees available in the literature, the author describes them extensively in Table 2.

According to the Encyclopedia of Management, the term key employees refers not only to technology specialists who possess unique knowledge, experience or skills, the loss of which may lead to a significant decrease in the market value of the organisation, but also to those individuals who can facilitate the process of preparing and carrying out the integration. Depending on an organisation's sector of activity or the nature of the organisation, the 'key' employee may be something radically different for an individual employer. For one employer it will be the most experienced employee, for another it will be the scarce, hard-to-replace skilled IT specialist, and for yet another it will be the manager who can skilfully and effectively resolve internal conflicts (Cynk, 2016). All of these people are referred to as essential employees, the most valuable people, who are difficult to replace - and therefore cannot be afforded to lose, as they have the right potential and are particularly valuable to the organisation (valued employees) (Branham, 2011). They also have critical skills, are high performers or have high potentials, which can be crucial in achieving the organisation's diverse goals (Morawski, 2014).

**Table 2.**

*Analysis of the definition of key employees*

Author(s)	Key worker characteristics
G. Waisburg (2016)	They are primarily characterised by a high degree of flexibility in crossing obvious boundaries, demonstrating a fluidity of ideas in creating multiple possible solutions to a given problem and an independence of thought, subjecting any task that is put before them to close scrutiny. They also have the ability to manage conflict efficiently (tolerance for ambiguity), are inquisitive, and recognise and understand the needs of others. They also demonstrate a high degree of systematic work, action orientation and commitment.
R. Stuart-Kotze, C. Dunn (2021)	A high-potential employee who, in addition to his or her talent, is highly committed to the company, is motivated to climb the organisational hierarchy and wants to succeed in top positions.
A. Poczrowski (2004)	The term key employees refers not only to technology specialists with unique knowledge, experience or skills, the loss of which can lead to a significant decrease in the market value of the organisation, but also to those individuals who can facilitate the process of preparing and carrying out the integration, such as managers.
M. Białasiewicz (2015)	They are compared to another group of employees, the so-called talents, i.e. individuals who are original, have flexible thinking skills, creative approaches to problem solving, are characterised by openness, the ability to take constant risks, are very committed and persistent in their pursuit of their goals, have emotional intelligence, and are aware of the value and importance of their work.



Cont. table 2.

A. Cowling, O. Laudy (2016)	There is a strong emphasis on combining capability and commitment with aspirations to develop, advance and fulfil key roles in the organisation. Capability has to be defined as agile learning and consists of innate skills, (intellectual agility, emotional intelligence) and acquired technical and interpersonal skills that are used in daily work. Abilities also include predispositions to: process complex ideas, think logically, perceive and understand other people's emotions and learn new skills, e.g. technical, interpersonal. They also have a direct impact on employee performance.
M. Morawski (2012)	They are the top-class professionals who form the core of the company, its intellectual and substantive elite. They are the group of employees who decisively influence the value of corporate competence. In a highly competitive economy, such as the knowledge-based economy, having unique and at the same time important competences for the enterprise is a source of unique organisational positioning.
C. Fernández-Aráo (2014)	<ul style="list-style-type: none"> <li>– Striving for excellence in achieving a given goal - this is expressed in the employee's ambition and expectations of recognition, but also in his or her modesty and continuous investment in his or her own skills.</li> <li>– Curiosity, which implies a propensity to seek novelty, gain knowledge, seek feedback, and be open to learning and change.</li> <li>– Perspicacity defined as the ability to gather and learn from information that can create new opportunities.</li> <li>– Commitment defined as the talent to use knowledge and logic to share one's vision with others.</li> <li>– Determination defined as the ability to fight for complex goals and deal with difficulties and adversity.</li> </ul>
D. Ulrich, W. Brockbank (2014)	Employees defined as A-class (category) workers who achieve productivity many times that of average or weak workers.
J. Kopeć (2012)	Individuals who have a special ability to use their tacit knowledge.
E. van Stadem (2016)	Emphasis is placed on attributes that relate to leadership skills, the ability to analyse and synthesise sizable sets of information and to deal with uncertain and unclear situations. These individuals have a passion for continuous learning, for improving existing situations and for the ability to collaborate and communicate with other employees.
W.M. Grudzewski, I. Hejduk (2004)	A small number of professionals in an organisation who have a pool of individual skills, experiences, beliefs, intuition, non-formalised practical information and many others that make up a person's knowledge.
M. Kowalówka (2015)	Individuals who have the potential, ability and aspiration to successfully perform leadership roles in the organisation - only 3-5% of employees in companies are of such high potential.

Source: own study.

All of the above qualities and skills should be assessed not only from a current perspective, but above all from a long-term perspective, as this is the approach that is important in planning for the success of the organisation. The results of a highly committed employee are his or her hard and long-term work and citizenship, i.e. engaging not only in the obligations of a signed agreement or contract (Zdonek, 2015).

At this point, it is worth attempting some systematisation of the cited definitions and referring to the four factors characterising a high-potential employee created by D.A. Ready, J.A. Conger and L.A. Hill (2015):

- Striving for excellence - the constant striving for success can lead to extreme results. For it is not enough to achieve only very good results at work, one has to be the best - even at the expense of one's personal life.

- Acquisition and application of knowledge in business processes - to be recognised as a key worker you need to be a lifelong learner - taking knowledge and experience from every situation - in your professional and personal life.
- Entrepreneurial spirit - key workers must not be afraid to leave their comfort zone (in the professional and personal sphere). They need to adapt their personal style and develop new strategies.
- Ability to react appropriately - high potential also poses great challenges in terms of making key decisions. This is coupled with the risk of making a mistake - all of which can be a source of stress. The key worker must be aware of this and react appropriately (without emotion) in any situation.

On the other hand, the key employee also has expectations that are mainly about the organisation's support and investment in his or her development - he or she is committed to his or her career path and expects challenge and diversity. However, it is difficult to find a one-size-fits-all model (set of actions) to improve the performance of an organisation based on the potential of the employees it employs. It certainly needs to start with including employees in decision-making processes and introducing various forms of participative management. In the author's opinion, giving more and more autonomy to employees and making strategic decisions, based on their knowledge and skills, is an element of management in modern organisations. Therefore, getting creative people on board is a fundamental step towards increasing the creativity of all organisations (Igielski, 2017).

Once again, therefore, one cannot escape the question of who is this key employee and how to identify him or her? How to explore and assess his or her unique potential? According to the author, the main elements that can indicate the role of a particular employee in the home organisation include: motivation, determination, creativity and conceptual skills. Why these four and not a dozen others? Because they best reflect the 21st century employee and are the answer to most of the determinants of the modern market.

### **3. Materials and methods**

On the basis of his observations, the author of this article believes that the optimal management of key employees and their competences in a given economic organisation is entirely dependent on the specific characteristics and development determinants of all its components. Therefore, investment in this type of capital involves quite a significant risk, compounded by the fact that, for the most part, this capital does not belong to the organisation in question at all. It is held by employees or external stakeholders. For this reason, many company managements, although aware of the importance of implementing and managing this capital in their organisations, choose not to base their strategy on it.

The preparation of this article was preceded by the observation of economic phenomena and processes and a review of the literature. Theoretical considerations in this regard were complemented by empirical research, which was carried out in 2023. Qualitative research methods were applied, including a review of the Polish and foreign literature on the subject and an analysis, in 10 large enterprises, of a wide range of cases of personnel policy towards the management, perhaps not of identified key employees, but of those most important for individual organisations.

The basic normative act defining what the status of a large entrepreneur is Annex 1 to Commission Regulation (EU) No 651/2014 of 17 June 2014. According to this act, large entrepreneurs are considered those who:

- Have 250 or more employees.
- Have fewer than 250 employees, but their total balance sheet exceeds €43 million. At the same time, their total turnover exceeds €50 million. 25% or more of the capital, or voting rights at the shareholders' meeting, is controlled directly or indirectly, jointly or individually by one or more public entities.

The choice related to the analysed group of organisations resulted from the author's observations over the last years and from his personal experience related to his professional and scientific work - the research was therefore conducted based on probabilistic sampling techniques. In addition, the entire research process was conducted on the basis that the management of key employees can be determined by the organisational structure of the business entity, the nature of the organisation and its size, the number of employees and their knowledge and experience, together with the manner and type of employment.

The author used a number of research methods to achieve the research objective:

- critical analysis, including with reference to the collected literature,
- an observational method. which enabled a number of scientific insights into the behaviour of economic agents in changing external and internal conditions to be obtained and used,
- the intuitive method, which involved considering a range of concepts, problems and terms in the area of employee management and governance, which led to the development of new concepts that could support the process of improving the management of key employees with their competencies,
- intuitive method was also supported by the author's extensive practical experience in consulting activities, including those related to human capital management,
- a method based on individual case studies, which made it possible to explore the use of tools to manage identified key employees.

In addition, the research method proposed by R.S. Kaplan (1998) i.e. “research through action” (Action Research), was used to achieve the presented research objective. He claimed that this research method helps to create theories in the field of management, including human

capital management, by observing and documenting innovative practices in this area, discussing them, presenting them in scientific articles and finally implementing them in specific business organisations.

#### 4. Results and discussion

In this part of the article, the author presented an analysis of a wide range of cases of conducting personnel policy towards the management of the most important capital for the organisation - people. In addition, there could be no lack of an assessment of the adaptation measures undertaken, combined with the implementation of related systems. Such system actions (in the author's opinion, this is what they can already be called in these particular cases) occurred in the 10 companies involved in the study. The primary source of information used for this analysis, were reports from individual diagnoses carried out in the individual companies. Additional sources used in the work on these issues were publications, company websites, as well as various thematic articles posted on the Internet.

**Table 3.**  
*Analysis of the definition of key employees*

<b>Company No. 1</b>	<b>Description of the company</b>
	The company focuses on providing telecommunications solutions for small and medium-sized enterprises and individual customers. Industry: Telecommunications. Country: Sweden. Company size: large company - approx. 750 employees.
	<b>Case study</b>
	The first stage of the work to implement specific principles for managing the identified key employees was to organise the responsibilities between the departments in which they were employed. "Blurred" responsibilities at different levels of the structure up to that point were translating into staff attitudes and mindsets. The existence of a contractual division of competences between departments translated into interpersonal relations and work atmosphere. In its development, the company's structure grew disproportionately to the responsibilities assigned. The first stage of the development of the competence structure extended to the development of a coherent organisational structure. The next stage was team coaching, which aimed to strengthen the sense of belonging to the project team and to define the objectives of the individual teams. Teams in which key staff members were identified (in addition to all managers and the entire company management) were subjected to this process in the first instance. During the session, the following topics were covered: training policy, internal communication, communication with the client, the company's HRM policy. The next step was to create assumptions for the new employment policy - among other things, current methods of motivating employees were analysed - with a view to unifying them and creating packages for individual groups.
	<b>Benefits for key employees</b>
<ul style="list-style-type: none"> <li>- reinforcing at all levels of the organisation a culture of an active pro-active approach to work;</li> <li>- improving the ability to work as a team to achieve success;</li> <li>- increasing awareness of the responsibilities of the organisational unit to which the key employee belongs;</li> <li>- increasing awareness of responsibility for the individual tasks delegated within the organisational structure of the company;</li> <li>- increasing awareness of responsibility for the individual work performed within the company's organisational hierarchy.</li> </ul>	

Cont. table 3.

<b>Company No. 2</b>	<b>Description of the company</b>
	The company offers a wide range of products to adapt any type of engine to gas supply. Industry: Automotive. Country: Germany. Company size: large company - approx. 530 employees.
	<b>Case study</b>
	The target model in the area of key-employee management was to create a company image as an employer that would not only enable the company to retain its best specialists, but also to attract new experts from the market who would bring unique (core) personality competencies, expertise and valuable contacts. It was a necessity for managers to acquire the awareness that a company's most valuable asset and competitive advantage is its people. Actions taken: - attracting and hiring employees according to the developed recruitment procedure; - obtaining the right level of motivation for key employees - a remuneration system linked to performance; - career planning - building employment stability within the company.
	<b>Benefits for key employees</b>
	<ul style="list-style-type: none"> <li>- identification with the company - building loyalty;</li> <li>- increased comfort at work;</li> <li>- stronger cooperative attitude;</li> <li>- stimulation for self-improvement and transfer of knowledge to others.</li> </ul>
<b>Company No. 3</b>	<b>Description of the company</b>
	A rapidly growing technology company operating in the global IT software market. Industry: IT Country: Germany. Company size: small large company - approx. 320 employees.
	<b>Case study</b>
	The company is characterised by a high awareness of the needs and processes for the optimal involvement of employees (including key employees) in building the development of the organisation, based on the competences of the future. Aware of the global competition, the company has implemented a number of adaptation measures that specifically address the identification of key employees and their development: - the outline of the key employee appraisal system includes not only the evaluation of performance but also elements of assessment of their competences, skills and attitudes and behaviour; - description of the company's employee selection process - standardising the company's recruitment process; - description of job levels - developing job levels for key employees so that a precise salary grid can be defined and entry criteria for each level can be precisely described.
	<b>Benefits for key employees</b>
	<ul style="list-style-type: none"> <li>- gain practical tools to improve their own performance;</li> <li>- improve their ability to work as a team to achieve success;</li> <li>- increase the level of management equity;</li> <li>- to receive feedback on assessed competencies and potential;</li> <li>- to be able to self-evaluate and compare one's working solutions with others;</li> <li>- being able to plan and monitor one's own performance.</li> </ul>
<b>Company No. 4</b>	<b>Description of the company</b>
	The company is a leading producer of precast polymer concrete in the Scandinavian market. Country: Denmark. Company size: large company - approx. 810 employees.
	<b>Case study</b>
	Competence (mainly key) management is a way of conducting personnel policy - the concept of competence has become the main link between recruitment and selection activities, career paths, employee appraisals and motivation systems. Key employee management activities - tools used: - non-financial employee motivation system; - employee satisfaction and commitment survey; - schemes for the development of managerial competences; - principles of constructive communication in the superior-subordinate relationship.

Cont. table 3.

	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– stimulating motivation - proposing real action to meet employees' needs;</li> <li>– improving teamwork skills for success;</li> <li>– feedback on employees' needs, how they perceive the company they work for and whether they associate their future career plans with it.</li> </ul>
<b>Company No. 5</b>	<p><b>Description of the company</b></p> <p>Partner of the world's largest automotive filter companies. Industry: plastics. Country: Lithuania. Company size: large company - approx. 700 employees.</p>
	<p><b>Case study</b></p> <p>The company has implemented a human capital management strategy including the identification of key employees, which is combined with an expansion strategy aimed at gaining an even stronger market position by penetrating the market and leveraging the strengths of the management against the competition. It focuses primarily on optimal communication, building the authority of supervisors (including those with little experience) and well-motivated project teams.</p>
	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– improving communication skills, which influences the building of good relationships with others - this translates into success in professional and personal life;</li> <li>– identification of strengths and weaknesses in the company's information flow;</li> <li>– increase in internal and external customer orientation.</li> </ul>
<b>Company No. 6</b>	<p><b>Description of the company</b></p> <p>The company is one of the European market leaders in the production of specialised software for asset, receivables and records management. Industry: IT. Country: Latvia. Company size: large company - approx. 290 employees.</p>
	<p><b>Case study</b></p> <p>The procedures and standards that have been developed relate primarily to the area of internal communication and the development of managerial competences of Board members and executives. In addition, identified key employees were prepared to improve the condition of the company through knowledge and tools to overcome the leadership crisis. Activities and tools used in the area of key employee management:</p> <ul style="list-style-type: none"> <li>– individual and team coaching (key employees, Board members and executives);</li> <li>– systematisation of employee recruitment and selection rules.</li> </ul>
	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– increased motivation to build good relations with the company's clients - increased work efficiency;</li> <li>– ability to consciously manage the change process and work effectively in a rapidly changing environment;</li> <li>– identification of strengths and weaknesses in information flow;</li> <li>– diagnosis of own communication style;</li> <li>– developing skills of active listening, asking questions, directing the conversation;</li> <li>– improving communication skills and building good relationships with others;</li> <li>– reducing stress levels and resistance to new situations;</li> <li>– ability to react in conflict situations.</li> </ul>
<b>Company No. 7</b>	<p><b>Description of the company</b></p> <p>The company provides innovative lighting solutions for customers in a wide range of industries. Industry: Manufacturing. Country: Estonia. Company size: large company - approx. 270 employees.</p>
	<p><b>Case study</b></p> <ul style="list-style-type: none"> <li>– creation of assumptions for personnel strategy, including identification of key employees and competences for the company;</li> <li>– interviewing employees in a satisfaction survey process to determine the level of motivation;</li> <li>– examining job satisfaction and cooperation between subordinates and superiors;</li> <li>– initiating actions related to the assignment of additional competences to selected individuals.</li> </ul> <p>An important element was also to work together with identified key staff to develop a job card template, and in connection with the creation of new posts in the future and recruitment plans for existing posts. A competency profile form was also jointly developed.</p> <p>An additional issue was the creation of a system to effectively manage key competencies.</p>

Cont. table 3.

	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– gaining knowledge of promotion opportunities and developing career paths within the company;</li> <li>– having knowledge of the tasks, responsibilities and authority of their position;</li> <li>– having knowledge of the company's expectations in terms of competence requirements for their job;</li> <li>– higher job performance and satisfaction.</li> </ul>
<b>Company No. 8</b>	<p><b>Description of the company</b></p> <p>Germany's largest construction machinery and equipment rental company. Industry: Construction. Company size: large company - approx. 890 employees.</p>
	<p><b>Case study</b></p> <p>The preparation of precise job descriptions - so-called "key jobs" to be "filled" by key employees - was identified as the most important activity. A participatory method was used to create these descriptions - employees described their tasks and activities, which were then analysed and correct in terms of content and methodology. This process was complemented by an interview with the employee describing the job. This process made it possible to obtain not only a description of the activity, but also guidance from the job holder on what is particularly important or difficult to do. The next steps were to work on the creation of a selection procedure for the positions and activities to prepare managers to recruit and manage new employees.</p>
	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– acquiring practical skills to carry out a professional selection process for key employees;</li> <li>– improved competence in the accurate selection of the right people for the right positions.</li> </ul>
<b>Company No. 9</b>	<p><b>Description of the company</b></p> <p>The company is a global supplier of smart power sources. Industry: Energy (power sources - manufacturing). Country: Sweden .Company size: large company - approximately 1200 employees.</p>
	<p><b>Case study</b></p> <p>The company has structured and defined rules for identifying and working with key employees in HR documents.</p>
	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– increased level of management fairness;</li> <li>– ability to self-evaluate and compare their performance with others;</li> <li>– greater sense of belonging to the company;</li> <li>– clarified feedback on assessed competences;</li> <li>– having knowledge of the scope of tasks, responsibilities and authority of the job occupied by the identified key employee;</li> <li>– higher job performance and satisfaction.</li> </ul>
<b>Company No. 10</b>	<p><b>Description of the company</b></p> <p>The company provides comprehensive services aimed at institutions and individual clients in the field of advanced IT tools. Industry: IT. Country: Germany. Company size: Large enterprise - approx. 320 employees.</p>
	<p><b>Case study</b></p> <ul style="list-style-type: none"> <li>– a plan was developed to identify and develop key employees (the development plan also covered management);</li> <li>– the existing motivation system and employee appraisal system were synchronised with the identified key employees (any shortcomings diagnosed in these systems were removed in the process);</li> <li>– the flow of information across HR was improved.</li> </ul>
	<p><b>Benefits for key employees</b></p> <ul style="list-style-type: none"> <li>– gaining tools and information to build their own professional development;</li> <li>– increased commitment to their work;</li> <li>– increased sense of identification with the company;</li> <li>– increased job satisfaction in a company investing in staff development;</li> <li>– to learn about the multifaceted diagnosis of employee capabilities and potential;</li> <li>– the opportunity to create an individual, time- and cost-effective professional development plan.</li> </ul>

Source: own study.

The above list is a case study of identified good practices in supporting outstanding and highly valuable employees (one could say key employees) and implementing systems to manage them. Unfortunately, the list does not include representatives from the Polish market, which is certainly not the result of them not taking any action in this respect - simply that the examples described have already been implemented on the basis of the methodology developed. Importantly, most of the situations described, bearing in mind the very complicated and not always going in the right direction process of functioning of the existing HR policy in a given company, were implemented with the participation of external experts, who provided advisory support, after an earlier analysis of the current situation. This means that the changes introduced did not happen on their own, but were the result of direct assistance from consultants in developing procedures and tools as a response and solution to the need to implement specific actions for a given organisation in the field of key personnel management. It is therefore unlikely that the current organisational structures or the human capital management systems in place will evolve on their own to identify and exploit the competencies of these key employees.

It is also worth noting that often the effect of the measures outlined has been to streamline the entire human capital management system in the day-to-day running of a given enterprise. It should also be remembered that the implemented changes will not produce immediate effects - there is a rather long period of adaptation to changes at certain levels, and the results of the applied tools and prepared procedures are, or will be, visible after an appropriate period of time.

Furthermore, the analysis of the research carried out in the area of overall human capital management in many companies, further highlighted the extensive and diverse practices aimed at 'stimulating / activating' the most valuable employees for their organisation. This, of course, implied that the surveyed organisations had to develop and apply appropriate HR practices resulting in attracting, retaining, developing and motivating their employees. Through these examples, it is possible to see that the managers of the companies, realise that the changing conditions in the labour market, which are moving towards the crystallisation of the employee market, are forcing them to transform their personnel practices and enrich them with elements aimed at employee satisfaction (even if the key ones are not taken into account).

On the other hand, the measures presented, which should be seen as a 'test' of key worker management, show how rich and varied the practices undertaken by companies operating in Europe can be. Some rely on tried and tested solutions, others seek to meet the needs of employees in creative ways that are probably more appropriate when assessing the changes that are taking place in their environment. However, the objectives guiding these processes are the same for all. First and foremost, company managements are concerned with a high level and quality of education, decent work and economic growth.



## Conclusions

In conclusion, in the new economic reality created by globalisation, technological advances or the rise of intellectual capital, at the dawn of society 5.0, there will be changes in the perception of employees in every workplace. In every industry - in the factory and in the law firm - employees will need new competences in the face of the dominance of digital tools. They will expect completely different treatment and support from their employer. Daily experiences with Artificial Intelligence, the Internet of Things, robotics and automation will imprint on them and trigger unprecedented feelings and needs. This means that HR departments around the world need to be prepared for this.

At this point, the author would also like to point out that, in his opinion, business executives are aware of the challenges they face with the new determinants of the economy. They also understand that their workplaces will become digital age organisations that produce physical products and provide innovative services based on data analytics - there will be a radical transformation in the way they operate and the dynamics of market processes will also increase. They also know that data and information are the main elements of the changes to come and they have a long and arduous road ahead of them leading to advanced analytical capabilities. All of this undoubtedly confirms the trend described by the author, perhaps not yet, but certainly already the beginning of it, which is the desire of companies to develop their employees and provide them with the right working conditions that will influence the results obtained. These efforts also testify to an organisation's awareness of the importance of such valuable capital as people - valuable individuals - and their impact on the results achieved by companies. This is also very important in the long term. It is not just the "here and now" that counts, as in the face of a changing labour market, pro-employee measures, including those aimed at assisting and rewarding the most valuable, can contribute to attracting "new" and retaining "old" employees who pay attention to the organisation's attitude to the needs of its employees. Creating development opportunities for identified key employees, "opening the door" to their participation in the organisation's management, without limiting their ability to generate ideas and new solutions, always provides a double benefit, Firstly, it is an opportunity for the company to develop and achieve its business goals, and secondly, professional fulfilment for the employee who feels appreciated and needed by his or her organisation.

Of course, the author is aware that due to the limited research group, the conclusions should not be generalised and we should consider the study as a pilot. But he hopes that the need for science to develop conceptual frameworks and methods to study the management of key employees in companies will not disappear, and that the research presented in this study is headed in the right direction.

To sum up, all the presented corrective actions and prepared tools are, in the author's opinion, characterised by the best available practice applied in the field of personnel policy in organisations. Importantly, they are effective and innovative and at the same time universal, as they can be applied by different companies, in different industries and in different circumstances. This is undoubtedly evidenced by the fact that the companies described - although they come from many parts of Europe - operate on national and global markets, in a variety of industries. But they still face the same problems, major or minor, when it comes to identifying and optimising the management of their key employees and thus maintaining their position among their competitors.

## References

1. Annex 1 to Commission Regulation (EU) No 651/2014 of 17 June 2014.
2. Branham, L. (2011). *24 ways to hang on to your most valuable talent*. New York: AMACOM.
3. Cowling, A., Lundy, O. (2016). *Strategic Human Resources Management*. Kraków: Oficyna Ekonomiczna.
4. Cynk, R. (2016). Metody utrzymywania kluczowych pracowników w organizacji. *Journal of Modern Management Process, Vol. 1, No. 1*, pp. 71-79.
5. *Encyklopedia Zarządzania*. Retrieved from: [https://mfiles.pl/pl/index.php/Przewaga\\_konkurencyjna](https://mfiles.pl/pl/index.php/Przewaga_konkurencyjna); [https://mfiles.pl/pl/index.php/Raport\\_Konrada](https://mfiles.pl/pl/index.php/Raport_Konrada), 11.03.2024.
6. Fernández-Araó, C. (2014). 21st century talent spotting. *Harvard Business Review, Vol. 6, No. 92*, pp. 46-54.
7. Grudzewski, W.M., Hejduk, I. (2004). *Zarządzanie wiedzą w przedsiębiorstwach*. Warszawa: Difin.
8. Igielski, M. (2017). Rola kluczowych pracowników we współczesnym przedsiębiorstwie. *Handel Wewnętrzny, Vol. 1, No. 368*, pp. 142-152.
9. Kaplan, R.S. (1998). Innovation action research: Creating new management theory and practice. *Journal of Management Research, No. 10*, pp. 89-118.
10. Kopeć, J. (2012). *Zarządzanie talentami w przedsiębiorstwie*. Kraków: Uniwersytet Ekonomiczny w Krakowie.
11. Kowalówka, M. (2015). *HIPOs, czyli jak zarządzać pracownikami o wysokim potencjale?*. Retrieved from: <https://rynekpracy.pl/artykuly/hipos-czyli-jak-zarzadzac-pracownikami-o-wysokim-potencjale>, 11.04.2024.
12. Król, A. (2017). Kreatywność i innowacyjność jako kluczowy element zarządzania kapitałem ludzkim. In: W. Harasim (Ed.), *Wpływ zglobalizowanego świata na zarządzanie* (pp. 123-135). Warszawa: Wyższa Szkoła Promocji, Mediów i Show Businessu.

13. Morawski, M. (2012). Uwarunkowania dzielenia się wiedzą z udziałem pracowników kluczowych w przedsiębiorstwach turystycznych. Wnioski z badań. In: M. Morawski (Ed.), *Zarządzanie wiedzą w turystyce a efektywność gospodarki turystycznej* (pp. 45-60). Wrocław: Akademia Wychowania Fizycznego we Wrocławiu.
14. Morawski, M. (2014). Doskonalenie procesów dzielenia się wiedzą z udziałem kluczowych pracowników przedsiębiorstwa w świetle badań empirycznych. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No. 359*, pp. 316-328.
15. Poczowski, A. (2004). *Zarządzanie zasobami ludzkimi w procesach fuzji i przejęć*. Kraków: Oficyna Ekonomiczna.
16. Poczowski, A. (2007). *Zarządzanie zasobami ludzkimi. Strategie – procesy – metody*. Warszawa: PWN.
17. Ready, D.A., Conger, J.A., Hill, L.A. (2015). Are you a high potential. *Harvard Business Review, No. 88*, pp. 78-84.
18. Senge, P.M. (2014). *The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization*. London: Nicholas Brealey Publishing.
19. Stuart-Kotze, R., Dunn, C. (2012). *Gdzie są twoi najlepsi ludzie. Znajdź ich, oceń ich talent i osiągnij sukces*. Warszawa: Wolters Kluwer.
20. Ulrich, D., Brockbank, W. (2014). *Tworzenie wartości przez dział HR*. Kraków: Wolters Kluwer.
21. van Staden E. (2016). *Identifying and Developing High-Potential Employees and Emerging Leaders Creating*. Retrieved from: <http://www.talentinstitute.co.za/products/TI-Identifying-and-Developing-High-Potential-Employees-and-Emerging-Leaders.pdf>, 10.04.2024.
22. Waisburg, G. (2016). *Creatividad y transformatione*. Mexico: Trillas.
23. Zdonek, I., Wolny, M. (2015). Potencjał pracownika – koncepcja modelu badawczego. *Zeszyty Naukowe Politechniki Śląskiej, Vol. 3, No. 86*, pp. 205-215.



## FROM COMPETITIVENESS OF ENTERPRISES TO COMPETITIVENESS OF CITIES – A THEORETICAL REVIEW

Karolina JÓZEFOWICZ

Faculty of Economics, Poznan University of Life Sciences; karolina.jozefowicz@up.poznan.pl,  
ORCID: 0000-0003-0613-8572

**Purpose:** The aim of this paper is to present international studies concerning competitiveness, focusing on competitiveness of cities.

**Design/methodology/approach:** First a review of literature is provided referring to multifaceted definitions of competitiveness. Next selected approaches to city competitiveness are presented. Methods applied to measure city competitiveness are described, while examples of studies on city competitiveness both on the international and national scale are given. The article did not impose any restrictions regarding the time or territorial scope of scientific literature.

**Findings:** Rankings provide cities with a certain potential for promotion and marketing among similar entities. They need to be considered a key tool for the understanding of processes related to urban transformation. Quantitative studies concerning city competitiveness are not only attempts to identify the competitive position, but rather they represent the need for continuous identification and utilization of the competitive potential of cities.

**Originality/value:** The findings serve as both a theoretical resource for researchers. The research examples indicated can serve as a point of reference for competitiveness indices being developed at national and international level.

**Keywords:** competitiveness, city competitiveness, cities, measurement of competitiveness.

**Category of the paper:** Literature review.

### 1. Introduction

Competitiveness is a problem extensively discussed in terms of both theoretical and empirical aspects. It is considered to be a multifaceted phenomenon in view of the scope of its implications. Due to global changes and the evaluation of the approach to competitiveness it is now discussed not only when referring to enterprises or specific branches of the economy, but also to territorial units at varying aggregation levels such as regions, cities or rural areas.

It is generally acknowledged that the early 1900s mark the beginnings of research on competitiveness. At that time in the USA studies on enterprises were initiated to compare their economic standing, with competitiveness being associated with the maintenance of efficiency (Borowiecki, Siuta-Tokarska, 2015; Lee, Karpova, 2018). The 1980s was the period when competitiveness gained popularity in the context of territorial units (Podlińska, 2015; Ketels, 2016; Martin, Simmie, 2008). At that time competitiveness started to be investigated in the context of individual countries (as the capability to maintain prosperity), while since the late 1980s interest in competitiveness was extended to the scale of regional economy.

They review available research on competitiveness using available domestic and foreign literature. The literature review was conducted without any time constraints. The outline of the article is as follows. The initial section provides a theoretical overview of the matter of competitiveness, taking into account the various levels of competitiveness. The next section focuses on territorial competitiveness, particularly urban competitiveness. Furthermore, a review of research into the competitiveness of cities in different countries is provided.

## **2. Literature review**

### **2.1. From competitiveness of enterprises to competitiveness of cities – theoretical connotations**

Interest in the problem of competitiveness may be originally ascribed to Krugman and Porter, who initially referred to competitiveness of enterprises. The definitions presented by those authors showed differing approaches to competitiveness. Krugman stressed that competitiveness is an attribute, which may be associated only with firms and it is determined by microeconomic factors. Criticism of competitiveness in reference to countries resulted from the incompatibility of assessment of the competitive position or conditions affecting competitiveness of a national economy (Zielenkiewicz, 2016; González Catalán, 2021). In turn, Krugman claimed that competitiveness takes the form of a dangerous obsession disseminated in the analysis of socio-economic phenomena in reference to territorial phenomena (Krugman, 1994). In the opinion of Krugman, countries and firms do not compete in the same manner. This was supported by an argument that an uncompetitive firm is eliminated from the market, whereas in the case of an uncompetitive country this is not the case (González Catalán, 2021). In turn, a different approach was presented by Porter, who acknowledged the importance of the territory and the socio-economic environment as significant conditions of competitiveness in the case of enterprises (Begg, 1999; Kresl, 2013; Vegara, 2016), thus indicating that the environment in the form of local authorities or the local community influences improved outputs of firms. In turn, he justified competitiveness of national economies by the fact that since the competitive advantage of an enterprise from one country is evident when compared

to a firm from another country, it needs to be determined what results from the fact that in a given country it is easier to run economic activity, leading to a level constituting competitive advantage (Porter, 1990; Frączek, 2009). Porter and Krugman agreed that productivity may be considered as a factor generating the standard of living for local inhabitants (González, Catalán, 2021).

Since the evolution of research on competitiveness from the point of view of various aspects of economic life has led to its categorization, in scientific literature on the subject various scales have been distinguished, within which this problem was systematized (Borowiecki, Siuta-Tokarska, 2015):

- meta (the level of the future),
- mega (the level of international economies),
- macro (the national economy),
- meso (the level of industries, branches, sectors of the economy, regions),
- micro (the level of enterprises),
- micro-micro (the level of goods and services).

Competitiveness of cities is included in the meso level, which comprises competitiveness of various territorial systems. Due to the multifaceted character of competitiveness this phenomenon does not have one precise definition. Thus, Table 1 presents a synthesis of individual concepts together with the competitive perspectives.

**Table 1.**  
*Selected definitions of competitiveness*

Level of competitiveness	Definition	Authors
micro, meso, macro, mega	„... the ability of companies, industries, regions, nations or supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis”	Hatzichronoglou (1996, p. 20) (OECD definition)
	„the capability of enterprises, industries, nations or supra-national regions to permanently establish relatively high factor earnings and relatively high employment level while being exposed to global competition”	Martus (2013, p. 128) after Lukovics (2008, p. 8)
macro, mega	„an internationally competitive economy is such an economy, which when faced with free trade conditions and free flow of production inputs (particularly capital) is capable of relatively fast growth and long-term development”	Radło (2008, p. 78)
meso, macro, mega	„the degree, to which a region under free competition conditions is capable of producing goods and services, which are attractive to buyers on international markets, while simultaneously increasing prosperity for its inhabitants”	Łaźniewska et al. (2012, p. 28)
macro	„the ability to sell enough products and services (to fulfill an external constraint); at factor incomes in line with the (current and changing) aspiration level of the country; and at macroconditions of the economic, environmental, social system seen as satisfactory by the people”	Aiginger (1998, p. 164)

Cont. table 1.

macro, meso	„a set of institutions, policies and factors that determine the level of productivity of a country”	Szwab, Porter (2007)
	„the expected level of efficiency per person in the working age population, considering the overall quality of the country as a place of business”	Delgado et al. (2012, p.7)
	„an economy’s ability to achieve a high standard of living through the combination of income growth and qualitative change (new technologies, social and ecological transformation, etc.)	Peneder, Rammer (2018, p. 208)
	„the capacity to offer an attractive and sustainable living and work environment for firms and inhabitants”	Dijkstra et al. (2011, p. 4)
meso	„refers to the presence of conditions that enable firms to compete in their chosen markets and that enable the value these firms generate to be captured within a particular region”	Huggins et al. (2013, p. 156)

Source: the author’s study.

Definitions given by Hatzichronoglou (1996), Lukovics (2008) or Radło (2008) present a consistent approach fitting for many levels of competitiveness, such as e.g. regions or transnational regions. They indicate an increase in productivity and enhanced capital levels. These definitions are attempts at providing a synthesis for the concept, its generalization to encompass various levels of competitiveness. Both countries, regions and smaller territorial systems strive to increase prosperity of their populations by improving the economic sphere. This process occurs in different scales at various competitive perspectives.

As a rule, competitiveness is a set of mutual relationships between distinguished levels. International competitiveness may be referred to the national economy, by comparing the economy of a given country to the global economy. It is also a characteristic, which may be attributed to enterprises. In this context it refers to relations between micro and small enterprises and the national economy. Such connections are developed when an enterprise has generated an increase in its value, at the same time becoming a competitive entity (Józefowicz, 2024). Thus it may be stated that lower aggregation levels for competitiveness (regions, cities and other territorial units) provide better understanding and improvement of competitiveness at higher levels (macro competitiveness).

As it was stated e.g. by Komasi et al. (2023), Saygin (2023), or Hu (2015), initially researchers focused on the economic aspect of competitiveness; however, with time other aspects of competitiveness have gained recognition, such as the society, culture or the environment. It was recognized that regional competitiveness (and not only that) is best measured in terms of advantages of the business environment (Malecki, 2007).

In recent years degradation of the natural environment and climate change have become a significant problem. This has resulted in an evolution of this concept, with its redefinition including also environmental issues. This has extended outside the economic prosperity of the population and incorporated current directions related to improved quality of life for the inhabitants.



An important contribution to the creation of competitiveness at various levels has been associated with digitalization, which was analyzed in their studies e.g. by Dabbous et al. (2023). It results from their findings that the digital transformation plays a key role in attaining sustainable competitiveness and development.

Another approach is manifested at the level of meso competitiveness, and thus the reference of competitiveness to smaller spatial systems (regions, counties, cities, communes). As a consequence the framework of competitiveness has been expanded and territorial competitiveness has been distinguished, within which it is assumed that territorial units (similarly as enterprises) compete with one another to maximize profits and ensure economic growth. In the context of territorial units the attained profit, or rather the principal benefit, is related to an improved quality of life, while economic growth is generated through actions attracting investors, providing skilled labor force or creating an innovative environment, thus ensuring the expected desirable outcomes (Brenner, Wachsmuth, 2012).

As it was stated at the beginning of this chapter, competitiveness in the territorial perspective since the 1980s has been considered a primary problem in the context of local economic development (Krakowiak-Bal, 2019; Brenner, Wachsmuth, 2012). In the theoretical context, territorial competitiveness is directly associated with the concept of meso competitiveness and it is “the capacity of a town or region to generate high and growing income and improvement of living conditions for their inhabitants” (Mitrică et al., 2021, p. 2). Territorial competitiveness is a component of competitiveness at a higher aggregation level (e.g. competitiveness at the macro level), while it is modified also by competitiveness at a lower aggregation level (competitiveness at the micro level) (Józefowicz, 2024). City competitiveness gained popularity in the wake of the World Economic Forum in 1979, when “the best practices and conclusions drawn for the national competitiveness councils” were presented (Abusada, Elshater, 2021).

At present competitiveness in the context of cities is a natural phenomenon, modified by globalization, information technologies and structural transformations (Martin, 2005; Metaxas, 2010). Cities have been competing with one another since they were first established; however, the scope and dimensions of this competition have also been changing. Thus the concepts of city competitiveness have also evolved in response to the identified and emphasized changes (table 2).

**Table 2.**

*Selected definitions of city competitiveness*

<b>Definitions of urban/city competitiveness</b>	<b>Authors</b>
„the ability of an economy to attract and maintain firms with stable or rising market shares in an activity, while maintaining stable or increasing standards of living for those who participate in it”	Storper (1997)
„the capacity of a city to utilize or create a comparative advantage, and thus to generate high and sustainable economic growth in relation to its competitors”	D'Arcy, Keogh (1999)

Cont. table 2.

„ability of an urban region to produce and market a set of products (goods and services) that represent good value (not necessarily lowest price) in relation to comparable products of other urban regions”	Webster, Muller (2000)
“the capacity of a city to attract resources, manufacture products and services, control the market, effectively generate wealth and the ability to ensure prosperity to its inhabitants in the process of competition and development compared to other rivals”	Pengfei, Qinghu (2006)
„ability of city population to maintain competitive position within a specific area (market) of competition among other cities of similar type and pursuing similar aims by conserving resources and improving wellbeing of city members by management of factors of external and internal environment”	Sinkiene (2009)
„the capacity to generate relatively high income and employment level”	Łaźniewska (2010)
„a set of factors – policies, institutions, strategies and processes – that determines the level of sustainable productivity of a city, where sustainability encompasses economic, environmental and social issues”	McKinsey Global Institute (2012)
„ability to attract capital, business, talents and visitors”	Economist Intelligence Unit (2012)
„ability to attract capital, businesses, talent and visitors as a holistic concept, the environment and natural hazards are considered a determining factor”	Hu (2015)
„ability of a city to optimize the allocation of resources in its subordinate large area for its own development, so as to obtain the sustainable growth of urban economy, which is created and maintained under the comprehensive action of many factors such as society, economic structure, values, culture, system and policy”	Zhao et al. (2023)

Source: the author’s study.

According to Metaxas (2010), the concept of city competitiveness should not be limited solely to enterprises operating within its area, but rather reflect the entire reality of urban economy and its capacity to function. This is because a city is not only an economic unit, but a comprehensive socio-economic system constituting the urban environment, where the sphere of economic activity is only one of its segments (Jiang, Shen, 2010). As it was indicated in an earlier part of this paper, initially the problem of competitiveness focused on the economic aspect, but eventually global changes have led to an extension of its scope. It is also manifested in the manner, in which city competitiveness is defined. City competitiveness, identified as the ability to increase productivity and economic growth, is frequently referred to in the cited definitions. It is fully justified, since this is where success, attractiveness and competitive advantage of cities (as well as other entities) is found.

A city is competitive by providing economic entities with opportunities to maximize profits, thus increasing competitiveness of firms. It is an indirect process, in which enterprises operating in a city to some extent generate the quality of life for its inhabitants. On the other hand, it is the urban policy, which while aiming at increasing attractiveness of the city, in turn enhances the quality of life for its inhabitants (Szczech-Pietkiewicz, 2013; Józefowicz, 2024).

## 2.2. City competitiveness in view of selected international and national indexes

Rankings devoted to cities first appeared in the 1970s. One of the first indexes was established by the Swiss bank, UBS. At that time it focused on 72 cities worldwide and on the purchasing capacity of their inhabitants (Szczech-Pietkiewicz, 2019). Those indexes were

primarily concerned with the evaluation of the largest cities, while smaller towns were disregarded in that research.

Such rankings, indexes and evaluations of city competitiveness are prepared by specialized firms, as well as researchers in various scientific centers. Examples of rankings provided by the former group include e.g. Benchmarking Global City Competitiveness (the Economist Intelligence Unit (EIU)), the Global Cities Index (Kearney), the Global Power City Index (Institute for Urban Strategies) and the UK Competitiveness Index (Robert Huggins Institute). These analyses comprise mainly comparisons of competitiveness for the largest cities worldwide. However, there are also examples of reports focusing on cities within a given country, such as the UK Competitiveness Index (UKCI), the India City Competitiveness Report (ICCR) or the Smart City Index in Italy. These in turn are prepared by scientists representing universities or research institutions (more on the subject in Józefowicz, 2024).

Apart from the above-mentioned examples there are also some studies, in which their authors analyze competitiveness of selected cities, typically within a given country (table 3).

**Table 3.**

*A review of selected empirical studies concerning city competitiveness*

Study	Spatial scope (country)	Area of competitiveness (number of indicators)
Sáez, Periañez (2015)	159 cities over 100 thousand inhabitants from 26 EU countries	attract investment (31)
Dönmez, Atalan (2019)	30 cities located in 15 countries worldwide	general (38)
Rosa et al. (2020)	497 cities (Brasil)	competitiveness for the PV installation (18)
Bruneckiene et al. (2010)	24 cities (Lithuania)	general (30)
Bulu (2011)	81 cities (Turkey)	human capital and life quality (14), branding capability and innovation (7), trade capability and production potential (11), accessibility (10)
Józefowicz (2024)	112 small towns (Poland)	social (23), economic (16), environmental (10), general competitiveness
Cabrero Mendoza et al. (2009)	60 cities (Mexico)	general (45)
Hu (2015)	18 cities over 100 thousand inhabitants (Australia)	general (4)
Singhal et al. (2013)	5 cities (India)	general (32)
Kresl (2012)	23 cities (USA)	general (13)
So, Shen (2004)	215 cities (China)	social (20), economic (20), environmental (5)
Zhang et al. (2021)	13 mega-city regions (China)	economic (1), population (3), infrastructural (4), international (3), scientific and technological (4), sustainable (7)
Zhao et al. (2023)	35 cities (China)	general (27)
Guo et al. (2019)	75 cities (China)	tourism (13)
Komasi et al. (2023a)	15 cities over 500 thousand inhabitants (Iran)	environmental (9)
Komasi et al. (2023b)	15 cities over 500 thousand inhabitants (Iran)	socio-cultural (12)

Source: the author's study.

City competitiveness comprises complex components, which may be generally classified to groups of social, economic and environmental factors. In most above-mentioned examples the analysis of city competitiveness focuses on the general approach to the investigated phenomenon (e.g. Bruneckiene et al., 2010; Singhal et al., 2013; Hu, 2015; Dönmez, Atalan, 2019; Zhao et al., 2023).

Investigations concerning selected cities worldwide, conducted by Dönmez and Atalan (2019), showed cities from Europe, the Far East and the USA to be most attractive for investments (e.g. Tokyo, Paris, New York).

In a study on Lithuanian cities conducted by Bruneckiene et al. (2010) it was shown that the geographical location of cities does not have a marked effect on competitiveness of cities. The group of most competitive cities included both industrial, port, university and resort towns. Moreover, a connection was observed between competitiveness of cities and regions. Cities being most competitive are located in the regions, which are also classified as the most competitive.

In turn, a study by Zhao et al. (2023) showed that results of competitiveness measurements for some Chinese cities to a certain extent correspond to the regional economic development and technological innovativeness. Beijing, Shanghai, Shenzhen and Guangzhou were considered to be the most competitive. Considered differences were observed between these key cities and the other ones included in that analysis.

In other cases studies were devoted to a selected aspect of city competitiveness (e.g. Komasi et al., 2023a; Komasi et al., 2023b; Józefowicz, 2024; Rosa et al., 2020; Guo et al., 2019; Bulu, 2011; So, Shen, 2004). Among other things, such an approach made it possible to observe that in the analyzed cities in China (So, Shen, 2004) a lesser cohesion occurred between environmental competitiveness and economic or social competitiveness. In some cities economic or social competitiveness does not necessarily ensure environmental competitiveness. In their studies those authors observed that the advantage of the most competitive cities was based on their high economic and social position.

In the investigations conducted by Józefowicz (2024) a certain regularity was found for competitiveness of small towns in Poland. The environmental aspect was a supplementation to social and economic competitiveness of those towns. Moreover, in the analyzed periods an increased social, economic and environmental integration was reported in the competitiveness of small towns.

In turn, a study by Bulu (2011) concerning Turkish cities revealed regional disparities between cities from eastern and western Turkey. Moreover, in terms of the analyzed aspects of competitiveness considerable differences were observed in the levels of the investigated phenomenon between the cities. Compared to the other cities Istanbul proves to be exceptional. The level of competitiveness for the cities ranking next was markedly lower.

Irrespective of the scale of the analyses and the entities preparing the research results, a common element consisted in the groups of factors, to which the applied indicators may be classified. Both the international and national rankings comprise indicators related to education, entrepreneurship, public health, infrastructure or culture, i.e. areas reflecting the conditions and standard of living in cities. As it was reported by Bruneckiene et al. (2010), the concepts of urban, regional and national competitiveness are closely interrelated. The same tools, methods and benchmarks as in the analysis of regional and national competitiveness may be applied to describe and analyze the concept of city competitiveness.

The analysis conducted by Rosa et al. (2020), which focuses on the aspect of competitiveness in the context of investments in solar energy in cities, represents a distinct departure from the previously mentioned research examples. Concentrating on the attractiveness and competitiveness of cities in this particular region can prove to be a valuable tool, particularly for politicians. The outcomes obtained may aid in focusing resources, such as financial aid, on areas that possess significant potential in this particular domain. The analysis carried out indicated areas with favorable locations for the use of this energy source.

It is also worth mentioning that the review of empirical studies on urban competitiveness covered scientific publications published between 2004 and 2024. Although examples of studies from the past 20 years were identified, no significant changes were observed in terms of either the spatial scope or aspects of competitiveness. Research interests focused on a general approach. In terms of territorial scope, the largest cities represent the largest area of interest regarding competitiveness within an urban context (in example Hu (2015), Shan et al. (2012)).

The significance of large cities was recognized in the studies conducted by Bulu (2011) and Józefowicz (2024). Bulu (2011) found that the largest cities were the most competitive, while Józefowicz (2024) found that small towns located near large cities often achieved high competitive positions.

As it was indicated e.g. by Komasi et al. (2022), quantitative studies concerning city competitiveness are not only attempts to identify the competitive position, but rather they represent the need for continuous identification and utilization of the competitive potential of cities. Obviously a significant or even a primary obstacle in the comprehensive approach to this measurement is connected with the availability of quantitative data, which may have possibly resulted in the focus on the general evaluation of city competitiveness (as indicated e.g. by Bruneckiene et al. (2010)).

### 3. Concluding remarks

For a long time now the problem of competitiveness has no longer been connected with the micro level (enterprises), becoming rather a point of interest referring to countries, regions or cities. Competitiveness has proven to be a commonly investigated notion and considered, among other things, to be the foundation for the socio-economic development of countries (Dabbous et al., 2023). Competitiveness is seen fully justified at the meso level in view of the role played e.g. by cities in providing firms with competitive environmental conditions or facilitating accumulation of knowledge. In recognition of the growing importance of the human capital, including knowledge, in the generation of economic growth and competitiveness it should be stated that the importance of territorial competitiveness, primarily cities, will be maintained. This is because the concentration of labor and knowledge resources is highest in cities.

Based on a thorough review of selected scientific publications, it is imperative to articulate the necessity for research in the domain of medium-sized and small towns. Socio-economic changes are also reaching these areas. It is frequently the largest cities that are responsible for the transformation of smaller towns. They can lead to a reduction in socio-economic functions in cities located far from regional centres or a remodelling of the functional structure in cities located close to the largest cities. These cities are also involved in a process of competition.

The literature review indicates that there are two approaches to research city competitiveness: general and partial. The general approach compares different socio-economic features and then determines the level of competitiveness using various statistical methods. The partial approach focuses on selected aspects, such as culture, economy, and environment. However, it is worth noting that the research by Rosa et al. (2020) allows us to identify another approach, which involves focusing on a selected segment of a given aspect. This opens up opportunities for a more thorough approach to assessing city competitiveness.

As it was stated by Kresl (2012), rankings provide cities with a certain potential for promotion and marketing among similar entities. They need to be considered a key tool for the understanding of processes related to urban transformation. However, both the merit and sense are intrinsically related to the analytical interpretation and thus, identifying factors determining competitiveness of a given city. As a consequence, they constitute a source of information, which sometimes provides outcomes differing from initial assumptions. Although the evaluation of city competitiveness at least at the national level may be hindered by many problems related to reliable measurements, updating the proposed indicators is necessary and crucial in order to facilitate identification of the city potential.

## Acknowledgements

Funding: This work was supported by the Poznań University of Life Sciences under the research program “First grant” No. 8/2023.

## References

1. Abusaada, H., Elshater, A. (2021). Competitiveness, distinctiveness and singularity in urban design: A systematic review and framework for smart cities. *Sustainable Cities and Society*, 68, 102782. <https://doi.org/10.1016/j.scs.2021.102782>.
2. Aiginger, K. (1998). A framework for evaluating the dynamic competitiveness of countries. *Structural Change and Economic Dynamics*, 2, pp. 159-188.
3. Borowiecki, R., Siuta-Tokarska, B. (2015). Konkurencyjność przedsiębiorstw i konkurencyjność gospodarki Polski - zarys problemu. *Nierówności Społeczne a Wzrost Gospodarczy*, 41, pp. 52-66.
4. Brenner, N., Wachsmuth, D. (2012). Territorial Competitiveness: Lineages, Practices, Ideologies. In: B. Sanyal, L.J. Vale, C.D. Rosan (eds.), *Planning Ideas That Matter: Livability, Territoriality, Governance, and Reflective Practice* (pp. 179-204). Londyn: The MIT Press.
5. Bruneckiene, J., Guzavicius, A., Cincikaite, R. (2010). Measurement of Urban Competitiveness in Lithuania. *Inzinerine Ekonomika-Engineering Economics*, 21(5), pp. 493-508.
6. Bulu, M. (2011). Measuring competitiveness of cities: Turkish experience. *International Journal of Knowledge-Based Development*, 2(3), pp. 267-281. 10.1504/IJKBD.2011.042522.
7. Cabrero Mendoza, E., Orihuela Jurado, I., Ziccardi Contigiani, A. (2009). Competitividad urbana en México: una propuesta de medición. *Revista Eure*, 106, pp. 79-99.
8. Dabbous, A., Barakat, K.A., Kraus, S. (2023). The impact of digitalization on entrepreneurial activity and sustainable competitiveness: a panel data analysis. *Technology in Society*, 73, 102224. <https://doi.org/10.1016/j.techsoc.2023.102224>.
9. D'Arcy, É., Keogh, G. (1999). The property market and urban competitiveness: A review. *Urban Studies*, 5/6, pp. 917-928.
10. Delgado, M., Ketels, C., Porter, M., Stern, S. (2012). *The Determinants of National Competitiveness*. Cambridge: National Bureau of Economic Research Working Paper Series (18249).

11. Dijkstra, L., Annoni, P., Kozovska, K. (2011). *A New Regional Competitiveness Index: Theory, Methods and Findings*. Working Paper (No. 2). European Commission.
12. Dönmez, C.C., Atalan, A. (2019). Developing Statistical Optimization Models for Urban Competitiveness Index: Under the Boundaries of Econophysics Approach. *Complexity*, 19, <https://doi.org/10.1155/2019/4053970>.
13. Economist Intelligence Unit (2012). *Hot spots. Benchmarking global city competitiveness*. London/New York/Hong Kong/Genewa: The Economist Intelligence Unit Limited.
14. Frączek, P. (2009). Determinanty konkurencyjności sektorów i przedsiębiorstw. Ujęcie teoretyczne. *Przedsiębiorstwo i Region*, 1, pp. 7-17.
15. González Catalán, S. (2021). Regional competitiveness in Latin America: a comparative study of the key elements for regional performance. *Investigaciones Regionales – Journal of Regional Research*, 2, pp. 125-146.
16. Guo, S., Jiang, Y., Long, W. (2019). Urban tourism competitiveness evaluation system and its application: Comparison and analysis of regression and classification methods. *Procedia Computer Science*, 162, pp. 429-437. [10.1016/j.procs.2019.12.007](https://doi.org/10.1016/j.procs.2019.12.007).
17. Hatzichronoglou, T. (1996). *Globalisation and Competitiveness: Relevant Indicators; OECD Science*. Technology and Industry Working Papers. Paris.
18. Hu, R. (2015). Sustainability and Competitiveness in Australian Cities. *Sustainability*, 7, pp. 1840-1860. [doi:10.3390/su7021840](https://doi.org/10.3390/su7021840).
19. Huggins, R., Izushi, H., Thompson, P. (2013). Regional Competitiveness: Theories and Methodologies for Empirical Analysis. *Journal of Centrum Cathedra: The Business and Economics Research Journal*, 6(2), pp. 155-172. <https://ssrn.com/abstract=2332832>
20. Jiang, Y., Shen, J. (2010). Measuring the urban competitiveness of Chinese cities in 2000. *Cities*, pp. 307-314.
21. Józefowicz, K. (2024). *Konkurencyjność małych miast w Polsce i jej uwarunkowania*. Warszawa: Difin.
22. Ketels, C. (2016). *Competitiveness Frameworks Review. An Analysis Conducted for the National Competitiveness Council*. Dublin: National Competitiveness Council.
23. Komasi, H., Hashemkhani Zolfani, S., Prentkovskis, O., Šaparauskas, P. (2022). Urban Competitiveness: Identification and Analysis of Sustainable Key Drivers (A Case Study in Iran). *Sustainability*, 14, 7844. <https://doi.org/10.3390/su14137844>.
24. Komasi, H., Nemati, A., Zolfani, S.H., Kahvand, M., Antuchevičienė, J., Šaparauskas, J. (2023a). Assessing the environmental competitiveness of cities based on a novel MCDM approach. *Journal of Competitiveness*, 15(2), pp. 121-150. <https://doi.org/10.7441/joc.2023.02.07>.
25. Komasi, H., Zolfani, S.H., Nemati, A. (2023b). Evaluation of the social-cultural competitiveness of cities based on sustainable development approach. *Decision Making: Applications in Management and Engineering*, 6(1), pp. 583-602. <https://doi.org/10.31181/dmame06012023k>.



26. Krakowiak-Bal, A. (2019). *Zrównoważona konkurencyjność obszarów wiejskich w województwie małopolskim - ujęcie wielokryterialne*. Warszawa: C.H. Beck.
27. Kresl, P.K. (2012). Urban competitiveness and US metropolitan centres. *Urban Studies*, pp. 239-254.
28. Krugman, P. (1994). Competitiveness: A Dangerous Obsession. *Foreign Affairs*, 2, pp. 28-44.
29. Łażniewska, E. (2010). Konkurencyjność miast w teorii i praktyce. In: M. Nowak, T. Skotarczak (Eds.), *Zarządzanie miastem. Studium ekonomiczne i organizacyjne*. Warszawa: CeDeWu.
30. Łażniewska, E., Chmielewski, R., Nowak, P. (2012). Definicje, modele i studia nad regionalną konkurencyjnością. In: E. Łażniewska, M. Gorynia (eds.). *Konkurencyjność regionalna. Koncepcje – strategie – przykłady*. Warszawa: PWN.
31. Lee, J., Karpova, E. (2018). Revisiting the competitiveness theory in the new global environment: review and analysis of the competitiveness definition. *International Journal of Competitiveness*, 3, pp. 189-205.
32. Malecki, E.J. (2007). Cities and regions competing in the global economy: Knowledge and local development policies. *Environment and Planning C: Government and Policy*, 25(5), 638-654. dx.doi.org/10.1068/c0645.
33. Martin, R. (2005). *Thinking About Regional Competitiveness: Critical Issues*. Background 'Think-Piece' Paper Commissioned by the East Midlands Development Agency. Cambridge: Nottingham Trent University.
34. Martin, R., Simmie, J. (2008). The theoretical bases of urban competitiveness: does proximity matter? *Revue d'Économie Régionale & Urbaine*, 3, pp. 333-351.
35. Martus, B. (2013). The Role of Unemployment in the Regional Competitiveness. In: I. Lengyel, Z. Vas (eds.), *Regional Growth, Development and Competitiveness* (pp. 126-140). Szeged: University of Szeged.
36. McKinsey Global Institute (2012). *Urban World: Cities and the Rise of the Consuming Class, Working Paper*. Washington, D.C.: McKinsey Global Institute.
37. Metaxas, T. (2010). Cities competition, place marketing and economic development in South Europe: the Barcelona case as FDI destination. *Theoretical and Empirical Researches in Urban Management*, 5(14), pp. 5-19.
38. Mitrică, B., Dumitrașcu, M., Mocanu, I., Grigorescu, I., Șerban, P.-R. (2021). Territorial competitiveness, cohesion and sustainability in Romania's urban border areas. *Geografisk Tidsskrift. Danish Journal of Geography*, 65(3), pp. 1-26. 10.15292/geodetski-vestnik.2021.03.440-458.
39. Peneder, M., Rammer, C. (eds.) (2018). *Measuring Competitiveness*. Wien: Austrian Institute of Economic Research.
40. Pengfei, N., Qingh, H. (2006). *Comparative Research on the Global Urban Competitiveness*. Beijing: Chinese Academy for Social Sciences.

41. Podlińska, O. (2015). Infrastruktura jako czynnik konkurencyjności polskich regionów na tle Unii Europejskiej. *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu*, 17(5), pp. 213-218.
42. Porter, M. (1990). The Competitive Advantage of Nations. *Harvard Business Review*, pp. 73-91.
43. Radło, M.J. (2008). Międzynarodowa konkurencyjność gospodarki. Uwagi na temat definicji, czynników i miar. In: W. Bieńkowski, Z. Czajkowski, M. Gomułka, B. Brocka-Palacz, E. Latoszek, J. Misala, M.-J. Radło, M. Weresa, *Czynniki i miary międzynarodowej konkurencyjności gospodarek w kontekście globalizacji – wstępne wyniki badań* (pp. 75-100). Warszawa: Instytut Gospodarki Światowej; Szkoła Główna Handlowa.
44. Rosa, B.R., Wendt, J.F.M., Chaves, D.M.S., Thomasi V., Michels, L., Siluk, J. (2020). Mathematical modeling for the measurement of the competitiveness index of Brazil south urban sectors for installation of photovoltaic systems. *Energy Policy*, 136, 111048. <https://doi.org/10.1016/j.enpol.2019.111048>.
45. Sáez, L., Periañez, I. (2015). Benchmarking urban competitiveness in Europe to attract investment. *Cities*, 48, pp. 76-85.
46. Saygin, M. (2023). Competitiveness of the Cities: Branding and Positioning. *International Journal of Professional Business Review*, 8(6), e02210. <https://doi.org/10.26668/businessreview/2023.v8i6.2210>.
47. Schwab, K., Porter, M.E. (2007). *The Global Competitiveness Report 2007-2008*. Geneva, Switzerland: World Economic Forum.
48. Singhal, S., McGreal, S., Berry, J. (2013). Application of a hierarchical model for city competitiveness in cities of India. *Cities*, 31, pp. 114-122. <https://doi.org/10.1016/j.cities.2012.05.012>.
49. Sinkiene, J. (2009). Competitiveness Factors of Cities in Lithuania. *Viesoji Politika ir Administravimas*, 29, pp. 47-53.
50. So, M.S., Shen, J. (2004). Measuring urban competitiveness in China. *Asian Geographer*, 23(1-2), pp. 71-91. <https://doi.org/10.1080/10225706.2004.9684113>.
51. Storper, M. (1997). *The Regional World*. New York: Guilford Press.
52. Szczech-Pietkiewicz, E. (2013). Miasto konkurencyjne jako koncepcja i jej realizacji w Polsce. *Studia Humanistyczne AGH*, 12(4), pp. 35-52.
53. Szczech-Pietkiewicz, E. (2019). *Konkurencyjność miast w kontekście współczesnych koncepcji teoretycznych i zjawisk gospodarczych*. Warszawa: Oficyna Wydawnicza SGH.
54. Webster, D.R., Muller, L. (2000). *Urban competitiveness assessment in developing country urban regions: the road ahead*. Paper prepared for Urban Group, INFUD\*. Washington, D.C.: The World Bank.
55. Zhang, F., Lou, X., Ning, Y. (2021). The comparative study of China's mega-city regions: A perspective of competitiveness. *Growth and Change*, 52(1), pp. 425-442, <https://doi.org/10.1111/grow.12422>.

- 
56. Zhao, L., Fenga, Y., Zhanga, H., Liu, L. (2023). Evaluation of urban competitiveness based on factor analysis— Taking 35 key cities in China as an example. *Procedia Computer Science*, 221, pp. 130-137. 10.1016/j.procs.2023.07.019.
57. Zielenkiewicz, M. (2016). Konkurencyjność krajów UE w świetle globalnego kryzysu finansowego. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No. 449, Ekonomia*, pp. 740-751.



## ATTRIBUTES OF AN AGILE ORGANIZATION LEADER IN THE LIGHT OF OWN RESEARCH

Maria KOCOT<sup>1\*</sup>, Małgorzata GOLIŃSKA-PIESZYŃSKA<sup>2</sup>, Artur KWASEK<sup>3</sup>

<sup>1</sup> University of Economics in Katowice; maria.kocot@ue.katowice.pl, ORCID: 0000-0001-9240-857X

<sup>2</sup> Lodz University of Technology, Faculty of Organization and Management;  
malgorzata.golinska-pieszynska@p.lodz.pl, ORCID: 0000-0003-1088-4746

<sup>3</sup> University of Technology and Economics in Warsaw; artur.kwasek@uth.edu.pl,  
ORCID: 0000-0003-4386-1444

\* Correspondence author

**Purpose:** The purpose of this article is to identify and analyze the key attributes of leaders of agile organizations and to examine the extent to which these characteristics affect management effectiveness in a dynamic business environment. The survey aims to provide knowledge that can be used to develop the competencies of leaders in agile organizations.

**Design/methodology/approach:** The research was conducted in 2023 on a sample of 632 respondents, including leaders and managers from various industries. A survey methodology was used in which respondents rated eight key characteristics of an agile organization leader on a five-point scale. Sociodemographic data of respondents, such as gender, place of residence, professional activity, and type and year of study, were included in the analysis to provide a broad cross-section of data.

**Findings:** Research has shown that the most important attributes of leaders of agile organizations are: constantly looking for new ideas, taking advantage of opportunities, initiating new projects, creativity in action, speed in decision-making, willingness to take risks, quick adaptation to changing conditions, and extensive knowledge. The high correlation between these traits suggests that the presence of one trait favors the presence of others, confirming their interaction and importance for effective leadership.

**Research limitations/implications:** Research was limited to a single group of respondents, which may not fully represent the leadership population of agile organizations. In addition, the self-assessment method may have affected the subjectivity of the results. The lack of additional verification methods, such as in-depth interviews, may have limited the full understanding of the attributes studied.

**Practical implications:** The results of the research can be used to shape training programs and talent management strategies that promote the development of key leadership attributes of agile organizations. Organizations should focus on fostering creativity, quick decision-making, and a willingness to take risks.

**Social implications:** Agile leadership has the potential to significantly impact an organization's effectiveness and their ability to adapt in a changing business environment, which can help to improve market competitiveness.

**Originality/value:** The article provides new insight into the key attributes of leaders of agile organizations, highlighting their interconnectedness and importance for effective management. The research provides practical guidance for organizations seeking to increase their agility and competitiveness.

**Keywords:** organizational leader, agile organization, leadership attributes, organization, organizational agility.

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

## 1. Introduction

In a rapidly changing business environment, organizations need to be agile and able to respond quickly to change to stay competitive. Agile management methods such as Scrum or Kanban have become standard in many industries, especially in the IT sector, where variability and speed of action are crucial for success. In such conditions, leaders play the role of not only managers, but also mentors and coaches who support the development of teams and promote a culture of innovation and continuous improvement (Kurnia, Chien, 2020).

Therefore, it is important to understand what qualities and skills are necessary for leaders to function effectively in agile organizations. Research on the attributes of leaders of agile organizations provides valuable information that can be used to shape training programs and talent management strategies. Understanding these attributes is crucial for creating effective teams that can quickly adapt to new challenges and take advantage of opportunities.

The literature emphasizes that leaders of agile organizations must be creative, willing to take risks, and able to make decisions quickly and adapt to changing conditions (Akkaya, 2021). Examples from companies like Google and Spotify show that agile leadership can lead to a significant competitive advantage. These leaders must also have the broad knowledge and competencies that allow them to effectively manage teams and projects in a dynamic work environment (Rigby, Sutherland, Takeuchi, 2016; Denning, 2018).

The purpose of this article is to identify and understand the key attributes of an agile organization leader and to determine to what extent these characteristics are related. The research allows us to identify the key features that are necessary for effective leadership in agile organizations, and to understand how these features complement each other and affect management effectiveness. The analysis of the results allows for the formulation of recommendations for management practitioners, which can be used to develop the competencies of leaders in agile organizations.

## **2. Literature Review**

### **2.1. Agile organization and its determinants**

An agile organization is characterized by flexibility, adaptability, and quick response to changing market conditions (Kocot, Kwasek, 2022). The literature emphasizes that the essence of organizational agility is the ability to quickly adapt to new circumstances by shortening decision-making and operational cycles (Rigby, Sutherland, Takeuchi, 2016). Agile organizations are customer-centric, meaning they focus on delivering value and satisfaction to customers, which is accomplished through continuous and iterative processes to improve products and services (Denning, 2018).

An important determinant of an agile organization is an organizational culture that supports innovation, collaboration, and learning. These organizations promote open communication and transparency, which enables quick problem solving and decision-making at all levels of the organizational structure (Schein, 2010). In addition, agile organizations often use project management methodologies such as Scrum or Kanban, which enable effective management of the work of teams and rapid delivery of value (Schwaber, Sutherland, 2017).

Technology plays a key role in agile organizations, enabling process automation, better data analytics, and faster decision-making. Information systems and digital tools support collaboration and facilitate knowledge and innovation management (Westerman, Bonnet, McAfee, 2014). Examples of agile organizations such as Spotify or Google show that agility can lead to a significant competitive advantage in the market (Kniberg, Ivarsson, 2012).

In the context of an agile organization, leadership and change management are also crucial (Mycka, 2023). Leaders in agile organizations act as mentors and coaches, supporting team development and promoting an approach based on experimentation and learning from mistakes (Kotter, 1996). Agility also requires an organization to be able to continuously improve and adapt, which is accomplished through regular retrospections and performance analyses (Beck et al., 2001).

### **2.2. Attributes of agile workers**

Agile employees are key elements of the success of agile organizations (Fiddler, 2017; He, Harris, 2021; Rahimi, Mansouri, 2019). They are characterized by a number of qualities and skills that allow them to function effectively in a dynamic and unpredictable work environment. One of the primary attributes of agile workers is cognitive flexibility, which allows them to quickly adapt to new information and changing circumstances (DeRue, Ashford, Myers, 2012). These employees are open to change and can adapt quickly to new roles and tasks, which is crucial in an environment that requires constant adaptation (Seifollahi, Shirazian, 2021).

Another important attribute is the ability to cooperate and work as a team. Agile employees communicate effectively with others, both inside and outside the team, which allows them to effectively solve problems and achieve goals together (Edmondson, 2012). The ability to listen and openness to feedback are key in the process of iterative improvement, which is the foundation of agile work methodologies. In addition, agile employees have a high level of self-organization, which means that they can manage their time and tasks without the need for constant supervision (Hacker, 2018).

Innovation and creativity are other attributes that distinguish agile employees. They are able to generate new ideas and take initiatives (Chen, Li, 2021) that contribute to the continuous development of the organization (Amabile, 1996). As a result, they are able to quickly respond to customer needs and adapt products and services to changing market conditions. Agile workers often adopt an experimental mindset, where setbacks are treated as valuable lessons rather than obstacles (Carmeli, Gittell, 2009).

Agile employees also possess strong analytical skills. They are able to collect and analyze data, which allows them to make decisions based on facts rather than intuition (Davenport, Harris, 2007). This allows them to better predict the effects of their actions and adjust strategies in real time. Data analysis also allows you to identify trends and patterns that can be used to optimize processes and increase efficiency (Skyrius, Valentukevič, 2020).

An important attribute of agile employees is also a high level of commitment and motivation. These employees are determined to perform at high performance and constantly strive to improve their skills and knowledge (Ryan, Deci, 2000). The high level of autonomy and responsibility that is characteristic of agile working methods promotes intrinsic motivation and job satisfaction (Pink, 2009). Leadership skills cannot be forgotten either, which are important even at lower organizational levels. Agile employees often take on leadership roles in their teams, inspiring others and fostering a culture of innovation and collaboration (Goleman, 2000). The ability to influence others and manage conflict effectively is crucial in maintaining harmony and productivity within a team (Prieto, Talukder, 2023).

Agile employees also have a proactive approach to problem solving. Instead of waiting for problems to arise, they take the initiative to anticipate them and act preventively, which allows them to respond quickly to challenges and minimize their impact on the organization (Crant, 2000). This proactivity is associated with a willingness to continuously learn and develop, which is essential in a rapidly changing work environment (Sedej, Justinek, 2021).

In summary, the attributes of agile workers include cognitive flexibility, collaborative skills, self-organization, innovation, analytical skills, commitment, leadership, and proactivity. These qualities allow them to function effectively in agile organizations and contribute to their success.



### **2.3. The role of a leader in an agile organization and his attributes**

The role of a leader in an agile organization is crucial to its success. Leaders in such organizations not only lead teams, but also act as mentors and coaches, supporting employee development and promoting a culture of innovation and cooperation. Leaders must possess a number of specific attributes that enable them to function effectively in a dynamic and unpredictable work environment (The First Pillar, 2020).

One of the most important attributes of a leader in an agile organization is the willingness to constantly look for new ideas and take advantage of opportunities. Leaders must be open to innovation and constantly monitor the environment for opportunities that can benefit the organization (Rigby, Sutherland, Takeuchi, 2016). Leaders who can initiate new projects and respond quickly to changing market conditions contribute to the competitiveness of their companies (Denning, 2018).

Creativity in action is another key attribute of an agile organization leader. Research on organizational agility indicates that leaders who can think outside the box and implement innovative solutions are more effective in achieving organizational goals (Amabile, 1996). However, this creativity must be supported by extensive knowledge and competencies that allow leaders to effectively manage teams and projects (Westerman, Bonnet, McAfee, 2014).

Speed in action and decision-making is another important attribute of leaders in agile organizations (Chen, Siau, 2020; Ramadhana, 2021; Routledge, 2020). Efficiency in decision-making is essential in a dynamic environment where delays can lead to a loss of competitiveness (Schwaber, Sutherland, 2017). Leaders must be willing to take risks and adapt more quickly to changing conditions, which requires both courage and the ability to learn quickly from mistakes (Kotter, 1996).

The literature on the subject also emphasizes the importance of the broad knowledge and competences of leaders, which enable them to effectively manage teams and projects (Hacker, 2018). Leaders must not only be experts in their field, but also have interpersonal skills that allow them to communicate effectively with employees and build trust within the team (Goleman, 2000). Listening skills and openness to feedback are key to creating a culture of collaboration and continuous improvement.

Willingness to take risks is also an essential attribute of leaders in agile organizations. Leaders must be able to respond quickly to changing market conditions and make decisions that may involve some risk but at the same time bring significant benefits to the organization (Carmeli, Gittel, 2009). Examples of leaders who can adapt quickly to new challenges show that this approach can lead to success even in the most unpredictable conditions (Kt, Sivasubramanian, 2023).

In conclusion, the role of a leader in an agile organization is extremely complex and requires many specific attributes, such as constant search for new ideas, creativity, speed in action, willingness to take risks, and extensive knowledge and competence. These qualities enable leaders to effectively manage teams and contribute to the success of agile organizations.

#### **2.4. Research Methodology**

This article presents the results of research that was conducted in 2023. The aim of the research was to identify and understand the key attributes of an agile organization leader and to determine to what extent these traits are related. The research was aimed at verifying which of the above-mentioned attributes are the most important for effective leadership in dynamically changing conditions and how these attributes interact with each other in management practice.

The research hypothesis assumed that leaders of agile organizations are characterized by a high level of creativity, willingness to take risks, quick adaptation to changing conditions and constant search for new ideas, and these characteristics are closely related. Research questions were formulated: Which of the attributes of a leader are most often considered key in the context of an agile organization? How strong are the correlations between the individual characteristics of a leader and what are the most important characteristics of an agile organization leader according to the respondents? The research methodology involved surveying 632 respondents who rated eight key characteristics of a leader on a five-point scale.

The research conducted on a group of 632 respondents took into account a variety of sociodemographic data. The research sample consisted of 380 women and 252 men. The respondents lived in different types of towns: 161 people lived in cities with a population of 51 to 200 thousand, 56 people came from cities with more than 200 thousand inhabitants, 69 people lived in cities with a population of 21 to 50 thousand, 57 people lived in cities with a population of up to 20 thousand, and 289 people came from rural areas.

The economic activity of the respondents varied: 66 people were not employed, 434 people were permanently employed, 96 people were casual workers, 25 people were self-employed, 19 people were running a farm, and 10 people were combining permanent work with running a business. The type of study also differentiated the research group: 124 people studied full-time (full-time) and 508 part-time (part-time). As for the year of study, 286 people were in the second year, 218 in the fifth year, 51 in the third year, 19 in the fourth year, 59 in the first year.

#### **2.5. Presentation of Research Findings**

As part of the research conducted on the agile attributes of an organizational leader, data was collected from 632 respondents. Table 1 presents the results of the assessment of various characteristics of a leader on a five-point scale: Definitely NO, Rather NO, I have no opinion, Rather YES, Definitely YES.

**Table 1.***Agile Attributes of an Organizational Leader, N = 632*

	<b>Definitely NOT</b>	<b>Rather NOT</b>	<b>No opinion</b>	<b>Rather YES</b>	<b>Definitely YES</b>
Constantly seeking new ideas (1)	12	48	79	326	167
Utilizing arising opportunities (2)	9	41	91	329	162
Initiating new projects (3)	16	94	169	261	92
Creativity in action (4)	8	37	92	308	187
Speed in action and decision making (5)	18	106	121	271	116
Willingness to take risks (6)	35	153	133	221	90
Quick adaptation to changing conditions (7)	7	35	82	346	162
Broad knowledge (8)	12	40	118	317	145

Source: Own work based on conducted research.

In the category "Constantly looking for new ideas", 12 respondents indicated "Definitely NO", 48 "Rather NO", 79 "I have no opinion", 326 "Rather YES" and 167 "Definitely YES". In terms of "Taking advantage of opportunities", 9 people rated this trait as "Definitely NO", 41 as "Rather NO", 91 as "I have no opinion", 329 as "Rather YES", and 162 as "Definitely YES".

For the "Initiating new projects" feature, 16 respondents chose "Definitely NO", 94 "Rather NO", 169 "I have no opinion", 261 "Rather YES", and 92 "Definitely YES". Creativity in action was rated as "Definitely NO" by 8 respondents, "Rather NO" by 37, "I have no opinion" by 92, "Rather YES" by 308, and "Definitely YES" by 187 respondents.

Speed in action and decision-making was rated as "Definitely NO" by 18 respondents, "Rather NO" by 106, "I have no opinion" by 121, "Rather YES" by 271, and "Definitely YES" by 116 people. Willingness to take risks was rated as "Definitely NO" by 35 respondents, "Rather NO" by 153, "Not in my opinion" by 133, "Rather YES" by 221 and "Definitely YES" by 90 people.

In the category "Quick adaptation to changing conditions", 7 respondents indicated "Definitely NO", 35 "Rather NO", 82 "I have no opinion", 346 "Rather YES" and 162 "Definitely YES". On the other hand, the leader's broad knowledge was rated as "Definitely NO" by 12 respondents, "Rather NO" by 40, "I have no opinion" by 118, "Rather YES" by 317, and "Definitely YES" by 145 people.

In the context of the research conducted on the agile attributes of an organizational leader, the correlation table (Table 2) shows the degree of interdependence between various characteristics of a leader. All attributes show a high correlation with each other, suggesting that these traits are strongly related.

**Table 2.***Correlation Table, N = 632*

	1	2	3	4	5	6	7	8
1	1							
2	0,99	1						
3	0,83	0,85	1					
4	0,99	0,99	0,81	1				
5	0,93	0,94	0,95	0,90	1			
6	0,72	0,73	0,91	0,68	0,92	1		
7	0,99	0,99	0,84	0,98	0,93	0,73	1	
8	0,98	0,99	0,90	0,97	0,95	0,76	0,98	1

Source: Own work based on conducted research.

"Constantly looking for new ideas" (1) shows a very high correlation with "seizing opportunities" (2) and "creativity in action" (4), suggesting that leaders who seek out new ideas are often also creative and willing to take advantage of opportunities. The correlation between these traits is 0.99 and 0.99, respectively. Similarly, there is a high correlation between "seizing opportunities" (2) and "creativity in action" (4) and "adapting quickly to changing conditions" (7), at 0.99 and 0.99.

"Initiating new projects" (3) is strongly associated with "creativity in action" (4) and "speed in action and decision-making" (5), as evidenced by correlations of 0.81 and 0.95. This suggests that leaders initiating new projects are often creative and quick to act. "Speed in action and decision-making" (5) also has a high correlation with "willingness to take risks" (6) and "broad knowledge" (8), amounting to 0.92 and 0.95, respectively.

"Willingness to take risks" (6) correlates highly with "rapid adaptation to changing conditions" (7), which means a correlation of 0.73. This is important because risk-taking leaders tend to adapt quickly to change.

"Broad knowledge" (8) has a high correlation with most traits, especially "creativity in action" (4) and "rapid adaptation to changing conditions" (7), as evidenced by correlations of 0.97 and 0.98. These results indicate that knowledgeable leaders are also creative and adaptable.

Thus, Table 2 indicates that the agile attributes of a leader are closely related, which may suggest that the presence of one trait favors the presence of others. All attributes show a very high correlation with each other, which confirms the complexity and interplay of the characteristics of an agile organization leader.

Scientific research has shown that the agile attributes of an organizational leader are closely related, suggesting that these qualities complement and support each other. Leaders who are constantly looking for new ideas also show high creativity in action and a tendency to take advantage of opportunities. The high correlation between these traits indicates their synergistic effect, which is crucial for effective leadership in dynamically changing conditions.

## 2.6. Discussion

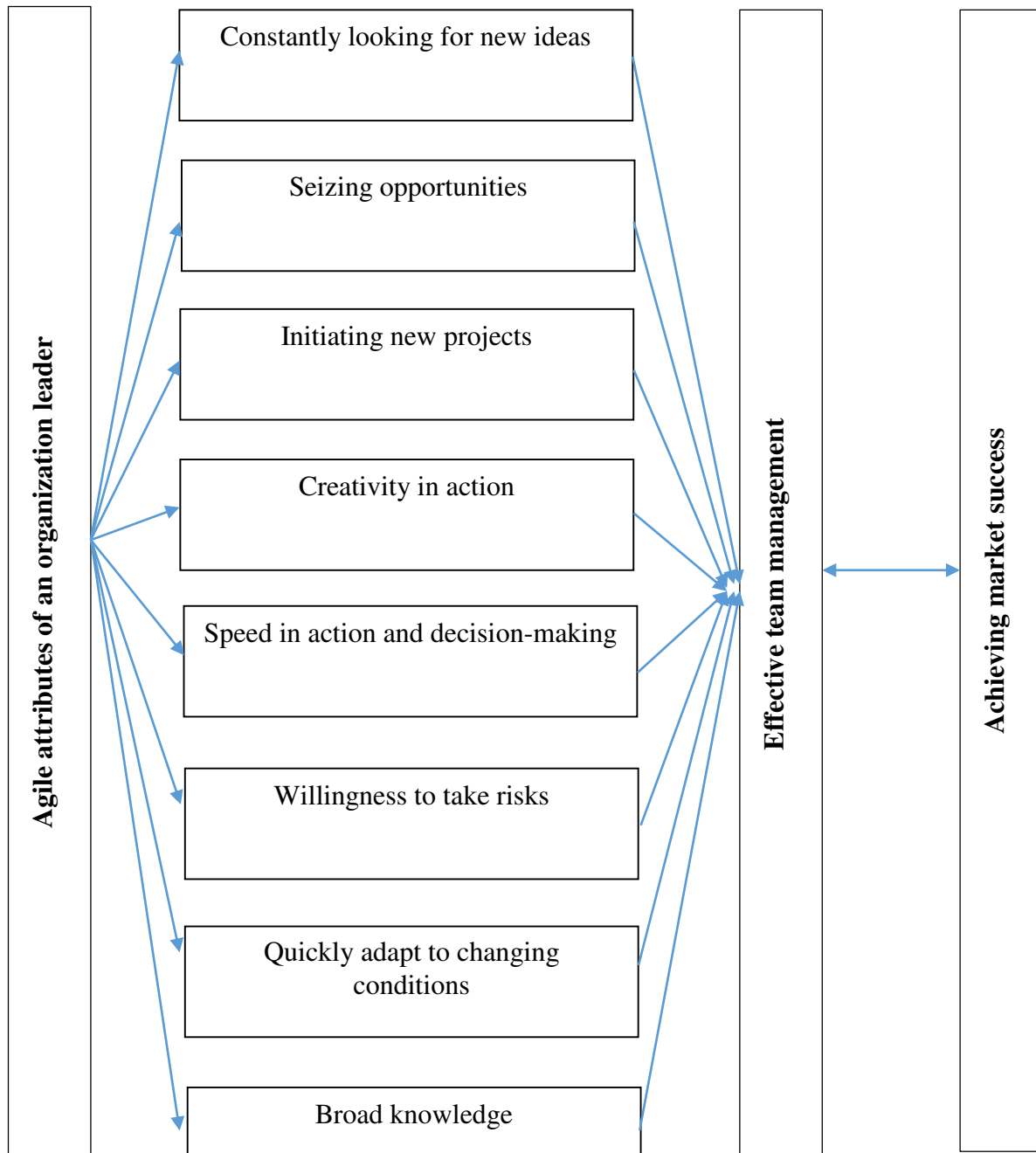
The analysis of the research allowed us to specify the attributes of a leader that are of key importance for achieving market success in agile organizations. Figure 1 illustrates these attributes in the context of their impact on effective team management and ultimately achieving success in the market. The identified characteristics, such as constant search for new ideas, taking advantage of opportunities, initiating new projects, creativity in action, speed in decision-making, willingness to take risks, quick adaptation to changing conditions and extensive knowledge, complement and support each other.

Figure 1 highlights that effective team and project management in a dynamic business environment is closely related to the presence and development of these attributes. The effectiveness of a leader in an agile organization depends on his or her ability to integrate these qualities into daily management practice. The high correlation between the individual attributes suggests that leaders who can effectively use these traits are better equipped to meet challenges and take advantage of emerging market opportunities.

The research has shown that initiating new projects is strongly associated with creativity and speed in decision-making. This suggests that leaders who are proactive and take new initiatives are also quick to act and make decisions. This speed is also linked to risk readiness, highlighting the importance of flexibility and adaptability in agile organizations. A willingness to take risks has a high correlation with rapid adaptation to changing conditions, indicating that leaders who are willing to take risks also have the ability to adapt quickly in the face of change. Leaders' broad knowledge is also closely linked to creativity and adaptability, which highlights the importance of comprehensive competencies in effective management.

The high mutual correlation of all the examined attributes of an agile organization leader confirms that these traits are crucial for effective leadership and management in a dynamic environment. The presence of one trait promotes the presence of others, suggesting that developing these traits can bring significant benefits to the organization. Research highlights the complexity and interplay of leader attributes, which is essential for understanding how to create and support effective leaders in agile organizations.

Based on the findings of the research conducted, it is recommended that agile organizations focus on developing the key attributes of their leaders. Above all, organizations should promote a culture of constant search for new ideas, fostering creativity and innovation in action. It is worth investing in training and development programs that emphasize developing the ability to take advantage of opportunities, which will allow leaders to more effectively manage change and adapt to a dynamically changing environment.



**Figure 1.** Agile attributes of an organizational leader and achieving market success.

Source: Own study.

It is also important to promote broad knowledge and continuous education of leaders so that they are able to adapt quickly to changing conditions. Organisations should provide access to a variety of sources of knowledge and encourage participation in training and industry conferences. Fostering interdisciplinary collaboration and exchange of experiences can further strengthen leaders' ability to solve problems creatively.

In summary, agile organizations should strive to create an environment that fosters the development and enhancement of key leadership attributes such as creativity, quick decision-making, risk appetite, and broad knowledge. Investing in these areas will benefit from more effective leadership and better adaptation to changing market conditions.

There were some limitations in the studies that could affect the results and their interpretation. First of all, the research was limited to one group of respondents, consisting of 632 people, which may not fully represent the population of leaders of agile organizations. In addition, the demographic structure of respondents, including their place of residence, professional activity, and type and year of study, may have influenced the perception and rating of a leader's attributes.

A methodology based on respondents' self-assessment can lead to subjective assessments that do not always reflect the actual characteristics of leaders. This effect could have been intensified by the lack of additional verification methods, such as in-depth interviews or observations in a professional context. Additionally, the focus on eight specific attributes may have limited the scope of the study, excluding other potentially relevant characteristics of leaders of agile organizations. The correlations between the studied traits, although high, do not provide a complete answer to the question of how these traits affect the success of the organization in different contexts.

### **3. Conclusions**

The results of the research presented in this article should be compared with those of other researchers to gain a broader context and understanding of the attributes of leaders of agile organizations. Research by Rigby, Sutherland, and Takeuchi (2016) highlights the importance of adaptability and speed in decision-making as key characteristics of leaders in agile organizations. Their research has shown that organizations that adopt agile management methods perform better when leaders are able to respond quickly to changing market conditions. These results are consistent with the findings of this paper, where velocity of action and decision-making have also been identified as key attributes of leaders.

Denning's research (2018) also confirms the importance of creativity and innovation in agile organizations. Denning notes that leaders who promote a culture of innovation and are open to experimentation contribute to greater flexibility in the organization and better adaptation to market challenges. These results are consistent with the findings of this paper, in which creativity in action and the constant search for new ideas were recognized as key attributes of leaders.

Cappelli and Tavis (2018) in their research on agility in human resource management emphasize the importance of risk-taking readiness and the ability to quickly adapt to changing conditions. The authors point out that leaders who can make bold decisions and adapt quickly to new situations are more effective in running agile organizations. These results correlate with the results of this study, which also identify risk-taking readiness and rapid adaptation as important characteristics of leaders.

Davenport and Harris (2007) in their research on business analytics point to the importance of analytical skills as a key attribute of leaders of agile organizations. The ability to collect and analyze data allows leaders to make fact-based decisions, which increases management efficiency. These results are consistent with the findings of this paper, where analytical skills have also been identified as crucial for effective leadership.

Similarly, Goleman's (2000) research on emotional leadership points to the importance of interpersonal skills and building trust in a team. Goleman emphasizes that leaders who can communicate effectively with employees and promote an open organizational culture perform better. These results are consistent with the findings of this paper, in which the ability to collaborate and openness to feedback were identified as key attributes of leaders.

In conclusion, the research results presented in this article are consistent with the findings of other researchers, which confirms their credibility and importance for understanding the attributes of leaders of agile organizations. In the future, it is worth focusing on further developing and deepening the understanding of the attributes of leaders of agile organizations, especially in the context of dynamically changing market and technological conditions. It will be important to study how different leadership styles affect the effectiveness of agile teams in different industries. In addition, future research may focus on the relationship between leadership attributes and organizational innovation, including the mechanisms that foster the creation and implementation of new ideas.

An interesting direction of research may also be the analysis of the impact of organizational culture on the development and effectiveness of leaders of agile organizations. Understanding what elements of organizational culture support the development of key leadership attributes can help create a more conducive environment for agility in organizations. Additionally, research can focus on the role of digital technologies and analytics tools in supporting leaders of agile organizations, especially in the context of collecting and analyzing real-time data.

Another important aspect to study is the impact of agile leadership on an organization's long-term performance, including their ability to survive and adapt in the face of crises. Research may also include an analysis of how agile leadership affects employee satisfaction, talent retention, and career development. It's also worth exploring how different demographic and sociocultural backgrounds of leaders affect their ability to lead agile organizations, which can provide valuable insights into diversity in leadership.



Another future direction of research could be to analyze the effectiveness of various training and development programs that are designed to develop the key attributes of leaders of agile organizations. Understanding which training methods are most effective can help organizations better prepare leaders for agility challenges. In addition, research may focus on the role of mentoring and coaching in developing leadership capabilities and best practices in this area.

In conclusion, future research should seek a better understanding of the complexity and interrelationships between the different attributes of agile leaders and their impact on organizational effectiveness. This will enable the development of more comprehensive and effective management strategies that will contribute to increasing the agility and competitiveness of the organization in a dynamically changing business environment.

## References

1. Akkaya, B. (2021). *Leadership 5.0 in Industry 4.0: Leadership in Perspective of Organizational Agility*. IGI Global. DOI: 10.4018/978-1-7998-8548-1.ch074
2. Amabile, T.M. (1996). *Creativity in Context*. Westview Press.
3. Beck, K. et al. (2001). *Manifesto for Agile Software Development*. Retrieved from <https://agilemanifesto.org/>
4. Cappelli, P., Tavis, A. (2018). HR goes agile. *Harvard Business Review*, 3-4, 46-52.
5. Carmeli, A., Gittell, J.H. (2009). High-Quality Relationships, Psychological Safety, and Learning from Failures in Work Organizations. *Journal of Organizational Behavior*, 30(6), 709-729.
6. Chen, X., Siau, K. (2020). Business Analytics/Business Intelligence and IT Infrastructure: Impact on Organizational Agility. *Journal of Organizational and End User Computing*. DOI: 10.4018/joeuc.2020100107
7. Chen, Y., Li, X. (2021). The Role of Organizational Agility in Managing the COVID-19 Pandemic: A Case Study of Two Chinese Hospitals. *International Journal of Environmental Research and Public Health*, 18(1), 70. DOI: 10.3390/ijerph18010070.
8. Davenport, T.H., Harris, J.G. (2007). *Competing on Analytics: The New Science of Winning*. Harvard Business Review Press.
9. Denning, S. (2018). *The Age of Agile: How Smart Companies Are Transforming the Way Work Gets Done*. AMACOM.
10. Fiddler, E. (2017). *Selected aspects of organizational agility*. SIGMA-NOT Publishing House, sp. z.o.o. DOI: 10.15199/48.2017.12.2.
11. Goleman, D. (2000). Leadership That Gets Results. *Harvard Business Review*, 78(2), 78-90.

12. Hacker, S.K. (2018). *Agile Transformation: Using the Integral Agile Transformation Framework to Think and Lead Differently*. CRC Press.
13. He, H., Harris, L. (2021). The impact of organizational agility on crisis management and firm performance: A moderation analysis. *Journal of Business Research*, 122, 698-708. DOI: 10.1016/j.jbusres.2020.11.026.
14. Joiner, B. (2019). Leadership Agility for organizational agility. *Journal of Creating Value*, 5(2), 194-208. journals.sagepub.com
15. Kniberg, H., Ivarsson, A. (2012). *Scaling Agile @ Spotify with Tribes, Squads, Chapters & Guilds*. Retrieved from: <https://www.infoq.com/articles/spotify-scaling-agile/>
16. Kocot, M., Kwasek, A. (2022). Organizational agility as a determinant of the effective use of ICT. *Scientific Journals of the Humanitas University of Management*, No. 23(4). DOI: 10.5604/01.3001.0016.2180
17. Kotter, J.P. (1996). *Leading Change*. Harvard Business Review Press.
18. Kt, M.A., Sivasubramanian, C. (2023). *Workforce Agility: A Review on Agility Drivers and Organizational Practices*. *Researchers' Forum*. Department of Commerce. University of Kerala, Karyavattom. DOI: 10.59640/cbr.v14i2.1-8
19. Kurnia, S., Chien, S. W. (2020). Building organizational agility through strategic management accounting: A case study of an Indonesian manufacturing company. *Journal of Asia Business Studies*, 14(4), 591-612. DOI: 10.1108/JABS-09-2019-0253.
20. Mycka, P. (2023). *The importance of internal environment factors for the competitiveness of small and medium-sized enterprises in the transport industry*. Retrieved from: [ruj.uj.edu.pl](http://ruj.uj.edu.pl)
21. Prieto, L., Talukder, M.F. (2023). Resilient Agility: A Necessary Condition for Employee and Organizational Sustainability. *Sustainability*. DOI: 10.3390/su15021552.
22. Rahimi, G., Mansouri, A.M. (2019). *The relation between the organizational intelligence and organizational agility (Case study: employees of municipality of Tabriz)*. IAJOBHRM. DOI: 10.9756/iajobhrm/v5i1/1810010.
23. Ramadhana, R. (2021). *Employee Agility*. *Center for Open Science*. DOI: 10.31219/osf.io/vrwnq.
24. Rigby, D.K., Sutherland, J., Takeuchi, H. (2016). Embracing Agile. *Harvard Business Review*, 94(5), 40-50.
25. Routledge, P. (2020). *Organizational Agility with Mobile ICT? The Case of London Black Cab Work*. DOI: 10.4324/9780080463681-26.
26. Schein, E.H. (2010). *Organizational Culture and Leadership*. Jossey-Bass.
27. Schwaber, K., Sutherland, J. (2017). *The Scrum Guide*. Retrieved from: <https://scrumguides.org/>
28. Sedej, T., Justinek, G. (2021). *Effective Tools for Improving Employee Feedback during Organizational Change*. DOI: 10.4018/978-1-7998-7297-9.ch022.

29. Seifollahi, S., Shirazian, Z. (2021). *On the relationship between employees empowerment with competitive advantage and organizational agility mediated by organizational intelligence (Case study: employees in gas company of Hamadan)*. EJM. DOI: 10.35429/ejm.2021.27.12.1.10.
30. Skyrius, R., Valentukevič, J. (2020). Business Intelligence Agility, Informing Agility and Organizational Agility: Research Agenda. *Informatics*, 90, 47. DOI: 10.15388/im.2020.90.47.
31. The First Pillar (2020). *Organizational Agility*. Auerbach Publications. DOI: 10.1201/9780429025693-12
32. Westerman, G., Bonnet, D., McAfee, A. (2014). *Leading Digital: Turning Technology into Business Transformation*. Harvard Business Review Press.



## AGILE BEHAVIORS OF ENTERPRISES IN THE ASPECT OF ECOLOGICAL USE OF IT EQUIPMENT

Maria KOCOT<sup>1\*</sup>, Damian KOCOT<sup>2</sup>, Janusz SOBON<sup>3</sup>, Artur KWASEK<sup>4</sup>

<sup>1</sup> University of Economics in Katowice; maria.kocot@ue.katowice.pl, ORCID: 0000-0001-5150-3765

<sup>2</sup> University of Economics in Katowice; damian.kocot@ue.katowice.pl, ORCID: 0000-0001-9240-857X

<sup>3</sup> Jacob of Paradies University in Gorzow Wielkopolski; jsobon@ajp.edu.pl, ORCID: 0000-0001-7855-2153

<sup>4</sup> University of Technology and Economics in Warsaw; artur.kwasek@uth.edu.pl,

ORCID: 0000-0003-4386-1444

\* Correspondence author

**Purpose:** The aim of the article is to examine the agile behavior of enterprises in the context of the ecological use of IT equipment. The focus was on analyzing how enterprises implement Green IT practices and how these activities affect their operational and environmental efficiency.

**Design/methodology/approach:** The research methodology was based on an anonymous survey among 578 enterprises representing various sectors of the economy. The survey aimed to collect data on practices related to the successive replacement of IT equipment, the implementation of technological innovations, the use of energy-saving devices and the integration of Green IT as an element of a business strategy.

**Findings:** Research has shown that enterprises that regularly replace IT equipment with new ones are more likely to implement technological innovations and use energy-saving devices. Strong correlations were observed between the implementation of innovations and energy efficiency. Choosing suppliers that promote Green IT is an important factor for companies striving for sustainable development.

**Research limitations/implications:** Research limitations include the subjectivity of respondents' responses and the lack of full representativeness of the sample. Focusing on specific aspects of the green use of IT equipment may have omitted other important factors. Research results have limited validity due to changing regulations and technologies.

**Practical implications:** The research results suggest that enterprises should focus on the gradual replacement of IT equipment with modern and energy-saving ones and on the integration of innovative technological solutions. This approach not only reduces energy consumption, but also reduces operating costs and improves the company's image as environmentally responsible.

**Social implications:** Implementing Green IT solutions as an element of a business strategy contributes to the protection of the natural environment and supports sustainable development. Companies that promote agile and green practices can gain greater trust from customers, business partners and local communities.

**Originality/value:** The article adds value by comprehensively analyzing the links between enterprise agility and their green practices in the use of IT equipment. The study highlights the importance of integrating Green IT into business strategies and shows how such activities can bring both operational and environmental benefits.

**Keywords:** agile behavior, ecology, IT equipment, enterprise, Green IT.

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

## 1. Introduction

The use of IT equipment in an ecological way is a key issue in contemporary IT management. In the face of growing ecological awareness and increasingly restrictive environmental protection regulations, companies must adapt their practices to new requirements. An ecological approach to IT equipment management not only allows for reducing the negative impact on the environment, but also brings economic and operational benefits (Torres, 2023).

The importance of the ecological use of IT equipment in enterprises results from several key factors. First, the energy consumption of IT infrastructure constitutes a significant part of the total energy consumption of enterprises. Optimizing energy consumption through the use of energy-efficient devices and technologies can lead to significant savings in operating costs. Second, the growing expectations of stakeholders, including customers, investors, and business partners, regarding sustainability and ecological responsibility are forcing companies to implement more sustainable practices (Alshehhi, Nobanee, Khare, 2018).

Agile enterprise behaviors, known as the agile approach, play a key role in integrating green practices in IT management (Trotta, 2018). Enterprises that effectively implement agile principles are more flexible and respond faster to changing market conditions and ecological requirements. This approach includes regular replacement of IT equipment with modern and more energy-efficient ones, which allows the use of the latest technologies with lower energy consumption. Additionally, the implementation of technological innovations, such as server virtualization or cloud computing, enables more efficient use of resources and reduction of energy consumption (Kocot, Kwasek, 2022).

Introducing Green IT practices as an integral part of business strategy is the next step that companies should take. Preferring suppliers offering ecological products and solutions and implementing systems that monitor energy consumption are just some of the actions that can significantly reduce the impact of IT activities on the environment. Enterprises that care about the ecological use of IT equipment gain not only operational benefits, but also build a positive image of socially and ecologically responsible companies (Zhou, Yang, 2016).

In the context of increasing pressure on sustainability, enterprises must adopt a holistic approach to IT management that combines operational agility with ecological responsibility. Research on enterprise agility and their green IT practices is essential to understand what strategies and actions are most effective in achieving these goals. Introducing and maintaining agile, green practices in IT not only benefits the environment, but also increases the competitiveness and innovation of enterprises in the long term.

## **2. Literature Review**

### **2.1. Agile behavior of enterprises**

Agile corporate behavior, known as the agile approach, is a key element of modern management in a dynamically changing business environment (Doz, Kosonen, 2008). Agile allows for quick adaptation to market changes, growing competition and changing customer needs (Womack, Jones, 2003). The key principles of agility include customer focus, dynamic organizational structure, iterative work model, transparency and communication, use of technology, and adaptability (Fitzgerald, Stol, 2017; Kocot, Kwasek, 2022).

In the agile approach, companies focus on understanding and meeting customer needs through direct communication and regular feedback. Organizational structures are flexible and based on cross-functional teams (Lambri, Sironi, Teti, 2024), which enables rapid knowledge exchange and decision-making. The iterative work model, based on short cycles called sprints, allows for ongoing adjustment of projects and minimizing risk by quickly detecting and correcting errors (Nath, Agrawal, 2020; Prahalad, Ramaswamy, 2004).

Transparency and communication are key in agile organizations. Regular team meetings, such as daily stand-ups and retrospectives, promote the exchange of information and build trust (Kt & Sivasubramanian, 2023). The use of modern technologies, such as project management tools and process automation, supports efficiency and innovation (Brown, 2009). Adaptability allows you to quickly respond to market changes and adapt your operating strategy (Sajdak, 2021).

The organizational culture of agile enterprises is based on values such as trust, cooperation, openness to change and continuous improvement (Loeser, 2013). Employees are encouraged to take initiative and experiment, which fosters innovation and commitment. Leaders act as mentors and coaches, supporting the development of teams and promoting agile values (Chen, Li, 2021).

To sum up, agile corporate behavior is a comprehensive management approach that allows for quick adaptation to changing market conditions, increases competitiveness and contributes to achieving better business results.

## 2.2. Green IT concept in enterprises

The concept of Green IT in enterprises refers to strategies and activities aimed at reducing the negative impact of information technologies on the natural environment. In the face of growing environmental awareness and increasingly stringent environmental regulations, companies are implementing a variety of initiatives to make their IT operations more sustainable and green (Petrescu, Bilcan, Petrescu, Popescu, Anghel, 2020).

Green IT covers a wide range of activities, from the design and implementation of energy-efficient data centers, through the use of energy-saving devices, to recycling and disposal of obsolete electronic equipment. A key element is minimizing energy consumption by IT infrastructure (Modanval et al., 2021), which can be achieved by optimizing cooling systems, server virtualization and using more efficient processors and other hardware components (Ojo, Raman, Downe, 2019).

An important aspect of Green IT is also the promotion of responsible IT product lifecycle management (VersionOne, 2020b). Enterprises take actions to extend the life of equipment, repair and modernize existing equipment, and dispose of it appropriately at the end of its service life (Gao, Zhang, Gong, Li, 2020). Electronic recycling recovers valuable materials and reduces the amount of waste sent to landfills (Hu, Yan, Guo, Cui, Dong, 2017).

As part of Green IT, it is also important to use software supporting energy management (VersionOne, 2020a). These tools enable monitoring and analysis of energy consumption by various components of IT systems, which allows for the identification of areas requiring optimization. Automating energy management, such as automatically turning off unused devices, also contributes to reducing energy consumption (Attar, Almusharraf, Alfawaz, Hajli, 2022).

Enterprises implementing the Green IT concept also engage in initiatives related to the responsible purchase of equipment. Products certified for energy efficiency and low environmental impact are preferred, which includes both computer hardware and peripherals. This approach supports the development of the green technologies market and motivates producers to innovate towards more ecological solutions (Joiner, 2019).

Sustainable IT practices are also an integral part of companies' CSR (Corporate Social Responsibility) strategies. The implementation of Green IT is part of broadly understood activities for corporate social responsibility, contributing to building a positive image of the company and strengthening relationships with stakeholders. Companies undertaking these initiatives often report their environmental activities in CSR reports, which increases transparency and commitment to environmental protection (Awasthi, Awasthi, 2023).

To sum up, the concept of Green IT in enterprises covers a wide range of activities aimed at reducing the negative impact of information technology on the environment. By optimizing energy consumption, responsible product life cycle management, using energy-saving solutions and engaging in responsible purchasing, companies can contribute to sustainable development



and environmental protection. The implementation of Green IT is an important element of the CSR strategy, which translates into building a positive image of the company and long-term business benefits.

### **2.3. Agile behavior of enterprises and ecological use of IT equipment**

Agile behavior of enterprises in the context of ecological use of IT equipment plays a key role in modern IT management. Enterprises that implement the agile approach (Borowski, 2021) increasingly pay attention to aspects related to environmental protection, which affects the way they manage their IT infrastructure (Borowski, Karlikowska, 2023). One of the key elements is the gradual replacement of IT equipment with new ones (Kurnia, Chien, 2020). Agile companies strive to regularly update their technological equipment, which allows them to use the latest, more energy-efficient and ecological solutions. Modern IT equipment is characterized not only by better performance, but also by lower energy consumption, which contributes to reducing operating costs and minimizing the negative impact on the environment (Jones, Adam, 2023).

The implementation of innovations in IT equipment is another important aspect. Companies using agile management methods often invest in modern technologies that allow for more efficient use of resources (He, Harris, 2021). Examples of such innovations include server virtualization, cloud computing, and advanced energy management systems (Ramadhana, 2021). Thanks to these technologies, it is possible to optimally use computing power and reduce energy consumption, which has a direct impact on environmental protection (Bhati, Hansen, Chan, 2017). The use of energy-efficient IT devices is an integral part of the strategy of environmentally conscious companies (Zou, Cheshmehzangi, 2022). Modern laptops, servers, and other peripheral devices are designed to minimize energy consumption (Rosário, Raimundo, 2021). Companies pay attention to energy certificates and technical specifications that confirm low energy consumption. The choice of such devices translates into lower operating costs and a reduction in carbon dioxide emissions (Mrugalska, Ahmed, 2021).

Green IT is becoming an increasingly important factor when selecting suppliers. Agile enterprises that strive for sustainable development prefer to cooperate with suppliers that offer green solutions and products (Luo et al., 2020). Choosing suppliers that promote sustainable practices allows you to build long-term, responsible business relationships that benefit both your business and the environment. Ensuring low energy consumption is a priority in agile enterprises (Prieto, Talukder, 2023). Optimizing energy consumption includes not only the selection of energy-saving devices, but also the implementation of systems that monitor and manage energy consumption in real time (Raschke, 2010). Enterprises implement solutions that allow automatic switching off of unused devices and effective resource management, which leads to a significant reduction in operating costs and negative impact on the environment (Patón-Romero, Baldassarre, Piattini, García Rodríguez de Guzmán, 2017).

The implementation of Green IT solutions as an element of business strategy is becoming more and more common (Chen, Siau, 2020). Enterprises realize that responsible management of information technologies not only contributes to environmental protection, but also strengthens their position on the market (Sedej, Justinek, 2021). Implementing the Green IT strategy allows you to build a positive image of the company as responsible and committed to sustainable development, which is valued by customers, business partners and investors (van den Brom, Meijer, Visscher, 2018).

To sum up, agile behavior of enterprises in the context of the ecological use of IT equipment includes the successive replacement of equipment with new ones, the implementation of innovations, the use of energy-saving devices, the selection of suppliers promoting Green IT, attention to low energy consumption and the implementation of Green IT solutions as an element of the business strategy. This approach allows you to achieve better business results while caring for the natural environment.

#### **2.4. Research Methodology**

The aim of the work was to identify the behavior of enterprises in the context of the ecological use of IT equipment and to understand how these behaviors are related to each other. The conducted research aimed to explore how enterprises approach the successive replacement of IT equipment with new ones, the implementation of technological innovations, the use of energy-saving devices, taking into account Green IT as an important factor in the selection of a supplier, ensuring low energy consumption and implementing Green IT solutions as an element of the strategy. business.

The research hypothesis assumed that there are strong correlations between the ecological behavior of enterprises in the field of IT, and especially between the implementation of technological innovations and energy efficiency. It was also assumed that companies that focus on one ecological aspect will be more likely to include other ecological practices in their operations.

The research method was an anonymous survey conducted in 2023, in which 578 respondents representing various enterprises participated. This survey allowed for the collection of data on various aspects of the ecological use of IT equipment and the analysis of the connections between them. Thanks to this, it was possible to obtain a comprehensive picture of enterprises' approach to ecology in the context of information and communication technologies.

The sociodemographic analysis of the study covers three main categories: the geographical scope of the company's operations, the sector to which the company belongs, and the assessment of the company's financial situation. 578 respondents participated in the study. With respect to geographical scope, the companies were divided into four groups. 109 companies declared their international scope of activity, 56 companies had a regional scope, 174 companies had a national scope, and 239 companies operated locally. In terms of sector affiliation, companies were divided into five sectors. Sector 1 (agriculture, forestry, fishing) included 19 companies.

Sector 2 (extractive industry, mining and processing, and construction) included 38 companies. The largest share was had by sector 3 (transport, communications, municipal and housing management and trade) with 205 companies. Sector 4 (finance, insurance, marketing and advertising, and real estate) included 163 companies, and sector 5 (health care, social welfare, education, scientific research, tourism and recreation, public administration, justice, police and military) included 153 companies. In terms of assessing the financial situation of companies, 221 enterprises described their situation as very good, 258 as good, 74 as average, and 25 as bad.

In conclusion, the sociodemographic data of the study present a diverse sample of enterprises in terms of geographical scope, sector of activity and financial situation, which allows for a comprehensive analysis of the ecological behavior of enterprises in various operational contexts.

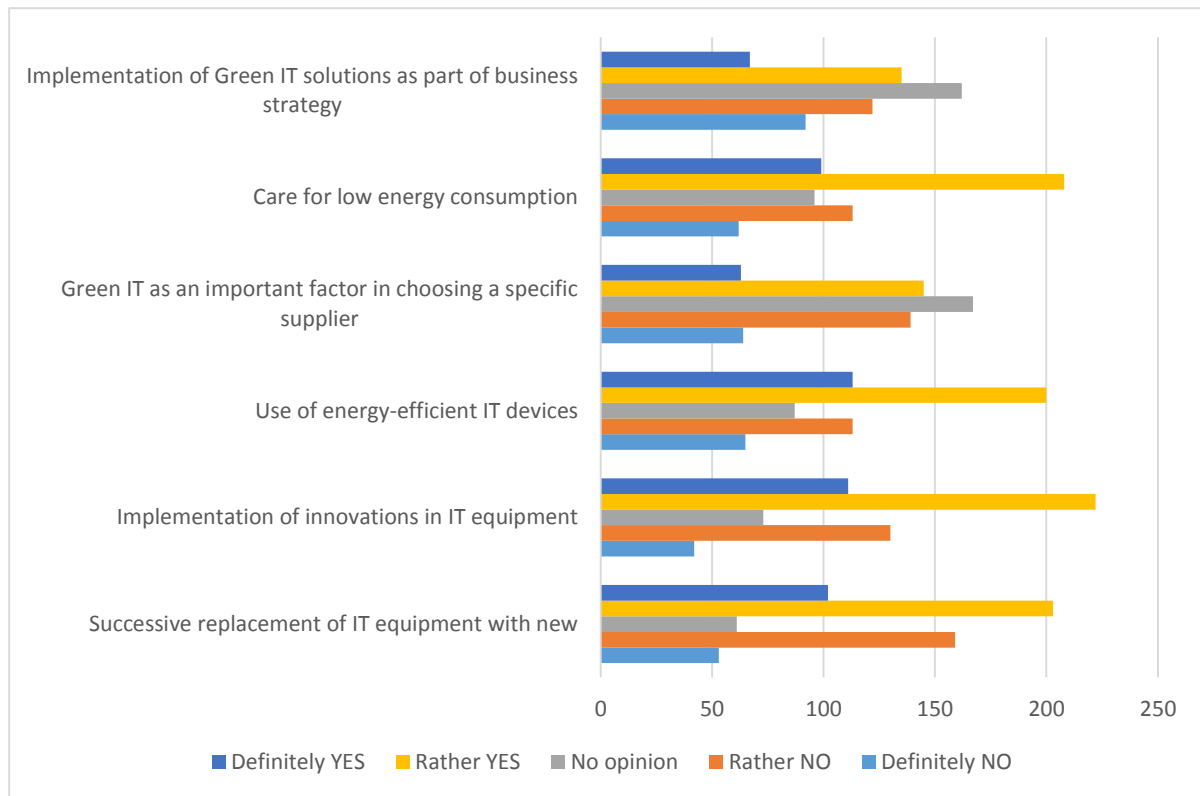
## **2.5. Presentation of Research Findings**

In the course of the research, attempts were made to identify the behavior of enterprises in the context of the ecological use of IT equipment (see Fig. 1). The answers of 578 respondents regarding various aspects of this issue were analyzed. In the case of successive replacement of IT equipment with new ones, 53 respondents declared a definitely negative opinion, 159 rather negative, 61 had no opinion, while 203 respondents expressed a rather positive opinion and 102 definitely positive. In terms of implementing innovations in the field of IT equipment, 42 people were definitely against it, 130 were rather against it, 73 had no opinion, 222 people rather supported such activities, and 111 strongly supported them.

The use of energy-saving IT equipment was met with mixed reactions: 65 respondents were strongly opposed, 113 were rather opposed, 87 had no opinion, while 200 were rather positive and 113 were strongly positive. Regarding Green IT as an important factor in choosing a specific supplier, 64 people were strongly opposed, 139 rather opposed, 167 had no opinion, 145 respondents rather agreed with this statement, and 63 strongly agreed.

The concern for low energy consumption was assessed by the respondents as follows: 62 people were definitely against it, 113 were rather against it, 96 had no opinion, 208 respondents were rather positive and 99 were definitely positive. The implementation of Green IT solutions as an element of a business strategy was met with responses from 92 people who were strongly opposed, 122 who were rather opposed, 162 who had no opinion, 135 who rather agreed with this approach and 67 who strongly agreed.

The conducted research shows the diversified approach of enterprises to the ecological use of IT equipment, showing both support for such activities and some doubts or lack of opinion on this subject among respondents.



**Figure 1.** Agile behavior of enterprises in the aspect of ecological use of IT equipment, N = 578.

Source: Own study based on research.

In the course of the research, attempts were made to identify correlations between various behaviors of enterprises in the context of the ecological use of IT equipment. Table 1 presents a correlation matrix that allows us to understand how these behaviors are related to each other. The analysis of the results presented in Table 1 shows that there are strong correlations between many of the variables studied. The correlation between the successive replacement of IT equipment with new ones and the implementation of innovations in the field of IT equipment is very high (0.96), which suggests that enterprises that replace IT equipment with new ones more often are also more likely to implement technological innovations. A similarly strong correlation (0.91) occurs between the successive replacement of IT equipment and the use of energy-efficient IT devices, which indicates the tendency of companies to replace older devices with more energy-efficient ones.

High correlation values are also observed between the implementation of innovations and the use of energy-saving IT devices (0.98), which emphasizes the importance of modern technologies in the context of energy efficiency. In turn, the correlation between the use of energy-saving devices and attention to low energy consumption (0.99) is almost complete, which clearly suggests that companies that focus on energy efficiency in the field of IT equipment also care about minimizing energy consumption in general.

Green IT, as an important factor in choosing a specific supplier, shows moderate correlations with other variables, for example with the successive replacement of IT equipment (0.38) and the implementation of innovations (0.47), which indicates that although it is an important factor, it is not so strongly linked to other ecological behaviors such as energy saving.

The lowest correlation values were recorded for the implementation of Green IT solutions as an element of the business strategy in relation to other variables, with the exception of Green IT as a significant supplier selection factor (0.94), which shows that the strategic approach to Green IT is strongly related to the selection of compliant suppliers. with these principles, but less so with other ecological practices.

**Table 1.**

*Correlation Table, N = 578*

	1	2	3	4	5	6
1	1					
2	0.96	1				
3	0.91	0.98	1			
4	0.38	0.47	0.44	1		
5	0.88	0.98	0.99	0.49	1	
6	0.11	0.26	0.28	0.94	0.35	1

Source: Own study based on research.

The analysis of the correlation table shows that the behavior of enterprises in the ecological use of IT equipment is largely interconnected, especially with regard to technological innovation and energy efficiency.

### 3. Discussion

The research showed that companies are taking a variety of approaches to the green use of IT equipment, reflecting both support for such actions and some doubts and lack of a strong position among respondents. The key conclusion is that enterprises' IT ecology behavior is strongly interconnected, especially in the context of implementing technological innovations and caring for energy efficiency.

Enterprises that successively replace IT equipment with new ones are more likely to implement innovative technological solutions and use energy-saving devices. This type of agile approach demonstrates flexibility and openness to technological changes that have a positive impact on the environment. Such companies are aware of the benefits of modern, energy-saving technologies, which translates into lower energy consumption and lower operating costs.

Additionally, companies that care about low energy consumption show high consistency in their environmental activities, which suggests that energy efficiency is a priority for them. This approach is particularly important in the context of growing ecological awareness and

expectations of customers and stakeholders. These companies use modern technologies not only to increase operational efficiency, but also as part of their sustainable development strategy.

Even though Green IT as a supplier selection criterion is not so strongly related to other ecological practices, companies that take this factor into account demonstrate consistency in selecting business partners consistent with their ecological values. The strategic approach to Green IT, although less related to other green practices, emphasizes the importance of consistency in achieving sustainability goals at different levels of a company's operations.

The implementation of Green IT solutions as an element of a business strategy is less correlated with other ecological practices, which may indicate the need for greater integration of these activities with the overall company strategy. Companies should therefore more consistently incorporate green IT practices into their long-term strategic plans, which will allow them to more fully exploit the potential of innovative, energy-saving technologies.

Agile behavior of enterprises, consisting in quick and flexible adaptation to technological and ecological changes, is key to achieving success in today's dynamically changing business environment. Enterprises that can quickly adapt new technologies and at the same time care for the environment can count on greater operational benefits and better customer perception.

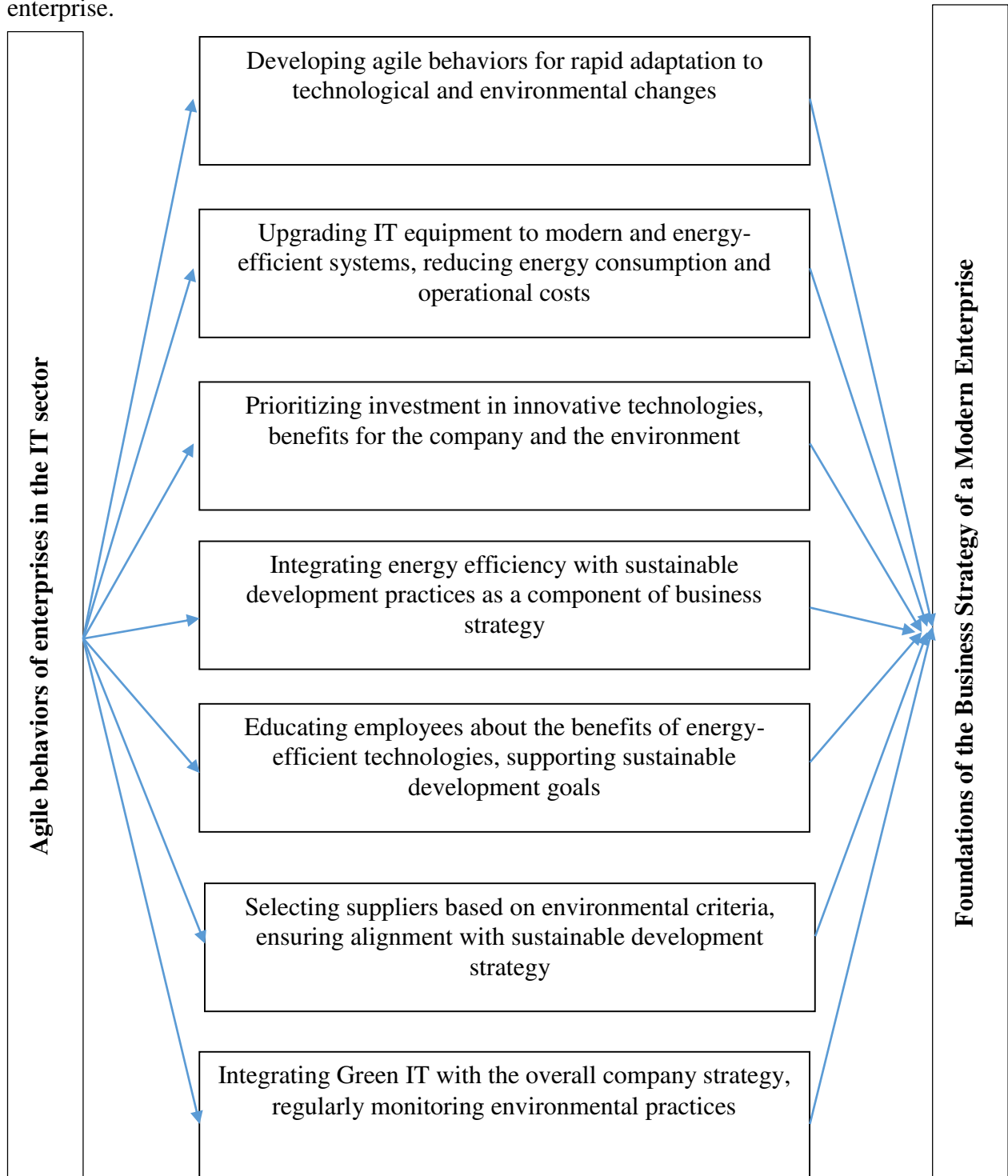
Based on the research conducted, several recommendations for enterprises can be made (see Figure 2). It is recommended that companies focus on developing agile behaviors that enable quick and flexible adaptation to technological and ecological changes. It is important for companies to gradually replace IT equipment with modern and energy-efficient ones, which not only reduces energy consumption, but also reduces operating costs. Investing in innovative technological solutions should be a priority, because modern technologies bring numerous benefits for both the company and the environment.

Companies should strive for consistency in their green operations by integrating energy efficiency with other sustainability practices. Attention to low energy consumption should be treated as an element of the business strategy, which will allow for better use of the potential of modern technologies and strengthen the company's image as ecologically responsible. Educating employees about the benefits of energy-saving technologies and promoting their use can make a significant contribution to achieving sustainable development goals.

The selection of suppliers should take into account ecological criteria, which will ensure consistency of the sustainable development strategy at all levels of the company's operations. Companies should consistently select business partners that share their environmental values to help achieve long-term sustainability goals.

The implementation of Green IT solutions as an element of business strategy should be more integrated with the overall company strategy. Companies should systematically monitor and evaluate their environmental practices to ensure their compliance with sustainable development goals. Regular energy audits and energy monitoring systems can help you identify areas for improvement and further increase energy efficiency.

Long-term planning and a flexible approach to technological and ecological changes remain crucial to success in today's dynamic business environment. Enterprises that can quickly adapt new technologies and at the same time care for the environment gain a competitive advantage, increase their operational efficiency and improve customer perception. Adaptability and flexibility should therefore be the foundation of the business strategy of every modern enterprise.



**Figure 2.** Agile behavior of enterprises in the IT area as the foundations of the business strategy of a modern enterprise.

Source: Own study based on research.

Limitations of the study included several important aspects that may affect the interpretation of the results. First of all, the research was based on anonymous surveys, which limits the possibility of verifying the authenticity and accuracy of the answers provided. Reliance on respondents' self-assessment may lead to subjective interpretations and potential distortions, as participants may want to present their companies in a better light than they actually are.

Another limitation was the size and representativeness of the sample. Although 578 respondents provide a solid basis for analysis, it does not guarantee full representativeness of all sectors of the economy. The study may not have taken into account the specific conditions and challenges faced by different industries, which could have influenced the results. Moreover, the focus on specific aspects of the ecological use of IT equipment may have limited the scope of the analysis and omitted other important factors influencing enterprises' decisions in this area.

Another limitation was the ability to interpret the concepts and terms used in the survey. Respondents may have had different understandings of some questions, which may have led to inconsistent responses. The inability to directly clarify doubts may have influenced the unambiguity of the results.

The timing of the study, 2023, may also have influenced the results, as market conditions and attitudes towards green IT practices may have changed since the data was collected. Changing regulations, policies and technologies may influence business decisions, which means that research results may have limited validity in future periods.

## 4. Conclusions

It is worth comparing the results of the obtained research with those of other authors. Analysis of enterprises' approach to the ecological use of IT equipment reveals both support for such activities and some doubts among respondents. A study by Luo and colleagues (2020) suggests that managing sustainability issues in companies faces barriers related to environmental and cognitive factors, which make it difficult to adopt proactive sustainability strategies (Luo et al., 2020).

Similarly, Petrescu and colleagues (2020) indicate that sustainability reporting has a significant impact on companies' financial performance. This research shows that metrics related to sustainability reporting can be integrated into the reporting of a company's financial performance, transforming sustainability into real value for all stakeholders (Petrescu et al., 2020).



In terms of the use of energy-efficient IT equipment, research by Alshehhi et al. (2018) shows that sustainable development practices have a positive impact on companies' financial performance, although there are still differences in research methodologies that lead to different views on this topic (Alshehhi et al., 2018). These results are consistent with the positive opinions of respondents of this study, who express support for energy-saving IT devices.

Future directions of research on the ecological use of IT equipment in enterprises, taking into account the aspect of agility, may cover several key areas that will allow for a better understanding of the dynamics and effectiveness of implementing such practices. One of the important areas is the analysis of motivations and barriers that influence enterprises in the context of implementing green IT practices. It is important to understand why some companies are more willing to adopt agile and green technologies, while others remain resistant. Research may focus on identifying internal factors, such as organizational culture, management structure, and external factors, such as legal regulations, customer expectations and competitive pressure, that may influence enterprise decisions.

Another direction of research may be to assess the long-term effects of agile ecological practices in IT on the operational and financial efficiency of enterprises. Analyzing how the rapid and flexible adoption of new technologies translates into reduced operating costs, increased energy efficiency and improved company image can provide valuable information for managers and decision-makers. This research may also include case studies of companies that have achieved success through agility in adopting green technologies, which will allow for the identification of best practices and strategies.

An important element of future research is also to examine the role of technological innovations in the process of ecological transformation of enterprises. It is important to understand what specific technologies and IT solutions are most effective in the context of sustainability and how companies can implement them effectively. Research may also focus on assessing the impact of new technologies, such as artificial intelligence, the Internet of Things (IoT) and blockchain, on the agility and greenness of business processes.

Future research may also take into account sector differences in attitudes towards the green use of IT equipment. Analyzing the specific challenges and opportunities that different industries face can provide a more nuanced picture and enable agile strategies to be tailored to specific needs and market conditions. It is important that this research covers both more technologically advanced sectors and those that are just starting their path to ecological transformation.

An equally important direction of research is the assessment of the impact of government policies and international regulations on the agility of enterprises in adopting green IT technologies. Understanding how different policies and regulations influence companies' incentives to adopt agile green practices can help shape more effective legal frameworks and support for businesses.

In summary, future research should focus on analyzing motivations and barriers, assessing long-term effects, the role of technological innovation, sectoral differences, and the impact of government policies on enterprise agility in the context of green use of IT equipment. Such a multidimensional analysis will allow for a better understanding of the dynamics and effectiveness of implementing green IT practices, which will contribute to promoting sustainable development and increasing the competitiveness of companies.

## References

1. Adan, H., Fuerst, F. (2016). Do energy efficiency measures really reduce household energy consumption? A difference-in-difference analysis. *Energy Efficiency*, 9(4), 1207-1219. <https://doi.org/10.1007/s12053-015-9423-8>
2. Akkaya, B. (2021). *Leadership 5.0 in Industry 4.0: Leadership in Perspective of Organizational Agility*. IGI Global. DOI: 10.4018/978-1-7998-8548-1. ch 074
3. Alshehhi, A., Nobanee, H., Khare, N. (2018). The impact of sustainability practices on corporate financial performance: Literature trends and future research potential. *Sustainability*, 10(2), 494.
4. Attar, R.W., Almusharraf, A., Alfawaz, A., Hajli, N. (2022). New Trends in E-Commerce Research: Linking Social Commerce and Sharing Commerce: A Systematic Literature Review. *Sustainability*, 14(23), 16024. <https://doi.org/10.3390/su142316024>
5. Awasthi, K., Awasthi, S. (2023). Green computing: A sustainable and eco-friendly approach for conservation of energy (A contribution to saving the environment). In: S. Awasthi, G. Sanyal, C.M. Travieso-Gonzalez, P. Kumar Srivastava, D.K. Singh, R. Kant (Eds.), *Sustainable Computing: Transforming Industry 4.0 to Society 5.0* (pp. 319-333). Springer International Publishing. [https://doi.org/10.1007/978-3-031-13577-4\\_19](https://doi.org/10.1007/978-3-031-13577-4_19)
6. Bhati, A., Hansen, M., Chan, C.M. (2017). Energy conservation through smart homes in a smart city: A lesson for Singapore households. *Energy Policy*, 104, 230-239. <https://doi.org/10.1016/j.enpol.2017.01.032>
7. Borowski, P.F. (2021). Digitization, digital twins, blockchain, and Industry 4.0 as elements of management process in enterprises in the energy sector. *Energies*, 14(7), 1885. <https://doi.org/10.3390/en14071885>
8. Borowski, P.F., Karlikowska, B. (2023). Clean hydrogen is a challenge for enterprises in the era of low-emission and zero-emission economy. *Energies*, 16(3), 1171. <https://doi.org/10.3390/en16031171>
9. Brown, T. (2009). *Change by design: How design thinking transforms organizations and inspires innovation*. HarperBusiness.

10. Chen, X., Siau, K. (2020). Business Analytics/Business Intelligence and IT Infrastructure: Impact on Organizational Agility. *Journal of Organizational and End User Computing*. DOI: 10.4018 / joeuc.2020100107
11. Chen, Y., Li, X. (2021). The Role of Organizational Agility in Managing the COVID-19 Pandemic: A Case Study of Two Chinese Hospitals. *International Journal of Environmental Research and Public Health*, 18(1), 70. DOI: 10.3390/ ijerph 18010070.
12. Doz, Y., Kosonen, M. (2008). The dynamics of strategic agility: Nokia's rollercoaster experience. *California Management Review*, 50(3), 95-118. <https://doi.org/10.2307/41166447>
13. Fitzgerald, B., Stol, K.-J. (2017). *Continuous Software Engineering*. Springer.
14. Gao, P., Zhang, J., Gong, Y., Li, H. (2020). Effects of technical IT capabilities on organizational agility: The moderating role of IT business spanning capability. *Industrial Management & Data Systems*, 120(5), 941-961. <https://doi.org/10.1108/IMDS-07-2019-0394>
15. He, H., Harris, L. (2021). The impact of organizational agility on crisis management and firm performance: A moderation analysis. *Journal of Business Research*, 122, 698-708. DOI: 10.1016/ j .jbusres.2020.11.026.
16. Hu, S., Yan, D., Guo, S., Cui, Y., Dong, B . (2017). A survey on energy consumption and energy usage behavior of households and residential buildings in urban China. *Energy and Buildings*, 148, 366-378. <https://doi.org/10.1016/j.enbuild.2017.05.036>
17. Joiner, B. (2019). Leadership Agility for organizational agility. *Journal of Creating Value*, 5(2), 194-208. Available on: [journals.sagepub.com](http://journals.sagepub.com)
18. Jones, E., Adam, C. (2023). New frontiers of trade and trade policy: digitalization and climate change. *Oxford Review of Economic Policy*, 39(1), 1-11. <https://doi.org/10.1093/oxrep/grac048>
19. Kocot, M., Kwasek, A. (2022). Organizational agility as a determinant of the effective use of ICT. *Scientific Papers of the Humanitas University of Management*, No. 23(4).
20. Kt, M.A., Sivasubramanian, C. (2023). *Workforce Agility: A Review on Agility Drivers and Organizational Practices*. *Researchers' Forum*. Karyavattom: University of Kerala. Department of Commerce. DOI: 10.59640/ cbr . v 14i2.1-8
21. Kurnia, S., Chien, S.W. (2020). Building organizational agility through strategic management accounting: A case study of an Indonesian manufacturing company. *Journal of Asia Business Studies*, 14(4), 591-612. DOI: 10.1108/JABS-09-2019-0253.
22. Lambri, M., Sironi, E., Teti, E. (2024). The Role of Digitalization in Cross-Border E-Commerce Performance of Italian SMEs. *Sustainability*, 16(2), 508. <https://doi.org/10.3390/su16020508>
23. Loeser, F. (2013). *Green IT and Green IS: Definition of constructs and overview of current practices*. *Completed research paper*. Proceedings of the Nineteenth Americas Conference on Information Systems. Chicago, IL, USA, pp. 1-10.

24. Luo, B.N., Ren, X., Cao, Z., Hong, Y. (2020). Corporate sustainability paradox management: A systematic review and future agenda. *Frontiers in Psychology, 11*, 579272. <https://doi.org/10.3389/fpsyg.2020.579272>
25. Modanval, R.K., Rakesh Kumar, S., Gayathri, N., Ramesh, C., Kumar, A., Sharma, S.K. (2021). Impact of Green Computing in shaping education. In: B. Balusamy, N. Chilamkurti, S. Kadry (Eds.), *Green Computing in Smart Cities: Simulation and Techniques* (pp. 171-188). Springer International Publishing. [https://doi.org/10.1007/978-3-030-48141-4\\_9](https://doi.org/10.1007/978-3-030-48141-4_9)
26. Mrugalska, B., Ahmed, J. (2021). Organizational agility in industry 4.0: A systematic literature review. *Sustainability, 13(15)*, 8272. Available at: [mdpi.com](https://www.mdpi.com)
27. Nath, V., Agrawal, R. (2020). Agility and lean practices as antecedents of supply chain social sustainability. *International Journal of Operations & Production Management, 40(10)*, 1589-1611. <https://doi.org/10.1108/IJOPM-10-2019-0676>
28. Ojo, A.O., Raman, M., Downe, A.G. (2019). Toward Green computing practices: A Malaysian study of Green belief and attitude among information technology professionals. *Journal of Cleaner Production, 224*, 246-255. <https://doi.org/10.1016/j.jclepro.2019.03.252>
29. Patón-Romero, J.D., Baldassarre, M.T., Piattini, M., García Rodríguez de Guzmán, I. (2017). A governance and management framework for Green IT. *Sustainability, 9(10)*, 1761. <https://doi.org/10.3390/su9101761>
30. Petrescu, A.-G., Bîlcan, F.-R., Petrescu, M., Popescu, D.-M., Anghel, E. (2020). Corporate sustainability reporting and financial performance. *Sustainability, 12(10)*, 4297.
31. Prahalad, C.K., Ramaswamy, V. (2004). Co-creating unique value with customers. *Strategy & Leadership, 32(3)*, 4-9.
32. Prieto, L., Talukder, M.F. (2023). Resilient Agility: A Necessary Condition for Employee and Organizational Sustainability. *Sustainability*. DOI: 10.3390/su15021552.
33. Ramadhana, R. (2021). *Employee Agility*. Center for Open Science. DOI: 10.31219/osf.io/vrwnq.
34. Raschke, R.L. (2010). Process-based view of agility: The value contribution of IT and the effects on process outcomes. *International Journal of Accounting Information Systems, 11(4)*, 297-313. <https://doi.org/10.1016/j.accinf.2010.09.005>
35. Rosário, A., Raimundo, R. (2021). Consumer Marketing Strategy and E-Commerce in the Last Decade: A Literature Review. *Journal of Theoretical and Applied Electronic Commerce Research, 16(7)*, 3003-3024. <https://doi.org/10.3390/jtaer16070164>.
36. Sajdak, M. (2021). *Strategic agility of enterprises*. Poznań University of Economics and Business Press. DOI: 10.18559/978-83-66199-32-3.
37. Sedej, T., Justinek, G. (2021). Effective Tools for Improving Employee Feedback during Organizational Change. DOI: 10.4018/978-1-7998-7297-9.ch022.

38. Torres, E.F. (2023). *Implementation of indicators in the sectors of operations of an e-commerce creation company*. Retrieved from: <https://repositorio.ufrn.br/handle/123456789/56103>.
39. Trotta, G. (2018). Factors affecting energy-saving behaviors and energy efficiency investments in British households. *Energy Policy*, 114, 529-539. <https://doi.org/10.1016/j.enpol.2017.12.042>
40. van den Brom, P., Meijer, A., Visscher, H. (2018). Performance gaps in energy consumption: Household groups and building characteristics. *Building Research & Information*, 46(1), 54-70. <https://doi.org/10.1080/09613218.2017.1301697>
41. VersionOne (2020). *13th Annual State of Agile Report*. VersionOne.
42. Womack, J.P., Jones, D.T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Free Press.
43. Zhou, K., Yang, S. (2016). Understanding household energy consumption behavior: The contribution of energy big data analytics. *Renewable and Sustainable Energy Reviews*, 56, 810-819. <https://doi.org/10.1016/j.rser.2015.12.001>
44. Zou, T., Cheshmehzangi, A. (2022). ICT Adoption and Booming E-Commerce Usage in the COVID-19 Era. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.916843>



## ACCOUNTING PROFESSION TRANSFORMATION AS PERCEIVED BY STUDENTS – RESULTS OF A PILOT STUDY

Beata KOTOWSKA<sup>1\*</sup>, Marta SIKORSKA<sup>2</sup>

<sup>1</sup> University of Gdańsk, Faculty of Management, Department of Accounting; beata.kotowska@ug.edu.pl,  
ORCID: 0000-0002-0709-9934

<sup>2</sup> University of Gdańsk, Faculty of Management, Department of Accounting; marta.sikorska@ug.edu.pl,  
ORCID: 0000-0001-8598-4077

\* Correspondence author

**Purpose:** The article aims to explore last-year accounting students' knowledge and awareness of the changing role of accountants in the wake of digitalization.

**Design/methodology/approach:** A literature review was carried out, and a pilot survey was conducted among final-semester graduate students in Poland and Romania, assessing their knowledge and awareness of the changing role of accountants due to digitalization.

**Findings:** The pilot study revealed that students are aware of the changing role of accountants in the wake of digitalization. They recognize the need to possess and advance technological competencies, rating such expertise currently at a medium to moderately high level. They simultaneously regard as impossible that, given the rise of digitalization, accounting positions will be filled by individuals without area-specific education, and that RPA and AI will replace professional judgment. The students are also familiar with digitalization tools, although to a significantly varying degree. They also do identify both the benefits of as well as the barriers to implementing digitalization.

**Research limitations/implications:** The empirical survey employed the method of selection by convenience, therefore the results obtained cannot be generalized onto the entire population.

**Practical implications:** The article reveals that students are aware of the changing role of accountants on the one hand, and of the utmost importance of technological competencies in the profession on the other.

**Originality/value:** The article partly fills the research gap in empirical studies on the changing role of accountants due to digitalization. It also provides the basis for the subsequent in-depth stage of the empirical research on the awareness of the students of applicable majors regarding the changing role of accountants and the profession in the wake of digitalization.

**Keywords:** digitalization, accounting profession, education.

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

## 1. Introduction

In today's world, virtually or nearly everything people do in their private and professional lives is assisted, in some way, by a variety of digital technologies (ACCA, 2020). Digitalization within the field of accounting has been progressing for at least the past two decades. Initially, active in this respect were entities seeking solutions to facilitate accounting. Later on, however, the need for changes was also recognised by public administration bodies. Businesses began to be obliged to utilise a wide range of digitalization tools through the introduction of various legal regulations, including tax and accounting provisions. The first changes concerned e-invoicing, followed by the introduction of mandatory reporting in the form of SAF-T files (Marcinkowska, 2021). In 2018, the obligation to compile financial statements in an electronic form of a specific structure and format came into force, with the requirement to include a qualified electronic signature, a personal signature or a trusted signature (art. 45, para. 1f of The Act on Accounting). The changes in data reporting methods, albeit bringing undoubted benefits, posed a major challenge for companies. Fairly common was the view that they were implemented too rapidly, preventing proper preparedness. Moreover, entities compiling their financial statements electronically faced many technical problems in registering or digitally signing the reports (Bucior, Jaworska, 2023).

In January of 2024, the Ministry of Finance was encouraging the public to become familiar with the report on the review of the Accounting Act, share their experience and submit comments (MF, 2024). The report featured, *inter alia*, suggestions to rewrite art. 25(1) of the Act on Accounting pertaining to manual bookkeeping, which is practically obsolete nowadays, or to fill the gap in the obligation to maintain records of documents using electronic document circulation. (Reform, 2023). In January 2024, a pre-consultation on the regulation of the accounting profession was recapitulated as well. The regulation would aim to include the profession in the catalog of regulated professions and provide regulations on reserved activities (Pre-consultations, 2024). All of the above will certainly affect the accounting profession.

In 2019, the International Federation of Accountants (IFAC) defined seven new functions of the accounting profession: a co-pilot, a navigator, a brand protector, a storyteller, a digital and technology enabler, a process and control expert, a trusted professional (International Federation of Accountants, 2019; Wojtas, 2022). It thus has indicated the directions in which the accounting profession will evolve in the future and the changes in the responsibilities accountants will have to meet. As such, digitalization does, on the one hand, signal possible changes in the profession, yet it comes with risks to the profession itself, on the other. The accounting profession is in fact ranked among the professions most threatened by the rise of robotization and artificial intelligence, as Personnel Service experts underline (Jarco, 2023).



According to Arkadiusz Lewandowski – the managing director of Altera sp. z o.o., in the near future the work of an accountant will involve analyzing, advising and suggesting lines of optimization within a company, rather than simply documenting accounting events (Lewandowski, 2021). In similar vein, Małgorzata Ściślak - a marketing and product strategy expert at Symfonia<sup>1</sup>, indicates that dedicated systems will be used for such repetitive tasks as entry of invoice data into records, and thereby the role of an accountant will be limited to analysis, verification and conclusion drawing. Accordingly, accountants will then become business advisors (Digitalization, 2022).

The progressive digitalization and digital transformation affecting the accounting profession have given rise to research on the changing role of accountants and the educational needs of future accounting adepts.

The main purpose of the article is to survey the knowledge and awareness of graduate students of accounting regarding the change in the role of accountants in the wake of digitalization. To achieve the objective, the following research questions were posed:

- Are the students aware of the changing role of an accountant?
- Do the students possess digital skills and are they aware of the demand for such skills within the realm of accounting?

For the purpose of the article, a literature review was carried out using the Scopus and Web of Science databases, both of which were searched for positions describing digitalization in accounting, including the aspects related to academic education in this area. The methodology of the planned empirical research has been outlined. A pilot survey was conducted among the last-semester students of adequate master's degree programs in Poland and Romania, with a focus on their knowledge and awareness of the changing role of accountants in the wake of digitalization.

## 2. Literature review

The literature review was carried out between November 24<sup>th</sup> and December 20<sup>th</sup>, 2022, drawing on an Internet search of two electronic databases: Scopus and Web of Science. The main objective of the preliminary literature review was to search for positions describing digitalization in accounting and the empirical research undertaken in this area. Two groups of keywords were used:

- digitalization, RPA, cloud computing, UiPath,
- accounting profession.

---

<sup>1</sup> Symfonia – a business management software provider.

Individual search queries involved simultaneous use of keywords from both groups. A total of 81 articles were targeted. Given the thematic focus on academic accounting education and the challenges inherent in digitalization, 12 articles from the Scopus database and 4 articles from the Web of Science database were selected for further study. A further supplemental review was carried out on January 10, 2024, yielding additional new positions addressing the aforementioned aspects of education. The same keywords were used. Three articles from the Scopus database and two articles from the Web of Science database were selected for further analysis. In each category, the Authors identified the conclusions and main research areas common to the papers reviewed (Table 1).

**Table 1.**

*Primary research area and conclusions - literature review*

Main research areas	Conclusions /Authors	Number of publications
Digital technology tools in academic education	<ul style="list-style-type: none"> <li>- suggestions to introduce more courses on such subjects as Big Data, cloud computing and information security, to equip future accountants with solid IT knowledge – Stanciu, Rindasu, 2017</li> <li>- courses relevant to data analytics, blockchain technology, artificial intelligence and cloud computing – Moore, Felo, 2022</li> <li>- implementation of new technologies – RPA, cloud accounting – Jordan et al., 2022</li> <li>- according to the authors, certain technologies, such as blockchain, are not covered in education, while others - Big Data, AI - are approached informatively and fail to provide students with the necessary digital competencies – Guşe, Mangiuc, 2022</li> <li>- Master's-level advanced data analysis courses covering RPA and AI – Ng, 2023</li> <li>- a set of three practicals designed to familiarise students with the application of RPA in accounting, implemented as part of practical classes - Keys, Zhang, 2020</li> <li>- an accounting education path based on the DES model – emphasis on accounting skills in the areas of Big Data, Intelligentization (the use of artificial intelligence for decision-making), mobile Internet and Cloud Computing - Xuxin, 2022</li> <li>- the accounting profession needs to keep abreast of the digitalization-related changes, thus it is vital to equip accounting students with state-of-the-art technology and encourage the use of accounting-relevant digital technology tools in education - Berikol, Killi, 2021</li> </ul>	8
Changes in academic education	<ul style="list-style-type: none"> <li>- alignment of student competencies with the current needs of the economic environment – Stanciu, Rindasu, 2017; Moore, Felo, 2022</li> <li>- business organizations such as NASBA, AICPA, AACSB provide the impetus to revise curricula, through professional certifications and standards – Moore, Felo, 2022</li> <li>- correlation of modern technology aspects with the academic accounting education domain to the needs of the digitalized business environment – Guşe, Mangiuc, 2022</li> <li>- the need for further development and refinement of accounting curricula has been identified – Suarta et al., 2023</li> <li>- accounting curricula must include RPA education – the article proposes a course on accounting process automation which could be incorporated into accounting curriculum - Vincent et al., 2020</li> <li>- the teaching of accounting should go hand in hand with technological changes, in response to the challenges of the 4.0 revolution - Bastos et al., 2022</li> <li>- an initiative for higher education institutions to integrate data analytics into their accounting curricula - SzeKee et al., 2023</li> </ul>	8

cont. Table 1.

Modern forms of teaching	<ul style="list-style-type: none"> <li>- online, hybrid courses – Jordan et al., 2022, Bastos et al., 2022</li> <li>- a practical case study on the processes of digitalization – Gușe, Mangiuc, 2022</li> <li>- the use of video lectures, cloud storage, online catalogs, and the blending of e-learning with traditional methods, best develops the skills students are in need of to pursue an accounting career – Volokhin et al., 2022</li> <li>- the use of digital technologies represents a vital mechanism in improving the effectiveness of accounting teaching – Thomas, 2021</li> </ul>	5
Analysis of syllabuses and curricula	<ul style="list-style-type: none"> <li>- an empirical study analyzing the current accounting curricula of 21 Romanian universities, covering a total of 67 study programs – Stanciu, Rindasu, 2017</li> <li>- 185 accounting school websites, curricula, course descriptions, syllabi, and learning outcomes were analysed to determine whether and how accounting departments incorporate data analytics into their curricula – Moore, Felo, 2022</li> <li>- analysis of undergraduate Accounting and Management Information System (CIG) programs, in four major university cities in Romania – the Bucharest University of Economic Studies – ASE, Babeș-Bolyai University of Cluj-Napoca – UBB (Faculty of Economics and Business Administration), ‘Alexandru Ioan Cuza’ University of Iași – UAIC (Faculty of Economics and Business Administration) and West University of Timișoara – UVT (Faculty of Economics and Business Administration) – Gușe, Mangiuc, 2022</li> </ul>	3
Accountant skills in the modern world	<ul style="list-style-type: none"> <li>- advanced spreadsheet skills and the ability to operate accounting software, including enterprise resource planning and cloud accounting systems, are in demand on the accounting labor market – Suarta et al. 2023</li> <li>- technical skills should be incorporated into the accountant's arsenal of tools – Stanciu, Rindasu, 2017; Moore, Felo, 2022; Gușe, Mangiuc, 2022; Ng, 2023</li> <li>- <i>“It is important for professional accountants to understand that they influence digital technologies even when they are not involved, as they allow other professional categories to forward own agenda”</i> – Gușe, Mangiuc, 2022</li> <li>- ICT competence is one of the core technical skills required of accounting graduates - Berikol, Killi, 2021</li> <li>- a survey of digital competence levels among postgraduate students of accounting - Taib et al., 2023; Awang et al., 2023</li> </ul>	9
RPA in education	<ul style="list-style-type: none"> <li>- the use of RPA in the process of analyzing students' exam performance - Patil et al., 2019</li> </ul>	1

Source: own elaboration.

The literature review carried out allowed the ordering of the positions within the field of accounting profession digitalization with respect to academic education. The publications were divided into six research areas. The first, consisting of eight positions, covered the subject of digital technology tools utilized in academic education. Suggestions were put forward in these studies to introduce more courses on Big Data, cloud computing, blockchain technology or data analytics, also incorporating RPA and AI. Another theme that emerged pertained to the need for changes in academic education. Eight publications advocated tailoring of accounting students' competencies to the needs arising from the digitalization of the accounting profession, including modification of the curriculum, which should factor in the ongoing technological changes as well as incorporate in-depth data analysis and RPA education. Incentives for the revision of accounting curricula can be provided by such certifications and business

organization standards as NASBA, AICPA, AACSB. Modern forms of teaching comprised the subject of yet another research area, which encompassed five articles on online and hybrid courses, video lectures as well as case studies on digitalization processes. A conclusion emerged from those publications that the use of digital technologies will prove vital in the efforts to improve the efficiency of accounting teaching. The topic of accounting-related academic syllabus and curriculum analysis was explored in three articles. Nine publications, in turn, focused on research carried out in specific countries, including Romania (Stanciu, Rindasu, 2017; Moore, Felo, 2022; Iordana et al., 2022; Gușe, Mangiuc, 2022), the United States (Ng, 2023), China (Xuxin, 2022), Malaysia (Taib et al., 2023; Awang et al., 2023) as well as Brazil and Portugal (Bastos et al., 2022). Contemporary accounting skills were covered by nine articles. The conclusion drawn was that a demand for technological competencies has arisen within the accounting profession. Accountants should be proficient in the use of spreadsheets and accounting software, including cloud accounting. Noted has also been the fact that ICT competencies are required of accounting and related studies graduates. Research was also undertaken to determine the level of digital competence among postgraduate accounting students at the University of Malaysia, finding, inter alia, a strong positive correlation between information literacy, ICT literacy as well as digital literacy, and digitalization. The last research thread identified indicated that RPA can also be utilized in the process of student exam performance analysis.

The literature review revealed a research gap in empirical investigations assessing last-year accounting students' knowledge and awareness of the changing role of accountants in the wake of digitalization. The authors of the present article aim to partially fill this gap.

### **3. Empirical research methodology**

The literature review carried out, the analysis of the legal acts in force in Poland, and the empirical survey conducted (on February 9, 2023) with the owner of an accounting office by means of a semi-structured interview indicated ample research opportunities within the area of digitalization in accounting (Kotowska, Sikorska, 2023a). The owner of the respondent office additionally emphasized during the survey that accountants need to be IT literate and familiar with technological innovations. A study consulted by ACCA (2020) also confirms the above – 89% of the respondents indicated that digital skills are of considerable or utmost significance in the accounting profession, and 68% of the surveyees utilize these skills continuously in their work. This prompted the authors of the present article to plan a study of previously unaddressed areas. The research has been planned to be implemented in three stages, divided into ten phases (Table 2).

**Table 2.**  
*Planned empirical studies*

Research stage/studies	Task	Study sample	Method
<b>STAGE 1</b>			
1) Preliminary study	Presentation of voluntary digitalization tools, including the associated benefits and barriers	Case study	Semi-structured interview
2) Literature review - preliminary	Scopus, Web of Science	-	Literature analysis
3) Legal regulations	Digitalization obligation under the law	-	Analysis of the law in Poland
<b>STAGE 2</b>			
4) Questionnaire 1	Change in the role of accountants due to digitalization	Accounting firm owners	Questionnaire - MsForms
5) Questionnaire 2	Change in the role of accountants due to digitalization	Accounting firm employees	Questionnaire - MsForms
6) Result analysis	Study summary and conclusions	-	Synthesis, deduction
<b>STAGE 3</b>			
7) Literature review	Scopus, Web of Science	Literature review has been supplemented with positions published in 2023	Literature analysis
8) Questionnaire 3	Survey of last-year accounting graduate students' knowledge and awareness of the changing role of accountants in connection with digitalization	Students – Poland, Romania – pilot study	Questionnaire MsForms
9) Questionnaire 4	Survey of last-year graduate and undergraduate accounting students' knowledge and awareness of the changing role of accountants in connection with digitalization	Students – Poland - main study	Questionnaire - MsForms
10) Result analysis	Study summary and conclusions	-	Synthesis, deduction

Source: own elaboration.

The first and second stages of the research have been completed. The results are presented in B. Kotowska i M. Sikorska (2023a, 2023b).

The present article highlights the findings of the pilot survey conducted as part of the third stage via a questionnaire tailored for last-year students of accounting. This survey was conducted among the students of the Faculty of Management at the University of Gdansk in Poland and the students of the Faculty of Economic Sciences and Business Administration at Transilvania University of Brasov in Romania.

#### 4. Results of the empirical research

In the summer semester of the 2023/2024 academic year, a pilot survey was conducted among last-year full-time and part-time students of accounting at the University of Gdansk

(Faculty of Management) and the Transilvania University of Brasov (Faculty of Economic Sciences and Business Administration). A total of 63 students participated in the study, in distribution into three research groups:

- full-time students of the Faculty of Management at the University of Gdansk (24 respondents),
- part-time students of the Faculty of Management at the University of Gdansk (28 respondents),
- full-time students of the Faculty of Economic Sciences and Business Administration at the Transilvania University of Brasov (11 respondents).

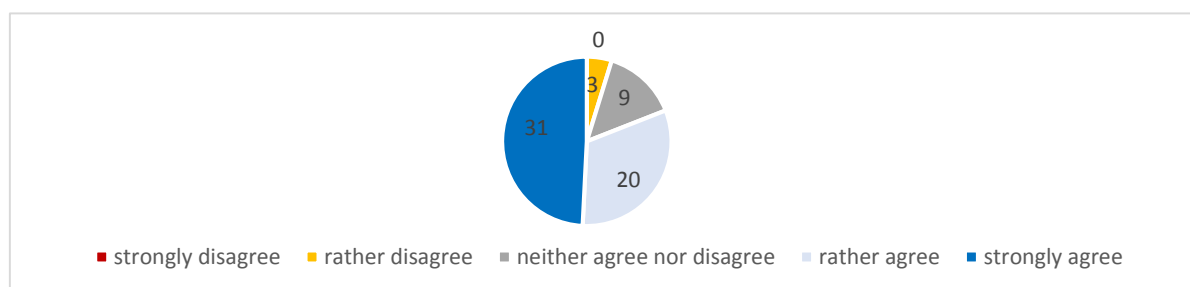
The underlying purpose of the survey was to assess last-year accounting students' knowledge and awareness of the changing role of accountants under the impact of digitalization. The questionnaire was divided into two parts, intended to provide answers to the following questions:

1. Are the students aware of the changing role of an accountant?
2. Do the students possess digital skills and are they aware of the demand for such skills within the realm of accounting?

Part one opened with four questions through which the students were to provide their responses to the following inquiries:

- Does digitalization change the role of an accountant?
- Is the accounting profession changing as a result of digitalization, in your opinion?
- Do you find it is possible that digitalization will in the future lead to a scenario in which individuals employed as accountants will not be required to hold specialist degrees?
- In your opinion, can RPA or AI technology replace the professional judgment of an accountant?

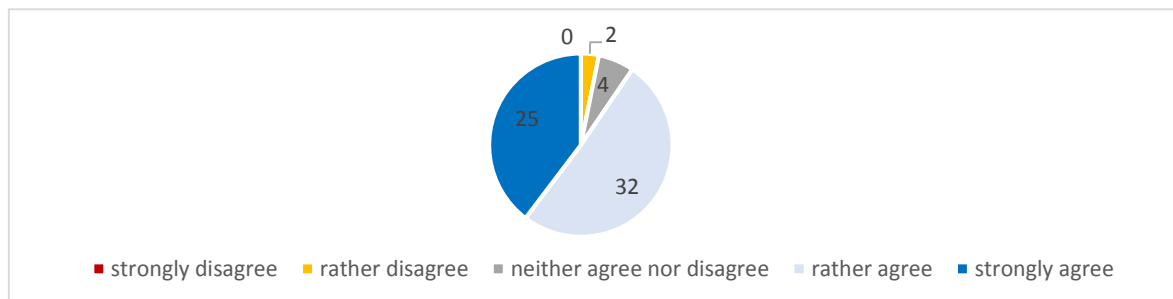
After aggregating the responses provided by all students, the results were compiled into the following four charts. The first (Figure 1) shows the students' opinions regarding the impact of digitalization on the change in the role of an accountant. The answers to the question were fairly unequivocal. Among the 63 respondents, the vast majority rather agree (20 students) or strongly agree (31 students) that digitization has been changing the role of an accountant. Only nine respondents have no opinion in this regard, and three rather disagree with the statement.



**Figure 1.** Does digitalization change the role of an accountant?

Source: own elaboration.

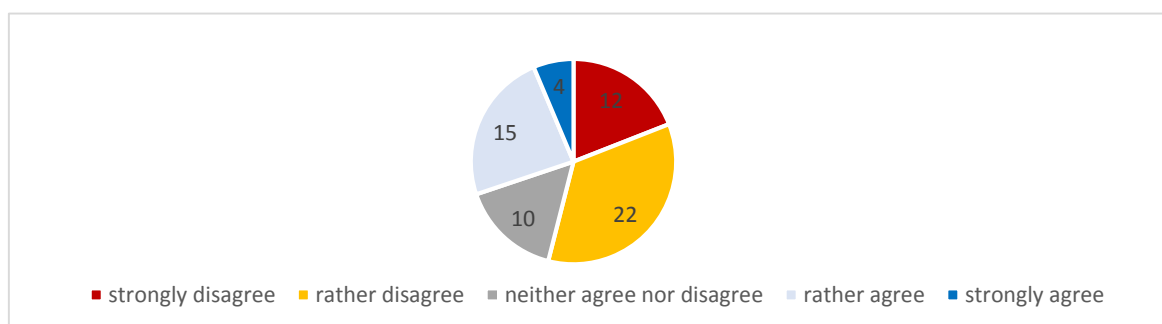
Figure 2 shows the students' responses regarding the change in the accounting profession under the impact of digitalization. The responses indicated clearly that the vast majority rather agree (32 students) or strongly agree (25 students) that the accounting profession has been changing as a result of digitalization. Only four respondents have no opinion in this respect, and two rather disagree with the statement.



**Figure 2.** Is the accounting profession changing as a result of digitalization, in your opinion?

Source: own elaboration.

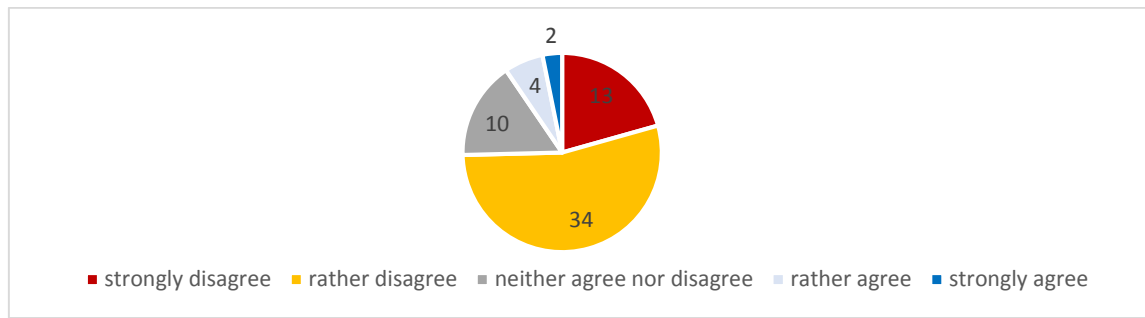
The responses to the question concerning the respondents' views on whether a scenario in which individuals employed as accountants will not be required to hold specialist degrees is possible in the future are illustrated in Figure 3. In this case, the responses were more heterogeneous, compared to the two prior addressed aspects. The majority of the respondents rather disagree (22) or strongly disagree (12) that area-specific education will not be required for the position of an accountant, in the wake of digitalization. Ten respondents expressed no opinion in this regard. Supporting opinions emerged among the respondents, however, that progressive digitalization will lead to a scenario in which accountants will not be in need of specialized knowledge – 15 students rather agree, and four strongly agree with the statement.



**Figure 3.** Do you find it possible that digitalization will in the future lead to a scenario in which individuals employed as accountants will not be required to hold specialist degrees?

Source: own elaboration.

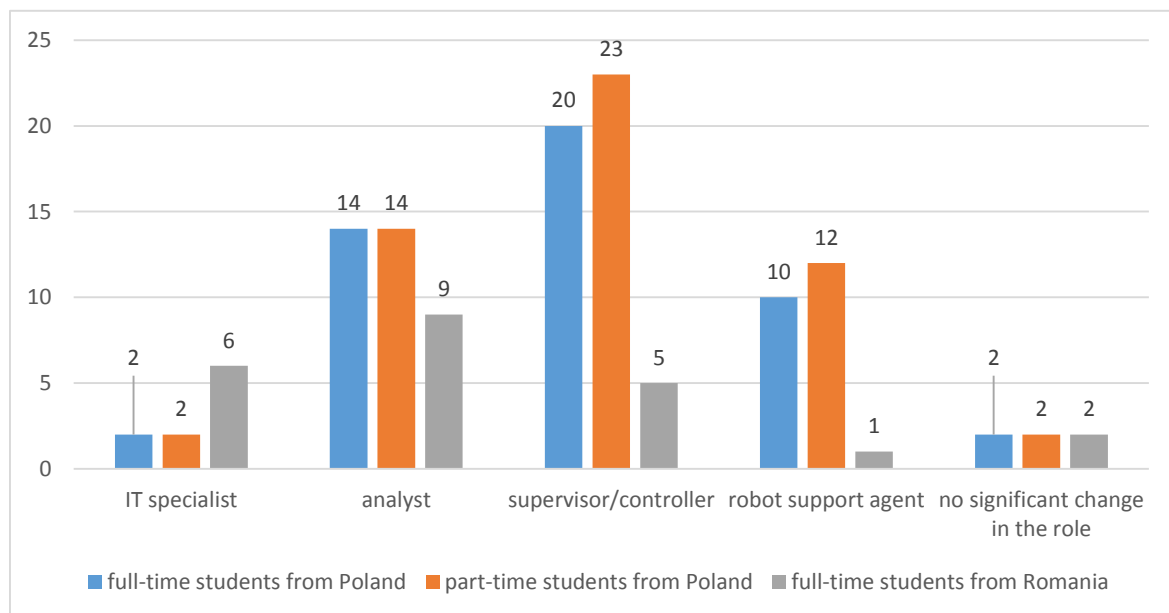
The vast majority of the surveyed rather disagree (34 students) or strongly disagree (13 students) that accountants' professional judgment could be replaced by RPA or AI (Figure 4). Only six respondents rather or strongly agree with the statement. Ten respondents expressed no opinion in this respect.



**Figure 4.** In your opinion, can RPA or AI technology replace the professional judgment of an accountant?

Source: own elaboration.

The students were also asked to indicate what role accounting professionals will assume, in the aftermath of digitalization. The respondents were free to select several answers out of the suggestions provided and/or indicate their own. The results are illustrated in Figure 5.



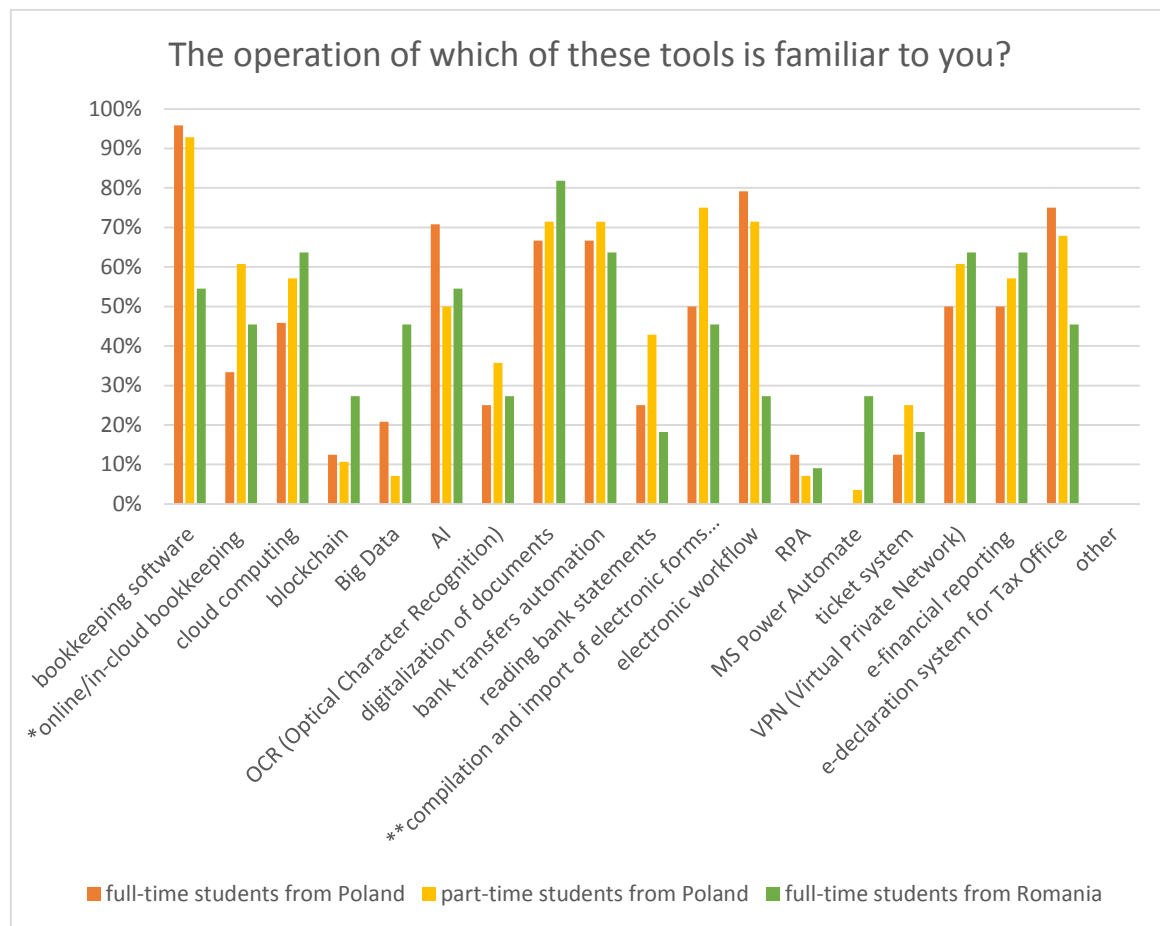
**Figure 5.** Digitalization-effectuated role of accountants.

Source: own elaboration.

The results were very similar across the three groups of respondents. The role of a supervisor/controller received the most indications in both respondent groups from Poland. Next most indicated was an analyst and a robot support specialist. The respondents' individual suggestions included an accounting IT systems implementer, a specialist verifying and approving the tasks performed by robots/artificial intelligence, and the role of a customer service consultant.

The students were also inquired on their knowledge of digitization tools. The responses are illustrated in Figure 6.





\* online/in-cloud bookkeeping software.

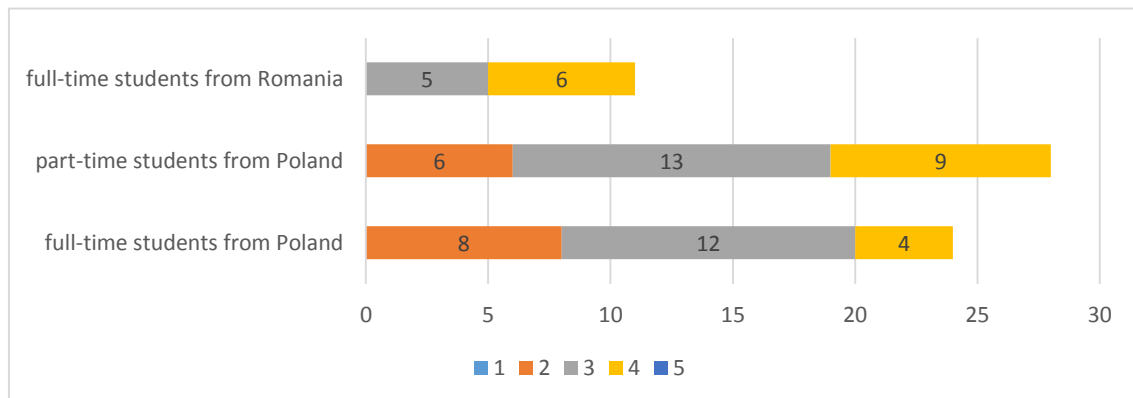
\*\* compilation and import of electronic forms corresponding to the logical structure of the Standard Audit File for Taxes (SAF-T).

**Figure 6.** The operation of which of these tools are you familiar with?

Source: own elaboration.

The results showed that the majority of the respondents in all three groups are familiar with the functioning of accounting software. They are also knowledgeable about document digitization, transfer automation, VPNs or electronic financial statements, and are familiar with how artificial intelligence operates. Tools such as cloud computing or online/in-cloud bookkeeping software are also known to the students, although in a lesser proportion across the groups surveyed. Optical Character Recognition (OCR) or bank statement reading software is known to roughly 30% of the respondents. The highest variation among the groups has been observed for electronic document circulation. Respectively, 79% of the Polish full-time students and 71% of the Polish part-time students indicated they are knowledgeable about what electronic document circulation entails, while only 27% of the Romanian students are familiar with the functioning of this facilitative tool. In contrast, more than 25% of the Romanian students indicated they are familiar with the functioning of such tools as blockchain, Big Data, or MS Power Automate, while the results for the Polish students in this regard oscillated below 5% (MS Power Automate), around 10% (blockchain) or varied - 21% of full-time students and only 7% of part-time students are familiar with the functioning of Big Data.

Figure 7 illustrates the respondents' rating of their knowledge of technological innovations in accounting digitalization on a scale of 1 to 5, where 1 represents non-existent knowledge on the subject, and 5 represents a high level of knowledge in this respect.

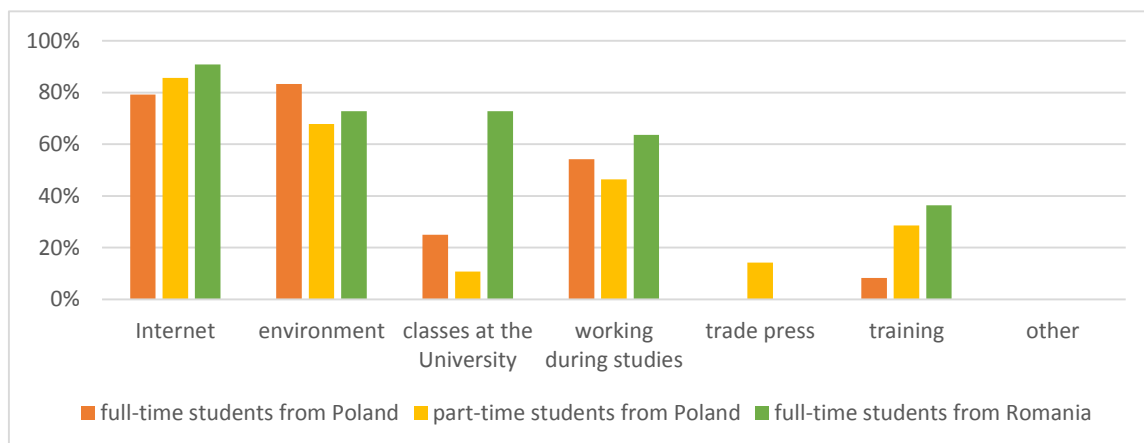


**Figure 7.** How would you rate your knowledge of technological innovations in accounting digitalization?

Source: own elaboration.

Half of the Polish full-time students rated their level of competence in this area at '3', eight respondents assigned a rating of '2', and four rated their level of knowledge at '4'. The part-time students from Poland rated their level of competence slightly higher – thirteen rated their knowledge at '3', while as many as nine respondents assessed their skills at level '4' on the survey scale. The Romanian respondents rated their knowledge at '3' (five students) or '4' (six students), thereby expressing a relatively sound knowledge of technological innovations in digitalization.

The surveyees were also inquired on the source of their knowledge of technological tools/novelties (Figure 8).



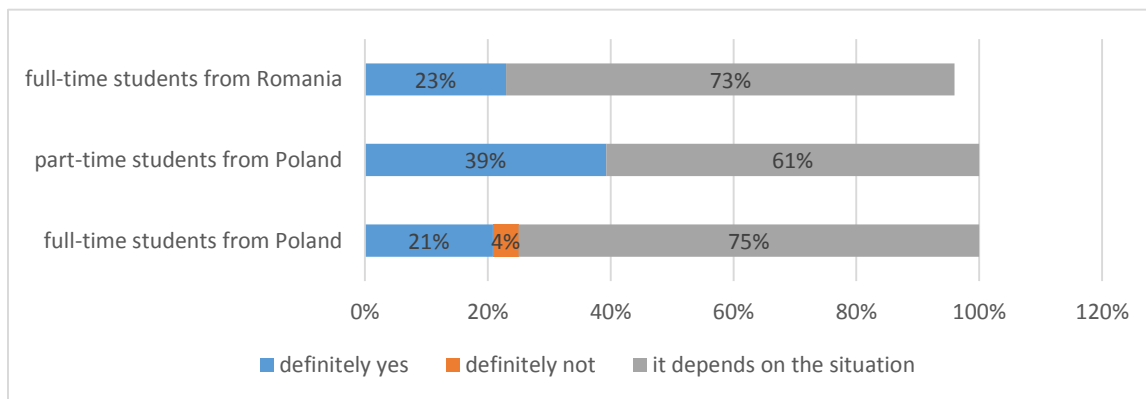
**Figure 8.** Where do you draw your knowledge of technological tools/innovations from?

Source: own elaboration.

Among the answer options specified, the Internet and the environment were selected most commonly. These sources were indicated by more than 60% of the respondents in all groups. Work during studies was indicated by approximately 50% of the students in all groups of

surveyees. University classes as a source of knowledge on technological innovations were indicated by as many as 73% of the Romanian students, with 25% and 11% of the Polish full-time and part-time students, respectively. Training courses were likewise indicated as a source of information on technological novelties, although by a much higher percentage of the part-time or Romanian students, compared to the Polish full-time students. Only a small percentage of the Polish part-time students, in turn, derive their knowledge from professional press.

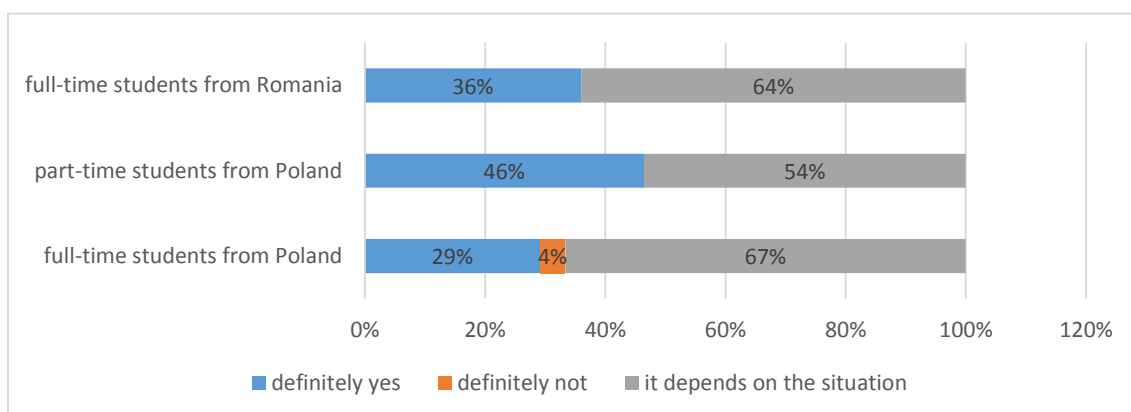
Figure 9 illustrates the responses to the question regarding whether the students surveyed prefer digitalization solutions over traditional ones.



**Figure 9.** Do you prefer digital over traditional/manual solutions?

Source: own elaboration.

Across all surveyed groups, the vast majority of the respondents expressed the opinion that their preference is contingent on a given situation. Strongly in favor of digitalization were 21% of the Polish full-time students, 39% of the Polish part-time students and 23% of the Romanian students. Among the former, one person opted for a preference for traditional solutions. When inquired whether they were willing to employ technological innovations, the majority of the respondents opined that it varies depending on the situation (Figure 10).

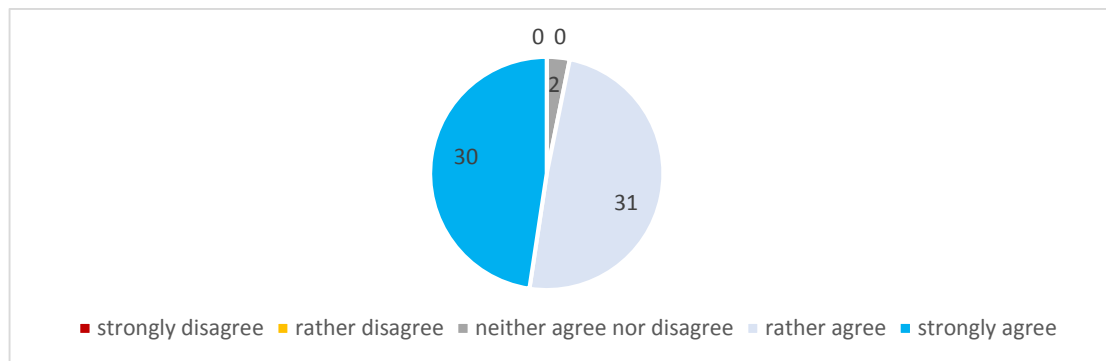


**Figure 10.** Are you keen on using technological innovations?

Source: own elaboration.

The answer ‘definitely yes’ was selected by 29% of the full-time students, 46% of the part-time students and 36% of the Romanian students. One Polish full-time student expressed strong reluctance to using technological innovations.

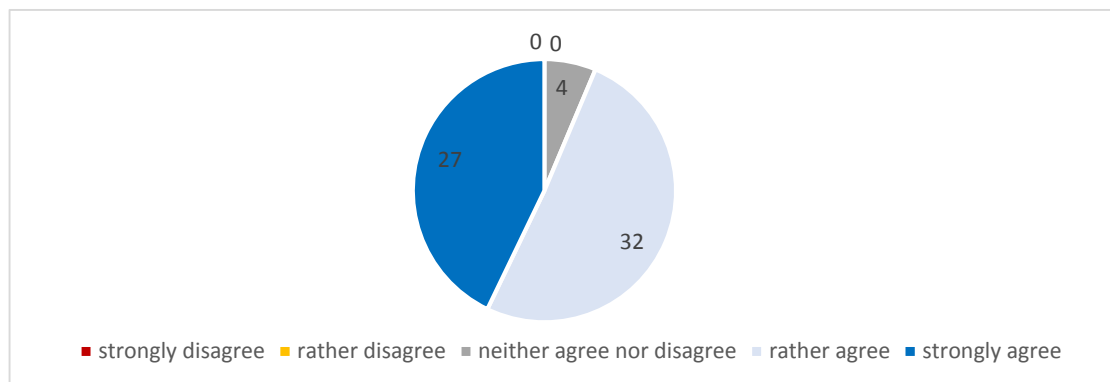
The results for the question regarding whether the respondents discern the need for digital skills and/or familiarity with digitalization tools in the accounting profession leave no room for doubt. Significant preponderance of responses ‘rather agree’ or ‘strongly agree’ that such a need exists has been found. The results are illustrated in Figure 11.



**Figure 11.** Do you discern the need for digital skills/knowledge of digitalization tools in the accounting profession?

Source: own elaboration.

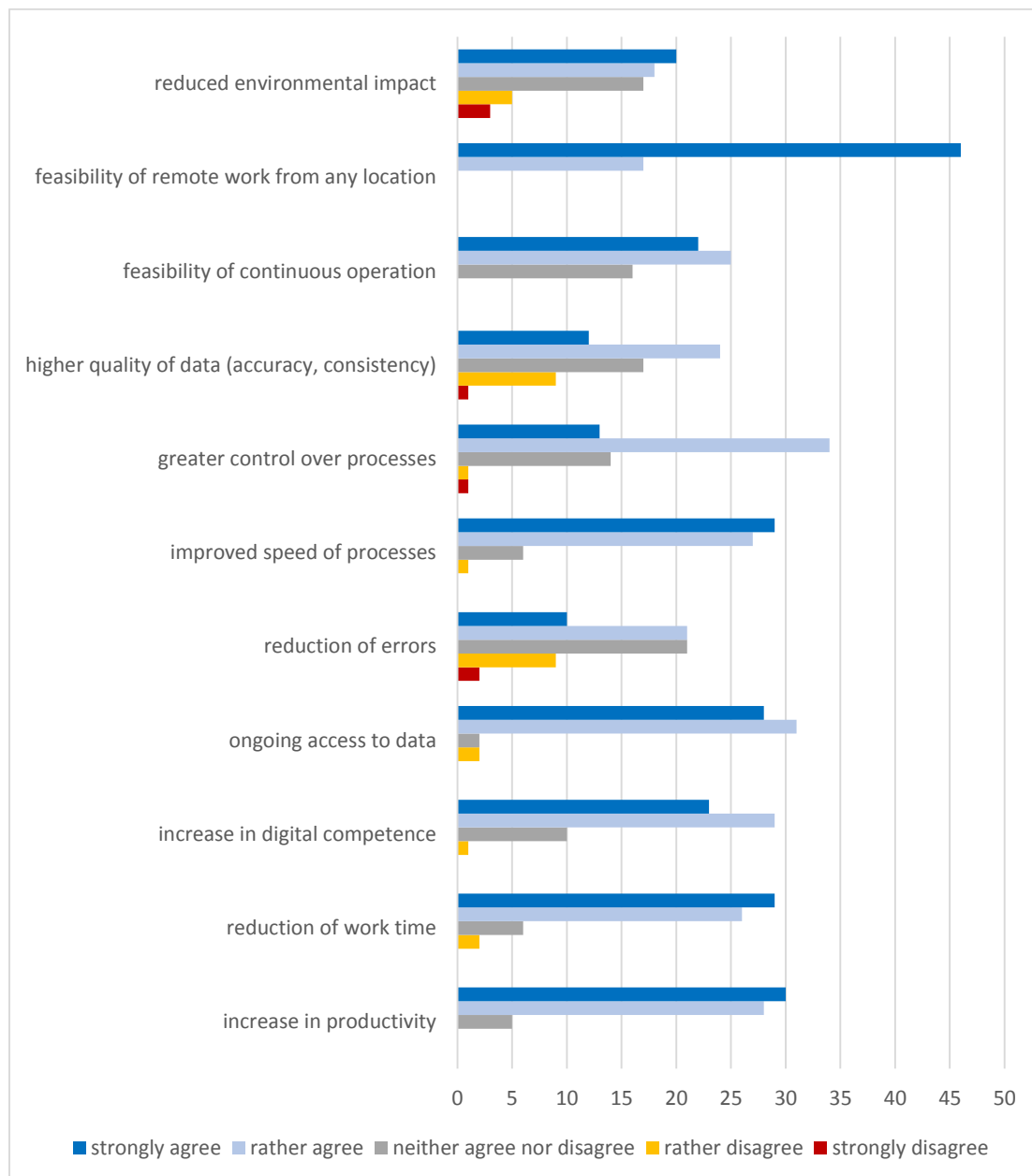
Likewise, almost unanimously assessed was the need for new technology-based digital competencies arising due to digitalization. The vast majority do discern such a need, as illustrated in Figure 12.



**Figure 12.** Are accountants in need of acquiring new technological competencies due to digitalization, in your opinion?

Source: own elaboration.

Figure 13 aggregates and illustrates the respondents' answers regarding the benefits of digitalization.

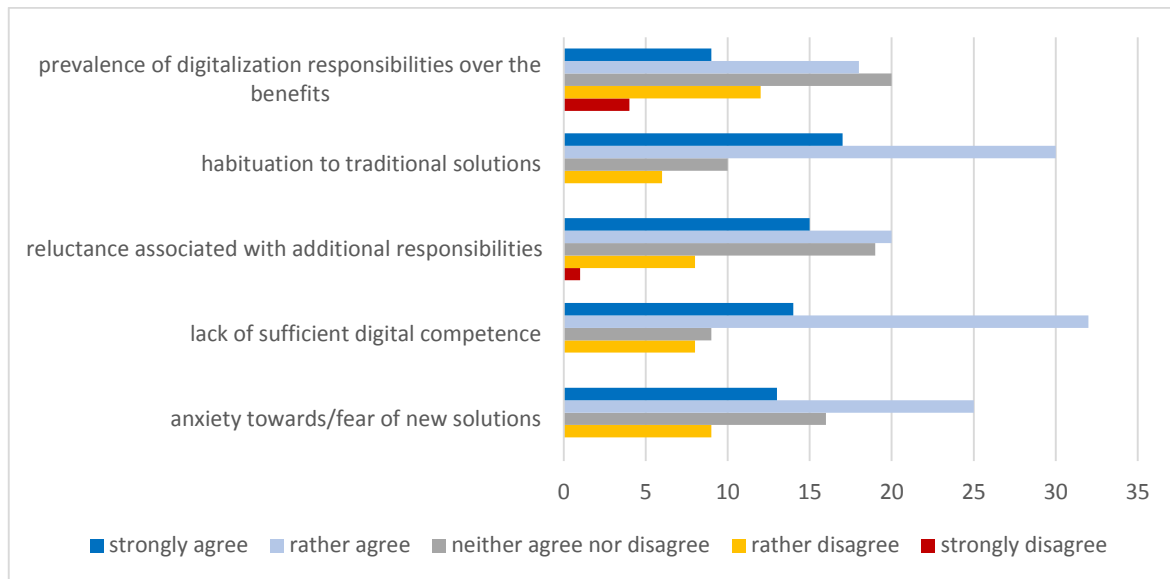


**Figure 13.** Benefits of digitalization.

Source: own elaboration.

Highest rated were such benefits as the ability to work remotely from any location - as many as 46 respondents strongly acknowledge and 17 respondents rather agree with the existence of this benefit. Also highly rated were increased productivity, greater speed of processes, continuous access to data or reduced working time. Slightly fewer respondents, though still in an overwhelming majority, perceive a benefit in the possibility of continuous work, improved digital competencies or greater control over processes. The benefit of reduced errors was rated the lowest, with only 31 respondents rather agreeing or strongly agreeing that such a benefit does arise as a result of digitalization.

Figure 14 illustrates the responses regarding the identification of barriers likely to hinder the implementation of digitalization.



**Figure 14.** Barriers to digitalization.

Source: own elaboration.

The greatest barriers identified were the lack of sufficient digital skills and habituation to traditional solutions. Over 50% of the respondents rather or strongly agree with the barriers of fear of new solutions and aversion to new responsibilities. Prevalence of digitalization-related responsibilities over the benefits appears to be the least significant barrier, with less than half of the respondents rather or strongly agreeing with the statement. Identification and a solid understanding of the barriers can prove contributive to the overcoming thereof.

Summing up, the pilot study conducted leads to the following several conclusions:

1. The students are aware of the transformation in the role of an accountant and the change in the functioning of the profession itself under the influence of digitalization.
2. The majority of the students find it impossible that in the future, due to digitalization, a person employed as an accountant will not be required to hold a professional degree. The results also indicate that, according to the respondents, RPA and AI will not replace the professional judgment of accountants.
3. Among the new roles of an accountant arising from digitalization, the role of a supervisor/controller received the most indications in all respondent groups. Next indicated were an analyst and a robot support specialist.
4. The results of the survey showed that the majority of the respondents across all three groups are familiar with the functioning of accounting software. They are also knowledgeable of what document digitization, wire transfer automation, VPN or electronic financial statements entail. Likewise, they are familiar with how artificial intelligence (AI) operates.
5. Noticeable is the different level of knowledge among the groups in terms of familiarity with certain digitalization tools.

6. The students most frequently rated their level of competence at '3' on a five-point scale. Some of the surveyees consider their skills to rank at the level of a '4'. None of the respondents rated their skills at the lowest (1) and highest levels (5), which reflects a similar assessment of self-reported level of knowledge among the respondents.
7. The Internet and the environment were most often indicated as sources of knowledge on technological innovations. Approximately 50% of the students in all surveyed groups also selected work experience during their studies as the source of such knowledge.
8. The choice of digitalization solutions over traditional ones, as well as the willingness to employ digitalization solutions, have been indicated as contingent on a given situation by the majority of the respondents.
9. The students clearly discern the need for digital skills and/or knowledge of digitalization tools in the accounting profession. They also recognize the need to acquire new competencies in these areas.
10. The surveyees do acknowledge the many benefits of digitalization, simultaneously identifying the associated barriers.

## 5. Conclusions

According to Brendan Sheehan (ACCA..., 2020), possession of digital skills is even presently essential in the accounting profession, and will continue to be of utmost significance in the future. It is therefore imperative to devote time to the understanding of the digitalization environment. Particularly relevant this aspect becomes in the context of educating future accounting adepts - they must be ready for the challenges ahead.

The literature review carried out allowed the ordering of the positions within the field of accounting profession digitalization with respect to academic education. The publications were divided into six research areas: digital technology tools in academic education, changes in academic education, modern forms of teaching, analysis of syllabuses and curricula, accountant skills in the modern world, RPA in education. The literature review carried out revealed a research gap of scant empirical research into the accounting students' knowledge and awareness of the changing role of accountants under the impact of digitalization. The only researches that addressed digitalization in the accounting profession from an academic perspective were those conducted by Taib et al., 2023 and Awang et al., 2023. In a group of 440 students of postgraduate accounting studies at the University of Malaysia, the level of digital competence and its impact on the digitalization of the accounting profession were examined. The results indicated a strong positive correlation between information literacy, ICT literacy as well as digital literacy, and digitalization (Taib et al., 2023). A similar study on digital literacy, also among Malaysian postgraduate students, indicates that mean scores for

information literacy, media literacy, information and communication technology literacy and digital literacy are high (Awang et al., 2023). It should be emphasized, however, that these studies do not allow for comparisons to be made with the results obtained by the authors, both due to the subject matter, country and type of studies. This indicates the originality of the research conducted by the authors and the research gap in this area. Partial contribution to filling this gap arose as the main objective of the present article.

The pilot survey was conducted among final-semester graduate students in Poland and Romania, assessing their knowledge and awareness of the changing role of accountants due to digitalization. The empirical survey employed the method of selection by convenience, therefore the results obtained cannot be generalized onto the entire population.

The survey found that students are aware of the change in the functioning of the accounting profession and the changing role of accountants, most commonly indicating a new role of a supervisor/controller. Most of the respondents are familiar with the operation of accounting software, and are not strangers to document digitization, transfer automation or electronic financial statements. The level of familiarity with such tools as blockchain, Big Data, and MS Power Automate was more varied. Most frequently, the students rated their technological competencies at the level of '3' on a five-point scale. They do agree, however, that the need for digital skills in the accounting profession is evident. The results of the survey, therefore, provided answers to the research questions posed.

In the future, further in-depth research is planned, involving a larger group of students, not only in their last semester of a master's degree in accounting, but also undergraduate students, as they too are becoming increasingly active in the profession after completing their undergraduate education. The authors are also considering to invite other economic universities in Poland and Romania to participate in the research, which would allow a cross-country comparison of accounting students' knowledge and awareness of the undoubtedly changing role of accountants in the modern economy. It would also be worth examining whether the current field of study program meets the needs of the market.

## **Acknowledgements**

The authors would like to thank Assoc. Prof. Dr. Suciú Titus for help in conducting surveys at the Faculty of Economic Sciences and Business Administration at Transilvania University of Brasov from Romania.



## References

1. ACCA (2020). *The digital accountant: Digital skills in a transformed world*.
2. Awang, Y., Taib, A., Mohamed Shuhidan, S., Zainal Zakaria, Z., Muhimatul Ifada, L., Sulistyowati, S. (2023). Mapping between Digital Competencies and Digitalization of the Accounting Profession among Postgraduate Accounting Students. *Asian Journal Of University Education*, 19(1), 83-94. doi:10.24191/ajue.v19i1.21226
3. Bastos, S.M., Girardi, S., Schvirck, E. (2022). Technology 4.0 in Accounting: What Future for Education? In: A. Mesquita, A. Abreu, J.V. Carvalho (Eds.), *Perspectives and Trends in Education and Technology. Smart Innovation, Systems and Technologies*, vol. 256. Singapore: Springer, doi:0.1007/978-981-16-5063-5\_23
4. Berikol, B., Killi, M. (2021). *The Effects of Digital Transformation Process on Accounting Profession and Accounting Education*, pp. 219-231, doi: 10.1007/978-981-15-1928-4\_13.
5. Bucior, G., Jaworska, E. (2023). Bidding farewell to paper financial reports – are Polish micro businesses coping with the phenomenon. 27th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2023), *Procedia Computer Science*, Vol. 225, pp. 3395-3403, doi: 10.1016/j.procs.2023.10.334
6. *Digitalization - Cyfryzacja wchodzi do księgowości. Pracownicy albo się dostosują, albo wypadną z rynku pracy*. Retrieved from: <https://www.bankier.pl/wiadomosc/Cyfryzacja-wchodzi-do-ksiegowosci-Pracownicy-albo-sie-dostosuja-albo-wypadna-z-ryнку-pracy-8373607.html>, 5.04.2023.
7. Gușe, G.R., Mangiuc, M.D. (2022). Digital Transformation in Romanian Accounting Practice and Education: Impact and Perspectives. *Amfiteatru Economic*, Vol. 24(59), pp. 252-267, doi: 10.24818/EA/2022/59/252.
8. International Federation of Accountants (2019). *Future-Fit Accountants: Roles for the Next Decade, Guidance & Support Tools*, <https://www.ifac.org/knowledge-gateway/preparing-future-ready-professionals/publications/future-fit-accountants-roles-next-decade>, 30.12.2023.
9. Iordan, M., Burca, V., David, D., Nicoara, S.A. (2022). Perception of students and master students from the western part of Romania over the digitalization process in the accounting education. *Studies in Business and Economics*, Vol. 17, Iss. 1, pp. 52-72, doi: 10.2478/sbe-2022-0004.
10. Jarco, M. (2023). *Zawody zagrożone przez robotyzację i rozwój AI*. Retrieved from: <https://serwisy.gazetaprawna.pl/praca-i-kariera/artykuly/8697887,zawody-robotyzacja-sztuczna-inteligencja-rozwoj-zagrozenie.html>, 5.04.2023.
11. Keys, B., Zhang, J. (2020). Introducing RPA in an Undergraduate AIS Course: Three RPA Exercises on Process Automations in Accounting. *Journal of Emerging Technologies in Accounting*, Vol. 17(2), 25-30.

12. Koh, S., Lee, H.H., Perdana, A. (2023). Data Analytics in an Undergraduate Accountancy Programme: The Spaced Retrieval Method. In: T. Rana, J. Svanberg, P. Öhman, A. Lowe, (Eds.), *Handbook of Big Data and Analytics in Accounting and Auditing* (pp. 415-437). Singapore: Springer.
13. Kotowska, B., Sikorska, M. (2023a). Digital transformation of a Polish accounting firm: tools, impediments, business performance benefits and implications – case study. 27th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2023). *Procedia Computer Science, Vol. 225*, pp. 327-336, doi: 10.1016/j.procs.2023.10.017.
14. Kotowska, B., Sikorska, M. (2023b). Accounting profession transformation in the wake of digitalization – survey results in Poland. *Scientific Papers of Silesian University of Technology – Organization and Management Series, Iss. 182*, pp. 147-165, doi: 10.29119/1641-3466.2023.182.9.
15. Lewandowski, A. (2021). *Cyfryzacja księgowości – czego powinien oczekiwać przedsiębiorca od nowoczesnego biura rachunkowego?* Retrieved from: <https://dmsales.com/blog/cyfryzacja-ksiegowosci-czego-powinien-oczekiwac-przedsiębiorca-od-nowoczesnego-biura-rachunkowego/>, 5.04.2023.
16. Marcinkowska, E. (2021) Proces przygotowania i składania e-sprawozdań finansowych – dotychczasowe doświadczenia. In: S. Kopera (Ed.), *E-management, t. 1, Digitalizacja procesów biznesowych* (pp. 29-41). Retrieved from: [https://ruj.uj.edu.pl/xmlui/bitstream/handle/item/278590/kopera\\_e-management\\_t-1\\_2021.pdf](https://ruj.uj.edu.pl/xmlui/bitstream/handle/item/278590/kopera_e-management_t-1_2021.pdf)
17. MF - MF opublikowało raport z przeglądu ustawy o rachunkowości. Retrieved from: <https://www.pibr.org.pl/pl/aktualnosci/2105,MF-opublikowalo-raport-z-przegladu-ustawy-o-rachunkowosci>, 22.01.2024.
18. Moore, W.B., Felo, A. (2022). The evolution of accounting technology education: Analytics to STEM. *Journal of Education for Business, Vol. 97, Iss. 2*, pp. 105-111, doi: 10.1080/08832323.2021.1895045.
19. Ng, C. (2023). Teaching Advanced Data Analytics, Robotic Process Automation, and Artificial Intelligence in a Graduate Accounting Program. *Journal of Emerging Technologies in Accounting, Vol. 20, Iss. 1*, pp. 223-243, doi: 10.2308/JETA-2022-025.
20. Patil, S., Mane, V., Patil, P. (2019). Social Innovation in Education System by using Robotic Process Automation (Rpa). *International Journal of Innovative Technology and Exploring Engineering, Vol. 8, Iss. 11*, pp. 3757-3760, doi:10.35940/ijitee.K2148.0981119
21. *Pre-consultations - Podsumowujemy prekonsultacje dotyczące kierunków rozwoju zawodu księgowego.* Retrieved from: <https://www.gov.pl/web/finanse/podsumowujemy-prekonsultacje-dotyczace-kierunkow-rozwoju-zawodu-ksiegowego>, 22.01.2024.
22. *Reform - Reforma systemu rachunkowości ze szczególnym uwzględnieniem cyfryzacji. Raport: Przegląd Ustawy o rachunkowości.* Retrieved from: <https://www.gov.pl/web/finanse/modernizacja-ustawy-o-rachunkowosci>, 22.01.2024.

23. Stanciu, V., Rindasu, S.M. (2017). Emerging Information Technologies In Accounting - Are The Aspiring Professional Accountants Prepared To Face The Challenges? A Case Study Of Romanian Universities. *Sustainable Economic Growth, Education Excellence, and Innovation Management Through Vision 2020, Vol. I-VII*, pp. 2455-2467.
24. Suarta, I.M., Suwintana, I.K., Sudiadnyani, I.G.A.O., Sintadevi, N.P.R. (2023). Employability and digital technology: what skills employers want from accounting workers? *Accounting Education*, 10.1080/09639284.2023.2196665.
25. Taib, A., Awang, Y., Mohamed Shuhidan, S., Zainal Zakaria, Z., Sulistyowati, S., Ifada, L. (2023). Digitalization of the Accounting Profession: An Assessment of Digital Competencies in a Malaysian Comprehensive University. *Asian Journal Of University Education*, 19(2), 365-380. doi:10.24191/ajue.v19i2.22229
26. The Act in Accounting of 29 September 1994, as amended, Journal of Laws 1994, No. 121, item 591.
27. Thomas, M. (2021). *On dual technology integration for effective teaching of digital accounting in a technology-rich, online learning context*. 8th International Conference on Educational Technologies 2021, ICEduTech 2021 and 17th International Conference on Mobile Learning 2021, ML 2021, pp. 250-254
28. Vincent, N.E., Igou, A., Burns, M.B. (2020). Preparing for the Robots: A Proposed Course in Robotic Process Automation. *Journal of Emerging Technologies in Accounting*, 17(2), 75-91.
29. Volokhin, Y., Mukhametzyanova, F., Khairutdinov, R. (2022). *Lifelong Learning of an Accountants (Digital Information Processing Masters) in the Context of Digital Economy*. IV International Scientific and Practical Conference (DEFIN-2021). Association for Computing Machinery, pp. 1-7. <https://doi.org/10.1145/3487757.3490923>
30. Xuxin, Y. (2022). The Path of Cultivating Applied Accounting Talents Based on DES Model under Big Data, Intelligentization, Mobile Internet and Cloud Computing. Proceedings of the 5th International Conference on Big Data and Education (ICBDE '22). Association for Computing Machinery, pp. 183-188. doi: 10.1145/3524383.3524399



## STATE-OWNED ENTERPRISES IN POLAND – ANNUAL AGGREGATED REPORT – PROPOSAL

Krzysztof KRZYWDZIŃSKI

University of Gdansk, Faculty of Management; krzysztof.krzywdzinski@edu.ug.pl,  
ORCID: 0000-0002-0411-887X

**Purpose:** The article aims to propose the scope of an aggregated annual report on the performance of state-owned enterprises (SOEs) in Poland.

**Design/methodology/approach:** Analysis of the literature regarding the publication by supervisory authorities of aggregated annual reports on state-owned enterprises. Analysis of aggregated annual reports from 5 EU countries selected for comparative analysis. The choice of 5 out of 24 countries preparing an aggregated annual report on all SOEs resulted from the number and importance of SOEs in these countries.

**Findings:** The analysis of aggregated annual reports from selected 5 countries showed that not all reports contain selected consolidated data of all SOEs or separate data about individual SOEs. In only 3 out of 5 countries (Sweden, Finland, and Norway) the reports contained aggregated data of all SOEs, and in 4 (apart from France) separate data of individual SOEs.

**Research limitation/implications:** Due to the length of the article, only 5 countries out of 24 preparing annual aggregated reports on SOEs were included in the comparative analysis.

**Practical implications:** The analysis is useful for all SOE stakeholders, especially politicians who create regulations concerning the state's ownership policy and Polish society.

**Social influence:** Introducing the need to publish an aggregated annual report on SOEs by the appointed state body (preferably the Ministry of State Assets) will positively impact the improvement of ownership supervision over these companies, to benefit the entire Polish society and other stakeholders.

**Originality/value:** The analysis of aggregated annual reports on SOEs prepared in other countries and the indication of elements in these reports that can be used in the Polish report is a new solution. The results of the analysis are useful to politicians responsible for creating the state's ownership policy, Polish society, and minority shareholders of SOEs interested in improving transparency in the supervision of SOEs, and thus in their operational effectiveness.

**Keywords:** state-owned enterprises, SOEs, corporate governance, aggregated annual report.

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

## 1. Introduction

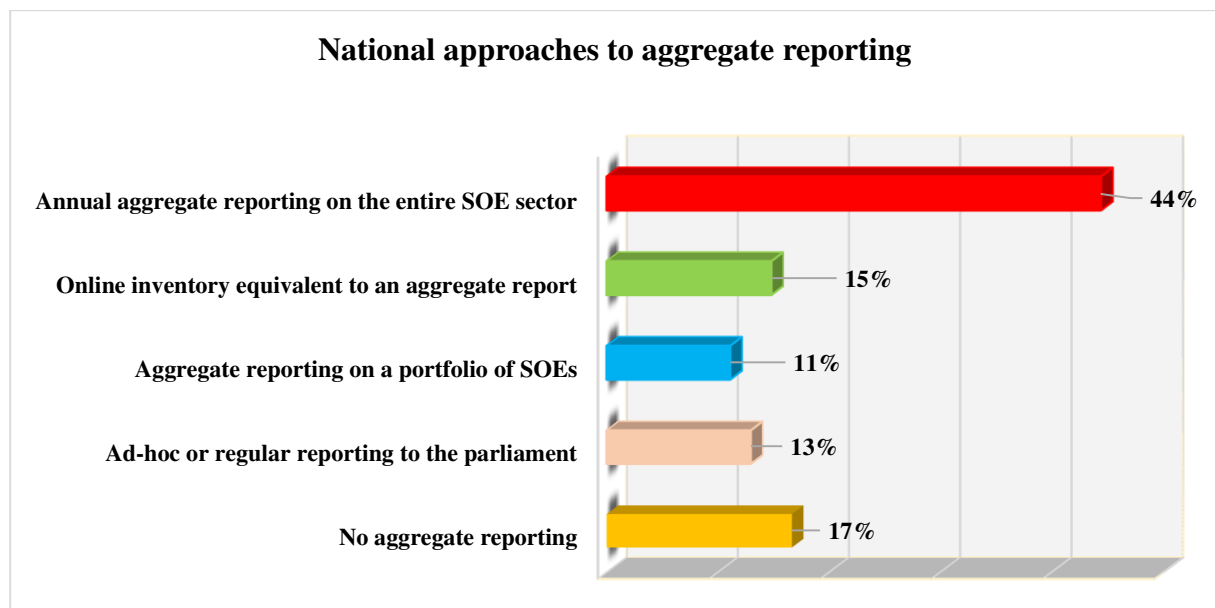
The article aims to propose the scope of information that should be included in the annual report on the performance of state-owned enterprises in Poland. Now, no report on this subject is being prepared, although the number and importance of these companies for the Polish economy is very large (detailed data in point 6). Expanding knowledge about state-owned enterprises is necessary to improve the corporate governance over these entities for the benefit of all their stakeholders, particularly Polish society.

To achieve the aim of the article, a research method was used consisting of the analysis of aggregated annual reports of state-owned enterprises in 5 selected countries. Both the purpose of the article and the research method are new solutions, never described by anyone before.

The state should strive to improve the quality of corporate governance because well-functioning corporate governance (S. Claessens, Y. Burcin, 2012, s. 17.):

- facilitates access to capital, and thus enables the implementation of larger investments leading to the development of the company and increased employment,
- reduces the cost of capital and thus increases the value of the enterprise, making investors more willing to invest in it, which contributes to its development and employment growth,
- increases the efficiency of enterprises through better allocation of resources and better management,
- reduces the financial risk of enterprises, thus reducing the risk of financial crises resulting in huge economic and social costs,
- contributes to improving relations between all stakeholders, which in turn leads to improved social and labour relations, and increased interest in environmental protection, and may consequently contribute to reducing poverty and social inequalities.

The research conducted by the OECD among 54 countries (Figure 1), including all 38 countries belonging to the OECD and the G20 countries, shows that aggregated reports on all SOEs were prepared in 24 countries (44%). The online inventory reports instead of annual aggregated reports on SOEs were published in 8 countries (15%). In 6 countries (11%) reports containing data on selected SOEs were prepared. In 7 (13%) countries, including Poland, reports were prepared only on ad-hoc or regular reporting to the parliament. In 9 (Belgium, Czech Republic, Iceland, Malaysia, Pakistan, Saudi Arabia, Tunisia, United Kingdom, and the United States) out of 54 countries, no aggregated reports on state-owned enterprises were prepared. The OECD report was based on materials sent by individual countries. However, in the case of Poland, according to the author, no published reports contained data on all state-owned enterprises. Only reports on listed state-owned enterprises in Poland are published from time to time.



**Figure 1.** National approaches to aggregate reporting.

Source: OECD, 2021, p. 45.

Of the 24 countries that were preparing the aggregated annual report, 15 are European Union countries. The scope of the aggregate report prepared by these countries is presented in Table 1.

**Table 1.**

*Annual aggregated reports on state-owned enterprises - scope of the report*

Country	Implementation of state ownership policy	Financial performance and value	Total employment in SOEs	Public policy objectives	Board composition and/or remuneration	Reporting on individual SOEs
Austria						
Bulgaria						
Denmark						
Estonia						
Finland						
France						
Germany						
Hungary						
Latvia						
Lithuania						
Netherlands						
Norway						
Portugal						
Spain						
Sweden						

full disclosure  
 partial disclosure

Source: OECD, 2021, pp. 47-50.

## 2. Literature review

The issue of corporate governance was formally introduced to economics by A. Smith in 1776, who in his book "An Inquiry into the Nature and Causes of the Wealth of Nations" noted for the first time the separation of ownership and control and its consequences in contemporary corporations (Jerzemowska, 2002, p. 11). The concept of "corporate governance" itself is defined differently in literature. According to A. Cadbury corporate governance is "The system by which companies are directed and controlled (A. Cadbury, 1992, p. 14). In turn, A. Shleifer and S. Vishny (Shleifer, Vishny, 1997, pp. 737-781) define it as "Methods ensuring that capital providers to corporations achieve a return on these investments". Another definition of corporate governance is provided by the OECD (OECD, 2015, p. 9), according to which "Corporate governance involves a set of relationships between a company's management, its board, its shareholders and other stakeholders. Corporate governance also provides the structure through which the objectives of the company are set, and the means of achieving those objectives and monitoring performance are determined". According to M. Aluchna, "corporate governance "can be analysed from the perspective of the achievements of economics, management, finance, legal sciences, sociology, psychology, and political science" (Aluchna, 2014, pp. 10-11).

In 1976, M.C. Jensen and W. Meckling published the most important elements of agency theory in a work entitled "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure". The essence of the problem of agency theory is the separation of management and control, or in other words, ownership and control (Jensen, Meckling, 1976, pp. 305-360). Eight years later, in 1984, R.E. Freeman published "Strategic Management - A Stakeholder Approach". According to Freeman, stakeholders are "any group or individual that can influence or be influenced by a corporation as a result of achieving its objectives" (Freeman, 1984).

Globalization processes, continuous development of corporations, and financial scandals (e.g. Enron - 2001; WorldCom - 2002 or Lehman Brothers - 2008) strengthen the role of corporate governance and the need to adapt it to the turbulent environment. One of the elements of this adjustment is changes or implementation of new legal regulations, e.g. in the USA the act known as the Sarbanes-Oxley Act of 2002 (The Sarbanes-Oxley Act, 2002). Moreover, in many countries or organizations such as the OECD, corporate governance codes were published for the first time or amended. The published codes apply not only to listed companies but also to investor associations, employers' associations, professional associations, and even governments (Aguilera, Cuervo-Cazurra, 2009, pp. 376-387).

The first corporate governance code, The report 'Financial Aspects of Corporate Governance Committee' (usually known as the Cadbury Report) was published in December 1992 in Great Britain and contained several recommendations to raise corporate governance standards (A. Cadbury, 1992).



In 2005, for the first time, the OECD issued a separate corporate governance code for state-owned enterprises - The Guidelines on Corporate Governance of State-Owned Enterprises. In 2015, the next version of the OECD Code was published, which replaced the first version.

In OECD Guidelines on Corporate Governance of State-Owned Enterprises (OECD, 2015, p. 25) the recommendation VI.C (Disclosure and transparency) states that “The ownership entity should develop consistent reporting on SOEs and publish annually an aggregate report on SOEs. Good practice calls for the use of web-based communications to facilitate access by the general public”.

Regulations regarding corporate governance are also issued in the European Union in the form of directives, regulations, and recommendations. One example is Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU (The European Union, 2022), as regards corporate sustainability reporting effective from 2023. Under the directive, the obligation to report on the company’s activities in the field of ecology, corporate social responsibility and corporate governance (so-called ESG report) will also apply to listed small and medium-sized companies (first time in 2027 for 2026), and large companies that are not listed on the stock exchange (first time in 2026 for 2025). The current regulation regarding the need to prepare the so-called ESG report concerns large listed companies employing 500 people. Legal regulations issued by the European Union divide enterprises into small, medium-sized, and large, as well as listed and non-listed. There are no regulations specific to SOEs.

Because SOEs perform not only commercial duties but also commercial-public and public duties, in many countries legal regulations only apply to the functioning of SOEs. One such regulation in Poland is the Act of June 9, 2016, on the principles of shaping the remuneration of persons managing certain companies (Ustawa, 2016). The Act regulates the amount of remuneration of members of management and supervisory bodies, as well as selected provisions of contracts concluded with members of management bodies in State Treasury companies, local government units or their associations, state legal units, and municipal legal persons,

As mentioned earlier, according to the OECD (OECD, 2015, p. 25) the ownership entity should develop consistent reporting on SOEs and publish annually. Preparing such a report increases the transparency of corporate governance, and thus increases the effectiveness of SOEs.

### 3. The size of SOEs in the EU countries belonging EU preparing annual aggregate reporting on the entire SOE sector (2012)

Table 2 shows the characteristics of listed state-owned enterprises in the countries presented in Table 1 (without Bulgaria due to lack of data) and in Poland. The data show that countries with the largest number of SOEs in which states had majority and minority shares were Poland (16), France (14), Finland (14), and Norway (8). In terms of the number of people employed in SOEs, France was in first place (1,119,722 employees), Germany was in second place (713,890 employees), and Finland was in third place (161,672 employees). The highest stock exchange value had SOEs from France, amounting to €165.3 billion. In second place was Norway, where the market value of 8 SOEs amounted to €119.3 billion. Finland was in third place with a market value of SOEs of €70.5 billion. Polish SOEs with a market value of €59.5 billion, took fourth place. Total market value of SOEs and total book value of SOEs in currencies other than EURO in Tables 2,3 and 4 were converted into EURO according to the average annual Euro exchange rate for 2012 (data in the table are for this year) provided by the National Bank of Poland, i.e. EUR/PLN = 4.1850; NOK/PLN = 0.5597; HUF/PLN = 1.4468; SEK/PLN = 0.4807; LTL/PLN = 1.2120.

**Table 2.**

*The size of SOEs in OECD countries from EU preparing aggregated annual reports on state-owned enterprises - listed companies*

Country	Values (except number of employees) in:	Majority-owned listed entities				Minority-owned listed entities				Total market value mn	Total market value in EUR
		Nr of enterprises	Nr of employees	Value of enterprises		Nr of enterprises	Nr of employees	Value of enterprises			
				Market	Book equity			Market	Book equity		
Austria	EUR mn	2	26281	8669	5808	2	45104	11510	15366	20179	20179
Denmark	DKK mn	1	621	797	992	2	16970	17869	13323	18666	2508
Estonia	EUR mn									0	0
Finland	EUR mn	3	21761	15380	14185	11	139911	55140	38770	70520	70520
France	EUR mn	3	165477	35103	37408	11	954245	130163	157617	165266	165266
Germany	EUR mn					3	713890	65669		65669	65669
Hungary	HUF mn									0	0
Latvia	LVL mn					1	32	5	24	5	1
Lithuania	EUR mn	2	701	146	191	1	1700	262	596	408	408
Netherlands	EUR mn									0	0
Norway	NOK mn	3	63187	631422	0	5	64211	260123	0	891545	119277
Poland	PLN mn	6	36074	90559	78979	10	64525	158622	105498	249181	59541
Portugal	EUR mn									0	0
Spain	EUR mn	1	20358	1028	-6188	2	7818	5151	1226	6179	6179
Sweden	(SEK mn)					3	73156	443165		443165	50903
TOTAL		21	334460			48	2081562				560452

Source: OECD, 2014, pp. 47-50, own calculations.

The data regarding non-listed state-owned enterprises in the countries detailed in Table 1 (without Bulgaria due to lack of data) and in Poland are presented in Table 3.

The data in Table 3 show that the countries with the largest number of non-listed state-owned enterprises in which the state had majority shares and statutory corporations and quasi-corporations were: Hungary (370), Poland (320), and Lithuania (135).

In terms of the number of people employed by these enterprises, France was in first place (1,419,024 employees), in second place was Germany (349,203 employees), and in third place was Portugal (171,534).

In turn, the highest net book value of non-listed state-owned enterprises belonged to Hungary, and it amounted to €511.0 billion. In second place was Norway, where the book value of these enterprises amounted to €105.1 billion. Third place belonged to France with a book value of non-listed state-owned of €51.5 billion. The Polish SOEs with a book value of €26.2 billion took fourth place.

**Table 3.**

*The size of SOEs in OECD countries from EU preparing aggregated annual reports on state-owned enterprises - non-listed companies*

Country	Values (except number of employees) in:	Majority-owned non-listed entities			Statutory corporations and quasi-corporations			Total book value	Total book value in EUR mn
		Nr of enterprises	Nr of employees	Value of enterprises	Nr of enterprises	Nr of employees	Value of enterprises		
Austria	EUR mn	6	47872	7554	1	8	961	8514	8514
Denmark	DKK mn	10	8867	47420	6	13335	20594	68014	9137
Estonia	EUR mn	29	16046	2766	24	9170	1450	4216	4216
Finland	EUR mn	37	60916	12174	2	2083	6818	18992	18992
France	EUR mn	34	309109	35172	20	1109915	16363	51535	51535
Germany	EUR mn	71	349197	36227	1	6	583	36810	36810
Hungary	HUF mn	370	123004	1478200				1478200	511030
Latvia	LVL mn	74	52240	2608				2608	755
Lithuania	EUR mn	46	26724	3067	89	13821	2009	5076	5076
Netherlands	EUR mn	26	78286	46943				46943	46943
Norway	NOK mn	25	49261	612240	17	108597	173430	785670	105113
Poland	PLN mn	295	117738	101017	25	5918	8598	109615	26192
Portugal	EUR mn	33	70981	8318	51	100553	-2337	5981	5981
Spain	EUR mn	44	10787	1117	8	64444	2144	3261	3261
Sweden	(SEK mn)	46	132727	332930	3	2881	12204	345134	39643
TOTAL		1146	1453755		247	1430731			873198

Source: OECD, 2014, pp. 26-55, own calculations.

## 4. Methods

Table 4 summarizes the number of SOEs, the number of employees, and the market and book values from Tables 2 and 3. Based on the data from Table 4, five countries were selected for further analysis: Finland, France, Germany, Norway, and Sweden. The lack of information on board composition and/or remuneration in the reports of 5 countries indicates low transparency of these reports. Therefore, they will not be analysed regarding their suitability for preparing a report for Poland. Also, reports without reporting on individual SOEs are not useful for this. Denmark and Spain were not selected for comparative analysis due to the low value of their SOEs.

The analysis of selected countries will involve examining their annual reports on state-owned enterprises and will allow to proposal of content for an aggregated report on state-owned enterprises in Poland.

**Table 4.**

*The size of SOEs in OECD countries from EU preparing aggregated annual reports on state-owned enterprises - listed and non-listed companies*

Country	Values (except number of employees) in:	Nr of enterprises	Nr of employees	Market value of enterprises	Book value of enterprises	Total value of enterprises	Total value of enterprises (EURO bn)	Reporting on individual SOEs
Austria	EUR mn	11	119 265	20 179	8 514	28 693	28.7	no
Denmark	DKK mn	19	39 793	18 666	68 014	86 680	11.6	yes
Estonia	EUR mn	53	25 216	0	4 216	4 216	4.2	no
Finland	EUR mn	53	224 671	70 520	18 992	89 512	89.5	yes
France	EUR mn	68	2 538 746	165 266	51 535	216 801	216.8	yes
Germany	EUR mn	75	1 063 093	65 669	36 810	102 479	102.5	yes
Hungary	HUF mn	370	123 004	0	1 478 200	1 478 200	511.0	no
Latvia	LVL mn	75	52 272	5	2 608	2 612	0.8	no
Lithuania	EUR mn	138	42 946	408	5 076	5 484	5.5	no
Netherlands	EUR mn	26	78 286	0	46 943	46 943	46.9	no
Norway	NOK mn	50	285 256	891 545	785 670	1 677 215	224.4	yes
Poland	PLN mn	336	224 255	249 181	109 615	358 796	85.7	-
Portugal	EUR mn	84	171 534	0	5 981	5 981	6.0	no
Spain	EUR mn	55	103 407	6 179	3 261	9 440	9.4	yes
Sweden	(SEK mn)	52	208 764	443 165	345 134	788 299	90.5	yes
TOTAL		1 465	5 300 508	1 930 783	2 970 569	4 901 351	1 433.6	

Source: Own calculations based on the date from Tables 2 and 3.

## 5. Results

### Norway

At the end of 2022, Norway had direct state ownership of 69 companies. All 69 state-owned enterprises (SOEs) were divided into 2 categories (Norwegian Ministry of Trade, Industry and Fisheries, 2022, p. 7):

- Category 1 – consisted of 21 companies where the State's goal as an owner is the highest possible return over time in a sustainable manner.
- Category 2 – consisted of 45 companies that do not primarily operate in competition with others, the State's goal as an owner is sustainable and the most efficient possible attainment of public policy goals.
- Three companies were not categorized.

The 69 enterprises were supervised by 12 ministries. Most enterprises, 28, were supervised by the Minister of Trade, Industry and Fisheries, of which 19 belonged to Category 1 and 9 to Category 2.

In 2022, the value of Norwegian state-owned enterprises, categories 1 and 2 (Table 5), was calculated as the sum of the value of listed shares held, and the sum of the net book values

of shares held in non-listed enterprises amounted to NOK 1449.7 billion. Of this amount, the market value of listed companies (8 companies) amounted to NOK 1069.5 billion, and book value of non-listed companies (58 companies) amounted to NOK 380.2 billion. All 66 companies had sales revenues of NOK 2597.8 billion and employed 334,072 people. The return on equity ratio (ROE) for listed SOEs was 41.8%, and for non-listed companies from Category 1, it was 17.9%. In 2022, the value of dividends paid by SOEs to the state budget amounted to NOK 112.2 billion. All 69 companies in 2022 emitted 495 million tonnes of CO<sub>2</sub> (scope 1: 38,578,224 tonnes; scope 2: 7264,025 tonnes and scope 3: 449,320,889 tonnes).

**Table 5.**

*Group accounting figures for 2022 – companies in category 1 and 2*

Company category	Companies	Market value of the State's ownership interest (NOK million)	Book value of State's ownership interest (NOK million)	Return	Operating revenues (NOK million)	Profit/loss after tax (NOK million)	Dividend to the State (NOK million)	Number of employees
Category 1	Listed companies (8)	1 069 506	0	41.8%	2 127 481	407 978	87 442	124 064
Category 1	Non-listed companies (13)		177 432	17,9%	142 763	29 072	17 481	36 127
Category 2	Companies cat. 2 (45)		202 775		327 580	18 638	7 238	173 881
	<b>Total</b>	<b>1 069 506</b>	<b>380 207</b>	<b>0</b>	<b>2 597 824</b>	<b>455 688</b>	<b>112 161</b>	<b>334 072</b>

Source: Norwegian Ministry of Trade, Industry and Fisheries State Ownership Report, 2022, pp. 13-15.

State policy towards SOEs was published in the Report to the Storting (white paper) and presented to Parliament by the Government. The new version of the report from 2022 (The Royal Ministry of Trade, Industry and Fisheries, 2022-2023) replaced the previous report to the Storting published in 2019 (Ministry of Trade, Industry and Fisheries 2019-2000). The 135-page document discusses the Norwegian government's policy towards state-owned enterprises, the reasons for holding shares in SOEs, and the principles of their management.

The state-owned enterprises in Norway report their financial and non-financial data following the government policy contained in the Report to the Storting (white paper). The financial data consists of selected data from financial statements and some indicators. The non-financial data can be divided into 3 groups:

- The data on specific spheres of the company's operation (for example company goals, results, tax policy, capital structure, selected risk level.
- Information on tonnes of CO<sub>2</sub> equivalent emitted, broken down into emissions directly related to its activity (Scope 1), indirect emissions related to energy consumption (Scope 2), and indirect emissions related to the purchase of products and services (Scope 3) and
- Information on international standards and guidelines applied by public enterprises. The guidelines standards used by Norwegian public companies (not only by listed companies) include Integrated reporting, International Financial Reporting Standards (IFRS), Good accounting practice (GAP), GRI Standards, TCFD, greenhouse Gas Protocol, Guidelines OECD Guidelines for Multinational Enterprises, UK Gender Pay Gap.

Every year the Norwegian Ministry of Trade, Industry and Fisheries, and Fisheries prepares the annual report “The State Ownership Report”. The report is prepared under the government policy contained in the Report to the Storting (white paper).

The first part of the report for 2022 – “State Ownership Report – The State’s direct ownership of companies, 2022” (86 pages), concerns all companies, while the second part discusses the financial and non-financial results of individual companies. An example of aggregated data is presented in Table 5, which contains information on all state-owned enterprises. Table 6 presents sample goals for the company: National-theatret AS (Category 2). In Table 7 presented the data included in the report in the part regarding individual companies. Financial and non-financial data of an individual company are presented on one page of the report.

**Table 6.**

*Goals and results for National-theatret AS – 2022*

	Long-term goals	Indicator	Goals 2022	Result 2022 (2021)
Public policy goal attainment	Research and innovation that increase the competitiveness of the industry by the results being used and creating value	Publication points per researcher	>0.7	0.78 (1.32)
		Participate in SFI projects	> 3	3 (3)
		National assignment revenues as a % of turnover	> 30%	36% (34%)
		Participation in EU projects	> 25	21 (22)
	Research infrastructure available to solve challenges in the business sector	Investment in research infrastructure as a % of net turnover	> 3.5%	4.4% (7.6%)
		Operation of buildings as a % of net revenues	< 15%	13.5% (11.7%)
Increased trust in research	National media reports	> 1,500	2,030 (1,688)	
Efficient operations	Deliver high-quality and relevant research	PhDs as a % of researchers	> 80%	81%
		Invoiced hours/R&D fulltime equivalents	> 1,140	1,103 (1,157)
	Focus on areas, methods and technologies that will be relevant in the future	Operating profit/loss %	> 0	-4.1% (0.2%)
		Equity ratio %	> 40%	40% (45%)

Source: Norwegian Ministry of Trade, Industry and Fisheries, 2022, p. 108.

**Table 7.**

*Date reported on individual companies – Statkraft – 2022*

Statkraft (category 1, non-listed companies)	
<b>Statement of comprehensive income (NOK millions)</b>	<b>Financial key figures</b>
Net operating revenues	Operating margin (EBIT margin)
Operating result (EBIT)	Equity ratio
Result before tax	Return on equity
Tax charge	Average return on equity in the past five years
Minority interests	Financial income
Result after tax and minority interests	Share of profits from associates
<b>Statement of financial position</b>	Capital employed
Total assets 3	Return on capital employed
- Of which cash reserves	Net cash flow from operations
Total equity	Net cash flow from investments
-Of which minority interests	<b>Other key figures</b>

Cont. table 7.

Total debt and liabilities	Number of employees
- Of which interest-bearing liabilities	Percentage of employees in Norway
<b>Assets and dividend</b>	Proportion of women in group:
Dividend for the financial year	- management/the company's
Dividend share	- management group
Average dividend percentage in the past five years	Percentage of women in the company, total
Dividend to the State	Greenhouse gas emissions (tonnes of CO <sub>2</sub> equivalents)
Repayment of capital	Scope 1, Scope 2, Scope 3
Capital contributions from the State	

Source: Norwegian Ministry of Trade, Industry and Fisheries, 2022, p. 79.

The next table, 8, contains the state-set goals and the degree of their implementation for the company Statkraft (category 1, non-listed companies) for 2022. Statkraft is Europe's largest producer of renewable energy and a major player in the European energy market. The share of the Norwegian state in the shareholding structure of the company at the end of 2022 was 100%.

**Table 8.**

*Date reported on individual companies – Goals and results - Statkraft – 2022*

Long-term goals	Indicator	Goals 2022	Result 2022 (2021)
Prevent corruption and unethical behaviour in all activities	Targets	No serious violation	0 (0)
Deliver solid returns on investments	ROACE	12%	43.2% (22.4%)
Efficient operation of the Nordic hydropower portfolio	Realised prices compared to market price	3.50%	5.6% (9.0%)
increase capacity in renewable energy (hydro, wind and solar power)	New capacity (GW)	9 GW by 2025	3.6 GW Cumulative (3.3 GW)
Greater diversity in terms of background, expertise and gender	Number of women in senior management positions	35% by 2025 and 40% by 2030	33% (30%)

Source: Norwegian Ministry of Trade, Industry and Fisheries, 2022, p. 79.

The scope of selected financial data reported for individual companies may slightly differ due to the specificity of the enterprise. The goals set for individual enterprises may be completely different for each enterprise and this results from the specificity of a given enterprise and belonging to particular categories.

## Finland

According to the 103-page document for 2022 - "Report on State Annual Accounts 2022 Annex 4 State corporate holdings" (Publications of the Finnish Government 2023:52, 2023), the Finnish government had shares in 69 state-owned enterprises at the end of 2022 of which 35 were commercial companies and 34 were special assignment companies.

Of the 35 trading companies, 16 were listed companies: 4 were directly owned by the government, and 12 were controlled indirectly by Solidium Oy, a wholly owned company of the Finnish government.

All 69 state-owned enterprises were divided into 3 categories:

- Category 1 a: The State has exclusively, or almost exclusively, a strong investor interest in the company. When control is exercised through ownership, due consideration must be given to the control or influence associated with the State's holdings as well as the owner's risk and involvement in decision-making based on such holdings.
- Category 1 b: Aside from a strong investor interest, the companies in this category involve strategic interests that make it advisable for the State to remain a strong shareholder or take other steps to secure such strategic interests in case its holdings are decreased or relinquished.
- Category 2: As a shareholder, the State has a special interest in the companies included in this category related to regulation or statutory duties; these companies have a state-defined political or other mission related to business and industry or society, or they play some other special role.

At the end of 2022, there were 15 SOEs in Category 1a, 20 SOEs in Category 1b, and 34 SOEs in Category 2.

The 69 enterprises were supervised by 9 ministries and Solidum Oy. Most enterprises were supervised by The Ownership Steering Department of the Prime Minister's Office: 4 listed companies, 17 non-listed commercial companies, and 9 companies entrusted with special state.

In 2022, 69 SOEs employed 299,000 people, reported €144 billion in net sales, €12.1 billion in operating income, and capital expenditure amounted to €7.7 billion. The value of state direct holdings in 2022 was €41 billion (€47 billion in 2021). The companies (without enterprises held by Solidium) paid €9 billion in tax. In 2022, the State received a total of EUR 1.4 billion in dividends and share sale proceeds from its corporate holdings. The return on all state-owned listed companies was negative -14.5% (2.9% in 2021). The return on Solidium's portfolio was negative -9.0% (33.4% in 2021) and the return on the portfolio of the state's direct holdings was -16.2% (-4.6% in 2021). The share of women on the boards of directors of all state-owned companies was 47% (47% in 2021). In state-owned companies, the percentage of women in management teams was 41% (35% in 2021).

The state-owned enterprises in Finland report their financial and non-financial data in under the government policy contained in the report – "Revenue through responsible ownership. Government Resolution on the State Ownership Policy 8 April 2020" (Prime Minister's Office 2020, 2020). The document discusses, among others: policy, the objectives of the Finnish government as a shareholder in state-owned enterprises, the social responsibility of the activities of these enterprises, and the rules for remunerating members of boards of directors, CEOs and managers. Based on this document, the Finnish government prepares an annual report on the Finnish government's shares in state-owned enterprises (Report on State Annual Accounts. Annex 4 State corporate holdings). State-owned enterprises were divided into the previously mentioned 3 categories: category 1a, category 1b and category 2.



As a shareholder, the state expects companies to act responsibly and obliges boards of directors to accept responsibility and report at annual general meetings of shareholders. As a shareholder, the state requires companies to take corporate social responsibility and sustainable development into account in their business activities and implement a goal-oriented CSR policy. The state expects state-owned enterprises to lead in corporate social responsibility and sustainable development.

In addition, the state expects companies to comply with international CSR guidelines, and principles, where applicable. These include the OECD Guidelines for Multinational Companies, the TCFD Carbon Risk Reporting Framework, the Science-Based Targets initiative, the UN Global Compact, the ISO 26000 Guidelines on Social Responsibility, and the UN Principles on Enterprise and Human Rights.

Annual report on the operation of state-owned enterprises for 2022, “Report on State Annual Accounts. Annex 4 “State corporate holdings”, presents the summed-up of selected financial and non-financial indicators for all enterprises (Table 9), discusses the general principles of remunerating management and employees, appointing members of the board of directors, and presents individual public enterprises. The report does not provide information on all 69 SOEs, but only 52: 4 listed companies, 19 non-listed commercial companies, and 29 companies entrusted with special state.

**Table 9.**

*Key figures for listed, non-listed and special assignment companies in 2022*

Net sales (MEUR)
Operating income (MEUR)
Operating margin, %
Total assets (MEUR)
Equity ratio, %
Gearing, %
Return on equity, %
Return on investment, %

Source: Publications of the Finnish Government 2023:52, 2023, pp. 34-36.

Table 10 presents the scope of financial and non-financial information of the listed, energy company Fortum Corporation with the State’s shareholding of 51.26%.

**Table10.**

*Date reported on individual companies – Fortum Corporation*

Key financial indicators	
Net sales MEUR	Dividends received by the State MEUR
Operating income MEUR	Investments MEUR
Operating margin %	Total personnel at 31 Dec.
Equity ratio %	Tax footprint in Finland MEUR
Gearing %	MtCO <sub>2</sub> e (Scope 1)
Total assets MEUR	MtCO <sub>2</sub> e (Scope 2)
Return on equity %	MtCO <sub>2</sub> e (Scope 3)
Return on investment %	
Dividend yield %	

Source: Publications of the Finnish Government 2023:52, 2023, p. 45.

## Sweden

According to the 126-page document for 2022 - “Annual Report for state-owned enterprises 2022” (Government Offices of Sweden, 2022, p. 12) the State’s enterprise portfolio consisted of 43 enterprises at the end of 2022. The supervision of over 43 enterprises was exercised by three ministers. The Ministry of Finance supervised the largest number of enterprises,

The supervisors of individual enterprises, together with their boards of directors, establish financial and public goals for these entities. Financial goals must be long-term, ambitious, and realistic. Financial goals include three indicators: return on equity (ROE), capital structure (financial leverage), and dividend paid. Of the 43 enterprises, 22 are entities implementing state public policy, which means that their goal is not to maximize financial indicators but to implement government policy. Implementation of the government’s public policy may mean supporting the development of culture, more sustainable consumption or the supply of medicines. For example, Systembolaget, an alcohol sales company in Sweden, reports 3 indicators: the Customer Satisfaction Index, the Alcohol Index, and the alcohol consumption report (liters per person/market share).

The value of the state’s direct shares in the 43 public enterprises in 2022 amounted to SEK 850 billion, which was SEK 30 billion more than in 2021. Sales revenues of all enterprises, employing 134,000 people, amounted to SEK 520 billion (including associates). All SOEs reported a net profit of SEK 23.3 billion (SEK 15.1 billion earned by LKAB) and paid dividends of SEK 23.0 billion to the state budget (SEK 49.7 billion paid in 2021). The largest dividends came from LKAB, at SEK 7.5 billion, and Vattenfall, at SEK 4 billion. Gross investments increased by 18.1% to SEK 57.3bn (48.5bn in 2021). In 2022 the share of women in board chairs and directors was 50%.

The document “Annual Report for state-owned enterprises”, prepared by the Government Offices of Sweden, is consistent with the guidelines contained in the document “State Ownership Policy and Principles for state-owned enterprises 2020” (Government Offices of Sweden, 2020). The current principles of state policy towards state-owned enterprises were published and adopted by the Swedish government on February 27, 2020, and replaced the previous regulations of December 22, 2016. The principles of state policy towards state-owned enterprises focus on three areas: the principles of government corporate governance (ownership) supervision, remuneration of senior officers, and external reporting. According to government policy, state-owned enterprises should focus on long-term development, and be efficient and profitable. They must perform in an exemplary manner in the area of sustainable business and in every other area in such a way that they enjoy the trust of the public. The principles of ownership policy apply to all state-owned enterprises with majority state ownership. In the remaining enterprises, i.e. those with minority state ownership, the state conducts dialogue with other owners to apply the government’s ownership policy. Every year, the government submits an annual report on state-owned enterprises to the Riksdag (Swedish

Parliament). The report aims to present the state's shares in state-owned enterprises, provide the value of these shares, and present the effects of managing these enterprises during the year. The report should include information on the implementation of the goals set for state-owned for a given year and information on compliance with government rules set for state-owned enterprises.

Under the principles of ownership policy, public enterprises are subject to the same regulations as private enterprises, including the Companies Act (2005:551), the Accounting Act (1999:1078), and the Annual Accounts Act (1995:1554). In addition, state-owned enterprises are obliged to prepare annual reports by the rules applicable to listed companies on the Stockholm Stock Exchange - Nasdaq Stockholm. This means, among other things, that state-owned enterprises are obliged to prepare an annual report on the remuneration of senior management staff by the guidelines for listed companies. This means, among other things, that state-owned enterprises are obliged to prepare an annual report on the remuneration of senior management staff under the guidelines for listed companies. SOEs also prepare a sustainability report by the Global GRI Standards or other internationally recognized guidelines.

The document - "Annual report for state-owned enterprises 2022", presents the summed-up of selected financial and non-financial indicators for all enterprises, discusses the general principles of remunerating management and employees, appointing members of the board of directors, and presents data on individual state-owned enterprises. Table 11 presents information about the aggregate data of all SOEs presented in the report for a period of 5 years.

**Table 11.**

*Scope of aggregated data - all state-owned enterprises*

SEK bn	
Net sales (incl. any appropriation)	Total equity
Net sales incl. associates (incl. any appropriation)	Total assets
Profit before changes in value	Number of employees excl. associates (thousands)
Changes in value	Number of employees incl. associates (thousands)
Operating profit (EBIT)	Dividend
Profit before tax	Estimated value h)
Profit after tax	Return on equity (%)
Gross investments	Equity/assets ratio (%)
Cash flow from operating activities (excl. SEK and SBAB)	Dividend yield (%)

Source: Government Offices of Sweden, 2022, p. 7.

The next Table, 12, presents the scope of financial and non-financial information of the non-listed company Vattenfall AB. The company is one of Europe's largest producers and retailers of electricity and heating and has around 19,000 employees. The enterprise's main markets are Sweden, Germany, the Netherlands, Denmark and the UK. State shareholding: 100.00%.

To sum up, the scope of information published by Swedish public enterprises is practically the same as that applicable to listed enterprises, i.e. very transparent. It is practically entirely consistent with the OECD requirements contained in the discussed document “OECD Guidelines on Corporate Governance of State-Owned Enterprises, 2015 Edition”.

**Table 12.**

*Data scope – enterprise - Vattenfall AB*

<b>Income statement, SEK m</b>	<b>Other key indicators</b>
Net sales	Operating margin, %
Operating profit	Return - equity, %
Profit before tax	Return - operating capital, %
of which, minority interests	Net debt/equity ratio
<b>Balance sheet, SEK m</b>	Equity/assets ratio, %
Total assets	Gross investments, SEK m
Noncurrent assets	Appropriation, SEK m
Equity	Divided, SEK m
- of which, minority interests	Carbon footprint (tCO <sub>2</sub> e)
Net debt	Scope 1
Operating capital	Scope 2
	Scope 3
	Sickness absence, %
	Average no. Of employees
	Reported in compliance with GRI - yes
	Reported in compliance with IFRS - yes
	A taxonomy report submitted - yes
	Climate targets set - yes
	Biodiversity targets set - no (in a process to set targets)

Source: Government Offices of Sweden, 2022, p. 85.

## France

In France, state-owned enterprises are supervised by the State Investment Agency (French: Agence des participations de l'État, APE), established in 2004 as a government agency. According to the report for 2021-2022 (Government Shareholding Agency (APE), 2021-22) of 48 pages, APE employed 55 people (49% women), including 32 senior executives and portfolio managers and 11 specialist and support staff.

At the end of June 2022, the market value of the French government's shares in 83 SOEs amounted to €128.4 billion, of which €64.6 billion in 11 listed companies (€25.4 billion were shares in the energy giant EDF).

Revenues from the sale of state-owned enterprises amounted to €140.59 billion, €23.16 billion less than a year earlier. In 2021-2022 SOEs reported a net profit of €6.97 billion (the previous year there was a net loss of €6.84 billion).

The largest 20 SOEs employed a total of 1.66 million workers. According to the report, 41% of people on boards of directors and supervisory boards were women. All 83 public enterprises contributed €2.085 billion to the state budget (dividends).

The 48-page report does not contain information about individual state-owned enterprises, only their list and some remarks about an individual company. The data contained in the report show that state-owned enterprises in France are of great importance to its economy and society. The report prepared by the State Investment Agency (French: Agence des participations de l'État, APE) contains a lot of information about the agency itself, which is important, but the very limited data about individual companies reduces the value of the report for comparative purposes.

## Germany

The German report on state-owned enterprises was prepared by the Minister of Finance. The latest available report, "Report on Government Shares 2023" (German: Beteiligungsbericht des Bundes 2023), has 469 pages and covers 2022. According to the report, at the end of 2022, the German government held direct shares in 118 state-owned enterprises and special funds (73 in companies, 16 in cooperatives, and 29 in government funds) and indirect shares in 390 investments in which the federal government held at least 25 percent with nominal capital of at least EUR 50,000 (Bundesministerium der Finanzen, 2023a).

In 54 of 73 SOEs the government's share was above 50%, and 34 of them were so-called large companies, i.e. meeting 2 of 3 criteria: employing more than 250 people, balance sheet total above EUR 40 million, revenues above EUR 20 million. Supervision of these 118 public enterprises was exercised by 14 ministers and one Federal Government Commissioner for Culture and Media (German: Die Beauftragte der Bundesregierung für Kultur und Medien). The report does not contain aggregate data for all state-owned enterprises, such as sales revenues, profit, or the number of employees.

According to the report, at the end of 2022, the share of women in supervisory bodies, i.e. supervisory boards, administrative boards, and trustee boards, was 40.6% (39.8% a year earlier). In turn, the share of women in managerial positions was 28.4% in 2022, and 29.5% in 2021.

The report includes data on individual state-owned enterprises. Information about each company has a similar scope, and differences may result from the specificity of the company. The state's share in the shareholding structure and the state-owned enterprise's shares in other entities are provided. Additionally, the report contains information on the remuneration of individual members of supervisory and management boards. In addition, selected information from the Profit and Loss Account, Balance Sheet, and other indicators are provided. In the document, the report on Deutsche Bahn AG covers 4.5 pages. Table 13 presents the scope of data on Deutsche Bahn AG.

**Table 13.***Date reported on individual companies - Deutsche Bahn AG*

<b>Profit and Loss Account</b>	<b>Balance sheet (in thousands of euros)</b>
Sales revenues	Total assets
Other income	Fixed assets
Cost of materials	Current assets
Personnel costs	including intangible assets
Other operational costs	including property, plant and equipment
Financial costs/income	Long-term liabilities
Annual result (net profit/loss)	Current liabilities
	Equity capital
	Accruals
	<b>Other parameters</b>
	Equity ratio (in %)
	Subsidies from the federal budget (€ thousand)

Source: Bundesministerium der Finanzen, 2023a, pp. 173-177.

“The Government Shares Report 2023” (German: *Beteiligungsbericht des Bundes 2023*) is prepared following the Corporate Governance Code “Principles of Good Management of Enterprises and Investments by the Federal Government” (German: “Grundsätze guter Unternehmens- und Beteiligungsführung im Bereich des Bundes”), released for the first time in 2009. On September 16, 2020, the government approved a new version of the document - “Principles of good and active management of enterprises and investments by the federal government” (German: “Grundsätze guter Unternehmens und aktiver Beteiligungsführung im Bereich des Bundes”). In December 2023, a new document was issued (updated version from 2020) replacing the one from 2020 - “Principles of Good Corporate Governance and Active Participation Management in the Federal Sector” (German: *Grundsätze guter Unternehmens- und aktiver Beteiligungsführung im Bereich des Bundes*).

The version from 2023 (193 pages) consists of two parts (Bundesministerium der Finanzen, 2023b):

The first part - the “Federal Code of Corporate Governance” (German: *Public Corporate Governance Kodex des Bundes, PCGK*) - is addressed to companies and their bodies. It supplements the legal provisions on the management and supervision of federally owned companies with additional standards of good and responsible corporate governance.

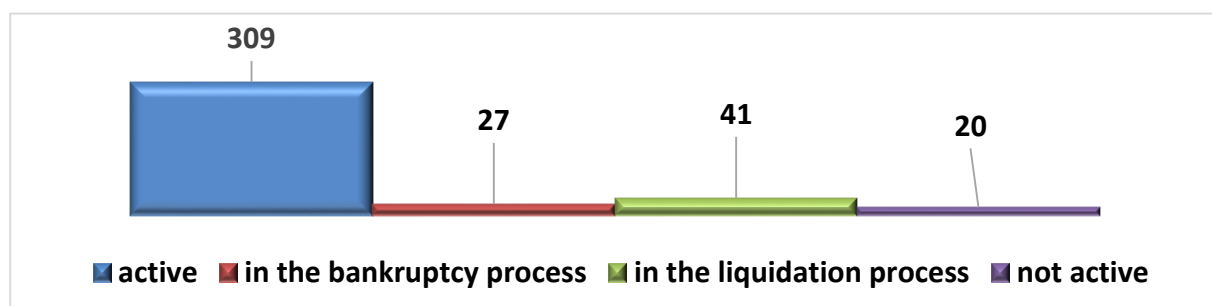
The second part - “Guidelines for active investment management in companies with federal participation” (German: *Richtlinien für eine aktive Beteiligungsführung bei Unternehmen mit Bundesbeteiligung*) is addressed to federal bodies entrusted with investment management or preparing members of supervisory bodies.

## 6. The state-owned enterprises in Poland

State-owned enterprises play a key role in Poland from the point of view of the economy and the state budget. In 2021, over half a million employees were employed in 669 SOEs (direct and indirect shares of the State Treasury in SOEs). In 2022, the capital expenditure of only 19 selected companies amounted to PLN 45.2 billion. In 2022, state-owned enterprises paid PLN 28.9 billion to the budget in excise duty, PLN 21.0 billion in VAT, and PLN 15.4 billion in corporate income tax (Ministerstwo Aktywów Państwowych, 2023, p. 3-24).

Until the end of 2016, state-owned enterprises were supervised by one state authority, i.e. the Ministry of the Treasury. At the time of the liquidation of the Ministry of the Treasury, the Minister of the Treasury supervised 432 companies. The Regulation of the Council of Ministers of January 3, 2017, on the list of companies in which the rights attached to State Treasury shares are exercised by members of the Council of Ministers, Government plenipotentiaries, or state legal persons other than the Prime Minister, decentralized ownership supervision over enterprises with State Treasury participation. From that moment, supervision over 432 enterprises previously supervised by the Minister of the Treasury was transferred to 10 ministers.

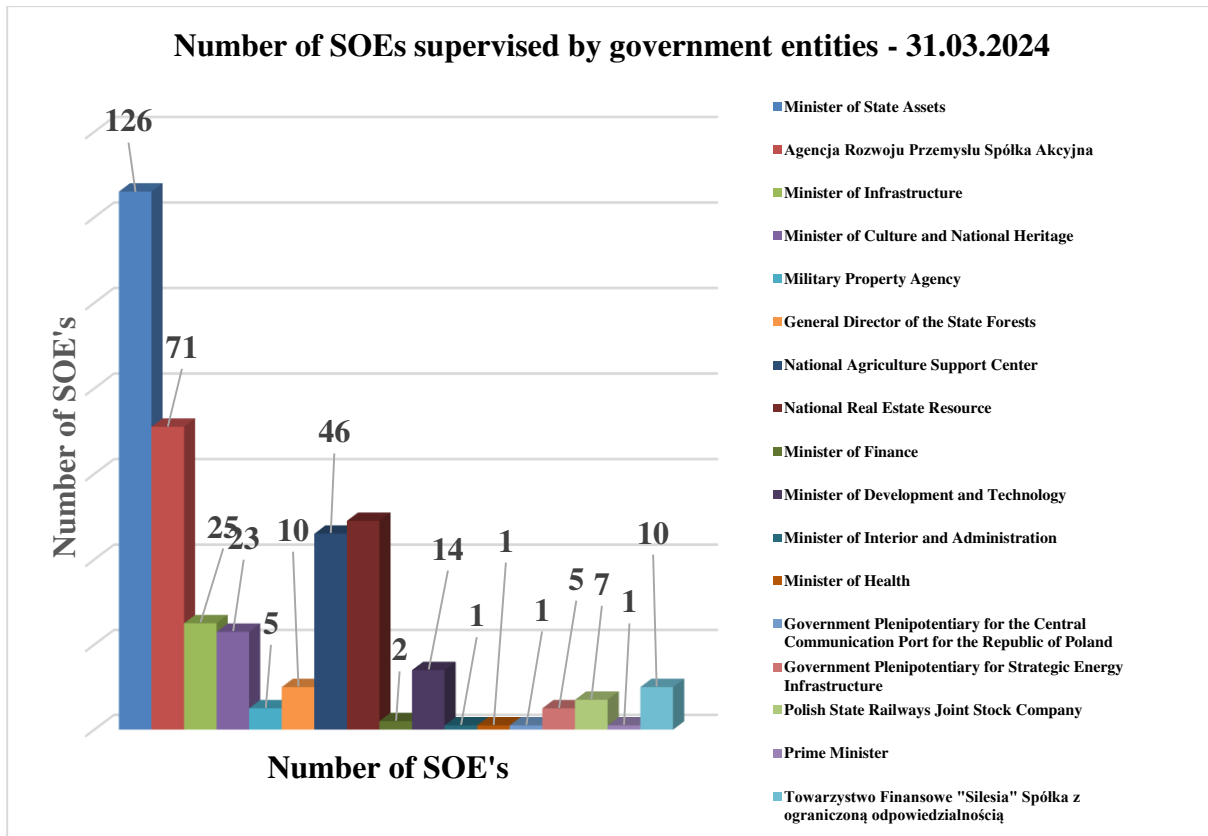
As of March 31, 2024, there were 397 state-owned enterprises in Poland in which the State Treasury had direct shares (Figure 2). Of the 397 companies, 27 were in the bankruptcy process, 41 were in the liquidation process, and 20 were not conducting business.



**Figure 2.** Number of state-owned enterprises as of March 31, 2024.

Source: Serwis Rzeczypospolitej Polskiej, 26.06.2024.

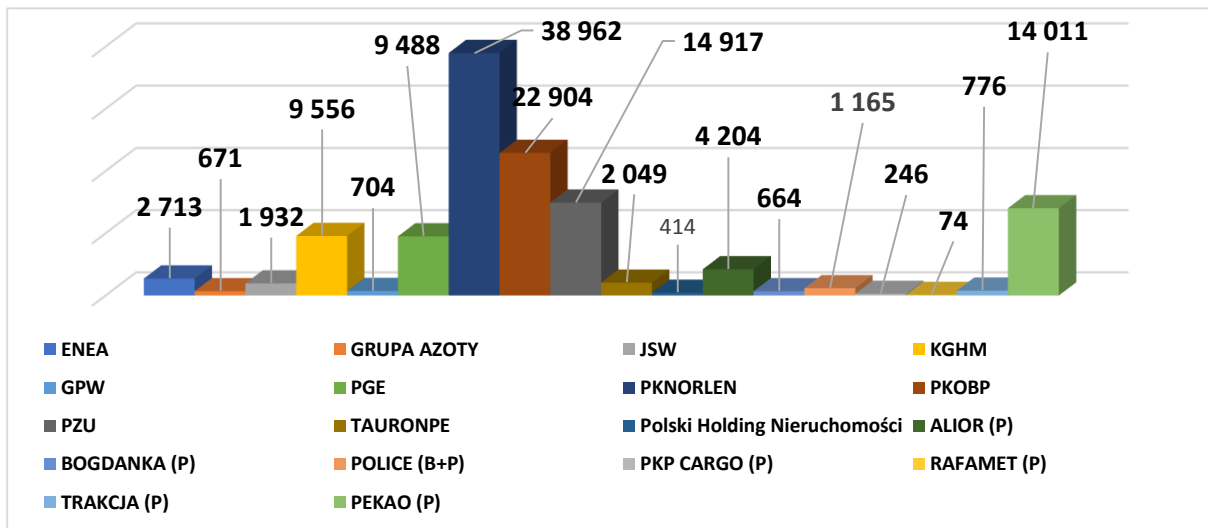
The 397 SOEs were supervised by 17 government bodies and entities (Figure 3). The largest number, 126, of companies were supervised by the Minister of State Assets. Industrial Development Agency S.A. supervised 71 companies, and the National Real Estate Resource 41 companies.



**Figure 3.** Number of SOEs supervised by government entities as of March 31, 2024.

Source: Serwis Rzeczypospolitej Polskiej, 26.06.2024.

As of June 26, 2024, the State Treasury held shares in 18 listed companies worth PLN 125.4 billion. In 11 of them, the State Treasury had direct shares worth PLN 104.3 billion, and in 7 companies indirect shares, through state-owned enterprises, worth PLN 21.1 billion (Figure 4).



**Figure 4.** The value of direct and indirect State Treasury shares in listed state-owned enterprises on the Warsaw Stock Exchange - as of June 26, 2024.

Source: Bankier.pl, Retrieved from <https://www.bankier.pl/gielda/notowania/akcje>, 26.06.2024. own calculations.



## 7. Summary

One of the elements of corporate governance is an aggregated report on SOEs prepared by the appointed government body. As mentioned earlier, in the OECD Guidelines on Corporate Governance of State-Owned Enterprises (OECD, 2015, p. 25) the recommendation VI.C (Disclosure and transparency) states that “The ownership entity should develop consistent reporting on SOEs and publish annually an aggregate report on SOEs”.

Table 14 presents the results of the analysis of aggregated annual reports on SOEs from the 5 analysed countries. The data shows that the most detailed report is the German one, containing 469 pages, on average 4 pages for the description of one company. In turn, the French report has the fewest pages, 46, with an average of 0.6 pages per company.

**Table 14.**

*The Annual aggregated reports on SOEs - summary*

	Norway	Finland	Sweden	France	Germany
1. Annual aggregate reporting on the entire SOE sector (examples)					
Nr of pages in the report for 2022	86	103	126	46	469
Nr of SOEs	69	69	43	83	118
Average number of report pages per 1 company	1.2	1.5	2.9	0.6	4.0
SOEs categories	2	3	2	0	0
Setting goals and reporting their achievement	yes	no	yes	-	-
2. Aggregated data on all SOEs (examples)					
Market or book value of the states shares	yes	yes	yes	yes	no
Revenues	yes	yes	yes	yes	no
Operating profits/losses	yes	yes	yes	yes	no
ROE	yes	yes	yes	yes	no
Dividends paid to the State	yes	yes	yes	yes	no
Investments	no	yes	yes	yes	no
Number of employees	yes	yes	yes	yes	no
Proportion of women in management	yes	yes	yes	yes	yes
3. Separated data on individual SOEs (examples)					
Goals and results	yes	no	yes	no	no
Selected items from the balance sheet and income statement	yes	yes	yes	no	yes
Equity ratio	yes	yes	no	no	yes
Return on Equity (ROE)	yes	yes	yes	no	no
Greenhouse gas emissions (tonnes of CO <sub>2</sub> equivalents)	yes	yes	yes	no	no
Proportion of women in management	yes	yes	yes	no	yes

Source: Own work based on tables from 5 to 13.

Only two reports, Swedish and Norwegian, provide annual goals for individual companies and the degree of their implementation.

Finnish, Norwegian, and Swedish SOEs were divided into categories (from 2 to 3), i.e. pursuing commercial, commercial-public, and public purposes. In turn, aggregated data on all or almost all SOEs were included in 4 reports, apart from the German report. Of these 4 reports, the French report contained the least aggregated data. The scope of information reported on individual SOEs is similar in Sweden, Norway, and Finland.

In the French report, there was almost no information about an individual SOE but the German one was very detailed.

To sum up, the best among the presented annual reports are the Swedish and Norwegian reports. The next place is taken by the Finnish report, which unfortunately does not contain information about the goals set for SOEs and the degree of their implementation. In third place is the German report, which deserves special attention for number of pages (469) and published data on the earnings of individual members of supervisory and management boards. The main disadvantage of this report is the lack of aggregated information for all SOEs. The French report is the least useful for comparative analysis because in fact, this report concerned the agency supervising SOEs, i.e. the State Investment Agency (French: Agence des participations de l'État, APE).

The analysis of 5 reports allows for the following conclusions to be drawn regarding the scope of data for the Polish report on SOEs:

- Aggregated values (financial and non-financial data) for all SOEs, including employment, sales revenues, financial result, dividends paid to the budget, CO<sub>2</sub> emissions, return on equity ratio (ROE), value of SOEs divided into stock exchange value (listed companies) and accounting value (non-listed companies).
- Financial and non-financial information about individual companies, including selected items of the balance sheet and profit and loss account, employment, dividends paid, investment expenses, ROE ratio, CO<sub>2</sub> emissions, set goals and the degree of their implementation, information on the remuneration of supervisory board members and management boards.

Due to the large number of SOEs in Poland, it may be decided that the consolidated data will concern companies that are not micro or small entities within the meaning of the Accounting Act (Ustawa z dnia 29 września 1994 r. o rachunkowości, Dz.U. 1994, nr 121, poz. 591).

In Poland, SOEs should be divided into 4 categories:

- Category 1a - companies with commercial targets, strategic ones for the State
- Category 1b - companies with commercial targets, the State is planning to sell the shares of these entities,
- Category 2 - companies with commercial-public targets, strategic ones for the State
- Category 3 - companies with public purposes, strategic ones for the State.

After the assignment of the appropriate categories to Polish SOEs will be possible to set goals for them.

A good solution would be to introduce in Poland the obligation to report the remuneration of members of supervisory and management boards of all SOEs. Information on these remunerations would then be included in the aggregated annual report (the information on the remuneration of members of the supervisory boards and management boards is in the German report).

What are the reasons for the absence of aggregated reports in some countries, including Poland?

State-owned enterprises are usually a “cash cow” for the ruling political parties in Poland and a trophy for the party winning the elections. Many politicians say that SOEs are necessary for the functioning of the country. The lack of an aggregated report on SOEs is particularly beneficial for the ruling party in the situation of deteriorating financial results of these companies.

According to stakeholder theory, stakeholders are “any group or individual that can influence or be influenced by a corporation as a result of achieving its goals” (Freeman, 1984). The most important stakeholders interested in the annual aggregated report on SOEs is theoretically the Polish society and minority shareholders. However, politicians who are stakeholders of SOEs are not willing to publish such reports for other stakeholders.

In turn, according to the theory of property rights. Representatives of property rights see the reasons SOEs exist in ideological factors, lack of sufficient information about the effects of SOE’s performance, and sometimes in the interest that some politicians may have in the form of access to certain positions (Iwanek, Wilkin, 1998, pp. 105-119.).

As of today, it is not even known what the exact number of SOEs in Poland is. According to Figure 2, as of March 31, 2024, there were 397 SOEs (Serwis Rzeczypospolitej Polskiej, 26.06.2024). However, according to the report of the Minister of State Assets (Ministerstwo Aktywów Państwowych, 2023), there were 669 SOEs in 2021 and these were enterprises employing 10 or more people keeping accounting books, with a direct and indirect share of the State Treasury above 10%. However, there is no list of these companies available anywhere. Therefore, the number of 669 does not include 109 companies out of 397 that were in the government database as of March 31, 2024, in which the State Treasury held less than 10% of shares (Serwis Rzeczypospolitej Polskiej, 26.06.2024). Of course, this database does not include subsidiaries of these 397 SOEs. Therefore, an aggregated annual report would sort out the problem of the number of SOEs.

This situation may be changed by another stakeholder, i.e. Polish society, by demanding the publication of such a report. Thanks to the report, the public would know the value of SOEs, and their annual financial results contained in one document.

Introducing the obligation to prepare the report by the Minister of State Assets and present it to the Sejm is only one of the elements of improving ownership supervision over these entities.

Another solution to consider is the use of the Swedish model for SOEs on external reporting recommended by the OECD, in which SOEs report following the requirements for listed companies.

Of course, moving from the point where there is no aggregated annual report to the point where not only there is such a report, but also non-listed SOEs report under the requirements for listed companies requires a lot of time and pressure on the politicians of the stakeholder, which is the Polish society.

The article aims to propose the scope of information that should be included in the annual report on the performance of state-owned enterprises in Poland to improve the corporate governance over them. Improvement of the corporate governance over SOEs by introducing an annual aggregated report on their performance will benefit all their stakeholders, particularly Polish society.

## References

1. Aguilera, R.V., Cuervo-Cazurra, A. (2009). Codes of good governance. *Corporate Governance: An International Review*, Vol. 17, No. 3, pp. 376-387.
2. Aluchna, M. (2014). Nadzór korporacyjny wobec krytyki koncepcji shareholder value. *Studia Prawno-Ekonomiczne*, vol. 16/2, pp. 10-11.
3. Bankier.pl, Retrieved from: <https://www.bankier.pl/gielda/notowania/akcje>, 26.06.2024.
4. Bundesministerium der Finanzen (2023a). *Beteiligungsbericht des Bundes*.
5. Bundesministerium der Finanzen (2023b). *Grundsätze guter Unternehmens- und aktiver Beteiligungsführung im Bereich des Bundes*.
6. Cadbury, A. (1992). *The report 'Financial Aspects of Corporate Governance Committee*.
7. Claessens, S., Burcin, Y. (2012). *Corporate Governance and Development: An Update, Global Corporate Governance Forum Focus 10 (rev.)*. International Finance Corporation, Washington, pp. 1-97.
8. Freeman, E. (1984). *Strategic Management – A Stakeholder Approach*. Boston.
9. Government Offices of Sweden (2020). *State Ownership Policy and principles for state-owned enterprises 2020*.
10. Government Offices of Sweden (2023). *Annual report for state-owned enterprises 2022*.
11. Government Shareholding Agency (APE) (2022). *Annual report 2021-2022*.
12. Iwanek, M., Wilkin, J. (1998). *Instytucje i instytucjonalizm w ekonomii*. Uniwersytet Warszawski, Wydział Nauk Ekonomicznych.
13. Jensen, M.C., Meckling, W.H. (1976). Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics*, Vol. 3, No. 4, pp. 305-360.
14. Jerzemowska, M. (2002). *Nadzór korporacyjny*. Warszawa: PWE.
15. Ministerstwo Aktywów Państwowych (2023). *Znaczenie spółek Skarbu Państwa dla Polski. Dlaczego nie warto ich wyprzedawać?* Retrieved from: <https://www.gov.pl/web/aktywa->

- panstwowe/znaczenie-spolek-skarbu-panstwa-dla-polski-dlaczego-nie-warto-ich-wyprzedawac--raport-map, 2.05.2024.
16. Ministry of Trade, Industry and Fisheries (2020). *The state's direct ownership of companies. Suitable value creation, Meld. St. 8 (2019-2020) Report to the Storting (white paper)*.
  17. Ministry of Trade, Industry and Fisheries (2022). *State Ownership Report – The State's direct ownership of companies, 2021*.
  18. Norwegian Ministry of Trade, Industry and Fisheries (2023). *State Ownership Report – The State's direct ownership of companies, 2022*.
  19. OECD (2014). *The Size and Sectoral Distribution of SOEs in OECD and Partner Countries*. OECD Publishing. Retrieved from: <http://dx.doi.org/10.1787/9789264215610-en>, 3.06.2024.
  20. OECD (2015). *OECD Guidelines on Corporate Governance of State-Owned Enterprises, 2015 Edition*. Paris: OECD Publishing. Retrieved from: <http://dx.doi.org/10.1787/9789264244160-en>, 3.06.2024.
  21. OECD (2021). *Ownership and Governance of State-Owned Enterprises: A Compendium of National Practices 2021*. Retrieved from: <https://www.oecd.org/corporate/ownership-and-governance-of-state-owned-enterprises-a-compendiumof-national-practices.htm>, 3.06.2024.
  22. Prime Minister's Office 2020 (2020). *Revenue through responsible ownership. Government Resolution on the State Ownership Policy 8 April 2020*. Helsinki.
  23. Publications of the Finnish Government 2023:52, K 2/2023 vp. (2023). *Report on State Annual Accounts 2022 Annex 4 State corporate holdings*.
  24. Serwis Rzeczypospolitej Polskiej. Retrieved from: [https://dane.gov.pl/pl/dataset/1198,wykaz-spoek-z-udziaem-skarbu-panstwa/resource/57392/table?page=1&per\\_page=20&q=&sort=](https://dane.gov.pl/pl/dataset/1198,wykaz-spoek-z-udziaem-skarbu-panstwa/resource/57392/table?page=1&per_page=20&q=&sort=), 26.06.2024.
  25. Shleifer A., Vishny R. (1997). A Survey of Corporate Governance. *The Journal of Finance*, Vol. LII, No. 2, pp. 737-781.
  26. The European Union, Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU. Official Journal of the European Union, L 322/15, 16.12.2022, pp. 15-80.
  27. The Royal Ministry of Trade, Industry and Fisheries (2023). *Greener and more active state ownership. The State's direct ownership of companies, Meld. St. 6 (2022-2023) Report to the Storting (white paper)*.
  28. The Sarbanes-Oxley Act (2002). Pub.L. 107-204, 116 Stat. 7450.
  29. Ustawa z dnia 29 września 1994 r. o rachunkowości (Dz.U. 1994, nr 121, poz. 591).
  30. Ustawa z dnia 9 czerwca 2016 r. o zasadach kształtowania wynagrodzeń osób kierujących niektórymi spółkami (Dz.U. 2016, poz. 1202).



## THE ROLE OF SOCIAL LENDING IN FINANCING ENTERPRISES

Wojciech LEOŃSKI

University of Szczecin, Faculty of Economics, Finance and Management; wojciech.leonski@usz.edu.pl,  
ORCID: 0000-0002-8391-1410

**Purpose:** The main purpose of the article is to examine and understand the specific role that social lending plays in financing enterprises in Poland. The article also aims to shed light on the benefits and drawbacks of social lending.

**Design/methodology/approach:** The article uses the prevailing literature as well as analysis and evaluation of documents, reports, and the websites of social lending platforms.

**Findings:** The obtained results will help to indicate the role of social lending in financing enterprises in Poland.

**Research limitations/implications:** The results cannot be generalised, but can form a basis for further deliberations. They shed certain light on the role of social lending in financing enterprises in Poland.

**Originality/value:** The article shows the role of social lending in financing enterprises in Poland. This article is mainly aimed at people who plan to start a business. Information on the role of peer to peer lending can be valuable for them, helping them to understand what opportunities they have and how they can use it to raise funds to develop their business.

**Keywords:** social lending, enterprises, peer to peer lending.

**Category of the paper:** General review.

### 1. Introduction

Social lending is a relatively new source of capital raising that can provide an alternative to traditional financing. Social lending constitutes a contract between private individuals that is concluded without the intermediation of banks or non-bank institutions. Instead, the loan is taken out through special platforms that connect those who need additional funds with those who are prepared to lend them. Social lending can be a good way to fund start-ups or to subsidise an existing business. These loans can also be used, for example, to launch new innovative products, invest in marketing campaigns or expand the business by hiring new employees, etc. It is worth adding that in the era of dynamic development of financial technologies, social lending platforms offer innovative solutions that can effectively support

the development of small and medium-sized enterprises. In Poland, the social lending system is not yet as developed as in the Western European countries or in the United States of America. On the other hand, it is worth noting that new online lending platforms are emerging all the time where funds can be obtained. In consequence, it seems that this modern instrument for financing, among other things, innovative business projects will also gain importance in Poland over time. The future of the crowdfunding and social lending sector seems promising, especially in the context of technological development and growing public awareness of alternative sources of financing. It is worth noting that the global social lending market is expected to reach US\$1,000 billion by 2025, while by 2050 the value is expected to be close to US\$1 trillion (Statista, 2023).

This article aims to provide an insight into the role that social lending plays in business financing. Among other things, the article outlines the mechanism of social lending and the main advantages and disadvantages of this model of business financing.

## 2. Literature review

The history of social lending dates back to 2005, as the first social lending site, Zopa (Zone of Possible Agreement), was launched in the UK. Zopa's business model consisted of an exchange of funds between those who have a financial surplus and have spare cash to offer and those who want to borrow it. In later years, other social lending companies quickly emerged in the UK, for example Assetz Capital, Funding Circle, Wellesley, Folk2Folk, Ratesetter. After the UK, the next services enabling social lending were established in the United States, e.g. Prosper and LendingClub (today, the world's largest social lending portal). In Poland, the first social lending site was kokos.pl, which was established in 2008.

A global trend in lending markets in recent years has been so-called peer-to-peer (P2P) platforms. P2P lending platforms bring speed and efficiency to the lending market due to the rapid advances in modern information technology and the easy availability of data and its processing (Pokorna, Sponer, 2016). Social lending (peer-to-peer lending or crowdlending) is a direct alternative to a bank loan with the difference that instead of a single source, companies can borrow directly from dozens or even hundreds of willing individuals. Lenders often offer loans by stating the interest rate at which they are prepared to lend their funds. Borrowers then choose the offers with the lowest interest rate. Online platforms are used to communicate between lenders and borrowers (European Commission, 2017).

Various interpretations and definitions of social lending in the management science literature have emerged over recent years. There is no one-size-fits-all, universal definition of social lending, so in order to better understand and properly interpret the concept, it is worth quoting a selection of authors' definitions.



Social lending is the practice of lending money, intended for previously unconnected people, without the intermediation of traditional financial institutions, i.e. banks. The lending process itself is carried out with the help of online platforms that have a number of tools available to the investor to carry out a complete credit verification. Most Social lending processes are unsecured by the borrower, and are intended for the individual (Jeżewski, 2021). By a Social lending contract, the lender (loan giver), which is an individual with spare cash, undertakes to transfer a certain amount of money to the borrower (borrower), who is either a consumer or a non-business individual, and the borrower (borrower) undertakes to return the same amount of money (Robinski, 2021). Peer-to-Peer lending, which is also known as P2P, is an online financial investment platform in which individual investors fund projects by lending money to individual borrowers through social networks. (Purkayastha, Tuzlukaya, 2021). Social lending or peer to peer are online marketplaces where individuals can borrow from and lend money to each other (Gonzalez, McAleer, 2011).

The idea of raising funds through social lending is to prepare your project or investment. An entity or person wishing to obtain a loan must, among other things, specify the amount of the loan, define the purpose for which the funds will be raised, and specify the repayment period and interest rate for the investor. Investors are mostly individuals investing their own funds. An entity seeking funding can find lenders online on specially designed platforms/services. To obtain a community loan, you do not need to meet stringent conditions. In theory, therefore, it could be for anyone. They are aimed at individuals who are looking for financing for any purpose, but also companies and businesses who want to raise funds to expand their business but do not meet the criteria set by the bank, for example as to the minimum length of time they have been in business.

The pattern of social lending platforms is usually similar, although some details may differ. Borrowers send applications to the platform, declaring the amount requested along with the interest rate, also describing the purpose of the loan. In turn, lenders, based on the information available, assess the riskiness (profitability) of the applications they are interested in and make investment decisions. If the required amount is raised within a certain time regime, it is allocated through the platform to the borrowers, and the platform takes a commission on the transaction (Dziuba, 2017).

The author of the study interprets social lending as a modern, alternative and flexible source for individuals or companies to raise capital from other individuals through an intermediary in the form of an online platform, without personal contact between the parties to the loan agreement. In this case, the transaction takes place without the intermediation of banks and other financial institutions. It should be noted that social lending occupies a growing segment of the non-bank lending market in Poland. This is evidenced, for example, by the growing number of sites operating on the basis of social lending. Social lending is a good example of how modern technology and the internet are creating opportunities for businesses to grow, especially in the SME sector.

### 3. The social lending market in Poland

The social lending market is not yet strongly developed in Poland. Social loans are encountered mainly in Western Europe and the United States, but there are also social loans in Poland, which are popular and have already managed to win the approval of their customers.

Private lending markets are an innovation that is part of the trend towards the de-mediation of financial markets, striking directly at one of the fundamental roles played by institutionalized intermediaries. Taking advantage of the unique properties of the global network, online marketplaces promise to effectively reduce transaction costs, connect actors in a dispersed market to each other, and ultimately eliminate the need for an intermediary entity. The rapid development of the social lending phenomenon, the budding of new ventures in various parts of the globe brings with it not only extensive growth in this segment of the financial market, but also innovations of various kinds (Kisiel, 2009, p. 443).

The first social lending platform on the Polish market was Kokos.pl. However, the service stopped offering community loans from private investors in 2019. For almost 10 years, it offered community loans that service users gave to each other. Investors willing to grant loans and earn on them as well as potential borrowers could register on the platform, while the merging of the parties took place as a result of an auction. A single loan was usually made up of several investors, which reduced their investment risk and meant that borrowers were more likely to receive a loan. The security of the transaction was overseen by the Kokos.pl service, which carried out initial verification of both investors and borrowers, set loan limits depending on the rating of the borrowers, or, finally, assisted investors in debt collection activities (Kaminski, 2021). Currently, Kokos.pl is only involved in brokering instalment loans from lending companies. In 2024, there are only a few social lending platforms active on the Polish market. At this point, it is worth recalling one of the rankings comparing European social lending sites that are popular in Poland. The *twojinteres.pl* ranking includes platforms that mostly have a Polish language version. In addition, some of these loan services have branches in Poland. The ranking was based on: the size and transparency of the platform, the returns offered, the guarantees offered, the minimum investment value, the types and variety of loans available, the functionality of the platform itself, customer service and any welcome bonuses for new investors. Six social lending platforms were ranked: Mintos, Bondora, Finansowo, Robocash, PeerBerry, Iuvo (*twojinteres.pl*, 2023).

In order for the idea of community lending to develop better, a sustained industry-wide effort is needed to create positive public relations. It should be borne in mind that this trend is still in its infancy, and its position is not yet as strong as that of the instant lending sector, and any negative action by at least one player could significantly undermine everything that has been achieved with so much hard work since the first Polish P2P service was established. Currently, the community lending sector is no threat to the banking sector. On the other hand,

in the future, when it gains more user trust, it will certainly become a player that banks will have to take into account. Accordingly, a new trend called social banking may form on the basis of the community lending trend, due to its social nature of operation, which differs from the traditional banking model (Jeżewski, 2021).

#### **4. Benefits and drawbacks of social lending**

Social lending has its strengths and weaknesses. Skillful use of such loans can prove profitable for a startup or growth-stage company. Undoubtedly, social lending can be a successful source of funding for small and medium-sized enterprises, providing an alternative to the banking market. The speed and convenience of raising capital, and often a more favorable interest rate than at a bank, are strong arguments for using community lending to fund a business. Online services offer the possibility of setting up company accounts and obtaining loans directly for the benefit of a business, whether in the form of an individual's company or a commercial company.

The main advantages of community lending include (Zastrzeżyński, 2019):

- wide range of loans, availability of significant amounts,
- high loan eligibility,
- loan outside of financial institutions,
- speed and application without leaving home,
- the possibility of using the money for any purpose,
- the possibility of obtaining better loan terms through voluntary verification,
- the possibility of adapting the loan to the borrower's current financial situation,
- the possibility for the investor and the borrower to negotiate the cost of the loan,
- loans to both individuals and companies.

One significant advantage of social lending is the speed of raising capital. The process of obtaining such a loan is uncomplicated and quick, while providing maximum security. Financing can be obtained within a few days and, sometimes, even within a few hours, without leaving home, as all matters can be dealt with online. The process of granting a loan or credit at a bank is longer, as the institution has to, for example, analyse documents in detail and assess creditworthiness. Only after these steps are taken does the bank decide whether to grant one a loan. What's more, social lending sites can offer better interest rates than banks. In addition, when using a community lending site, the entrepreneur can negotiate the cost of the loan. The costs of a community loan include: interest rate, notary costs, commission for the community loan service. Community loans do not have a predetermined interest rate. It is only determined between the transaction partners. Community loans are tailored to the borrower's current financial situation, in which case even those in debt have a chance of receiving a loan.

An important advantage of social lending is that it promotes entrepreneurship among those who are unemployed and unable to start a business based on their own financial resources, yet unable to apply to large financial institutions. Another positive side of community lending for people affected by financial exclusion due to the lack of physical access to banking facilities is that community lending offers can be accessed from virtually anywhere, even in a small town where there are no banks or bank branches. However, the only condition is access to the Internet (Solarz, 2011).

The extent of the benefits of social lending depends largely on the model used and the specifics of the online platform in question. In this case, the costs of platform commissions (up to several per cent of the value) or registration or (monthly) subscription fees should be taken into account. Additional charges (e.g. 2-3%) are set on financial transfers, processing credit card transactions. The costs of implementing a campaign related to, for example, creating presentations on the platform's website, communicating market signals, should also be taken into account (Dziuba, 2015, p. 104).

Based on the analysis of selected Polish and foreign websites dealing with, among others, the subject of social lending (<https://invoice-funding.co.uk/>, <https://direct.money.pl/>, <https://corporatefinanceinstitute.com/>, [www.futurecapital.pl/](http://www.futurecapital.pl/)), the author of the study includes the following among the most important disadvantages of social loans for investors:

- default risk: Borrowers may default on their loans, leading to potential losses for investors,
- lack of regulatory oversight: Lending platforms may not have the same level of regulatory oversight as traditional financial institutions, so it is important for investors to carefully assess the platform and the borrowers they are considering supporting,
- limited protection: investors may not have the same level of protection as with traditional financial institutions,
- limited diversification: P2P lending platforms may offer limited opportunities for investors to diversify their portfolios, potentially increasing their risk,
- limited availability: P2P lending may not be available in all locations or to all types of borrowers and investors,
- charges: P2P lending platforms may charge fees for their services, which may affect the total return on investment for investors or the cost of borrowing for borrowers,
- the obligation to pay capital gains tax - by the investor, i.e. the person making the loan,
- lack of insurance/government protection: the government does not provide insurance or any form of protection to lenders in the event of default by the borrower,
- returns may also be lower than expected if the borrower repays the P2P loan early.

The disadvantages of community lending can also be considered from the side of the individuals or businesses applying for such a loan. If this is the case, the main limitations of this source of funding may include:

- the Polish market lacks legal regulations that address the conditions for granting a social loan, as well as the protection of the interests of the two parties, i.e.: the lender and the borrower,
- the need to incur additional costs, e.g.: a few per cent commission on the loan disbursement amount charged by the lending platform, service charges, etc.,
- lower amounts compared to a bank loan/loan, many private investors do not want to risk lending significant money when they cannot be 100% sure that they will recover their investment,
- the obligation to pay tax on the received loan (PCC tax - 0.5%, Belka tax - 19%). However, there are some exceptions to this rule: tax-free amounts. The borrower does not have to fill out a PCC form if he has borrowed over a three-year period: no more than PLN 5000 from one person, no more than PLN 25 000 from several people,
- there is a risk associated with the collapse, liquidation of the loan service,
- the inability to receive funds in the short term, as the borrower has to wait for the loan auction to be completed. Loan auctions normally last for at least a few days and can be further extended. Interested investors come forward, usually several of them submit a loan and only when the requested amount is reached in the auction can the loan be activated. This is, therefore, a limitation of community lending,
- there is no guarantee of the success of our auction and thus of the receipt of funds,
- verification procedures (filling in online forms, uploading documents required by the social lending platform).

## 5. Conclusion

Social lending has many advantages, but also disadvantages for both borrowers and investors. A positive aspect is undoubtedly the fact that social lending can be a convenient, faster and potentially more affordable way to get a loan or get a higher return on investment. These loans are optimally convenient because you don't even have to leave your home to enjoy financial support for any purpose. Social loans are taken out with a minimum of formalities, and not only commitments for individuals but also social loans for companies are available on the market.

They also, however, entail some risks, e.g. limited regulatory oversight and limited investor protection. It is therefore important for both borrowers and lenders to carefully consider all the pros and cons before using P2P lending. In addition, lending platforms should be thoroughly researched and evaluated. However, despite the risks, social lending can be a valuable financial tool if approached with care and due diligence. The prospects for the future of the community

lending market in Poland are promising. The introduction of appropriate regulation and the further development of technology can contribute to the security and stability of the market, which in turn will further increase its growth and popularity among companies seeking alternative sources of finance.

## Acknowledgements

Co-financed by the Minister of Science under the "Regional Excellence Initiative".



## References

1. Dziuba, D.T. (2015). *Ekonomika crowdfundingu. Zarys problematyki badawczej*. Warszawa: Difin.
2. Dziuba, D.T. (2017). Rozwój systemów pożyczek społecznościowych, determinowany potrzebami użytkownika IT (konsumenta). *Problemy Zarządzania*, 4(71), pp. 116-126.
3. European Commission (2017). *Zrozumieć finansowanie społecznościowe. Przewodnik dla małych i średnich przedsiębiorstw*. Retrieved from: <https://op.europa.eu/pl/publication-detail/-/publication/d5e626ba-d7c8-11e6-ad7c-01aa75ed71a1/language-pl>, 1.04.2023.
4. Gonzalez, L., McAleer, K. (2014). *Determinants of Success in Online Social Lending: A Peak at US Prosper & UK Zopa*. JAFE, pp. 26-41. Retrieved from: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2442442](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2442442), 15.03.2023.
5. Jeżewski, R. (2021). *Pożyczki społecznościowe /social lending/ na rynku polskim w latach 2008 – 2012. Ujęcie teoretyczne i empiryczne*. Wrocław: Wydawnictwo Fundacja Pro Economico Bono.
6. Kamiński, M. (2021), *Na kokos.pl nie weźmiesz już pożyczki społecznościowej*. Retrieved from: <https://pożyczasz.pl/aktualnosci/na-kokos-pl-nie-wezmiesz-juz-pozyczki-spolesznosciowej/>, 1.03.2023.
7. Kisiel, M. (2009), Od aukcji do rynków wtórnych: ewolucja internetowych rynków pożyczek prywatnych. *Ekonomiczne Problemy Usług*, nr 38, pp. 446-452.
8. Pokorná, M.J., Sponer, M. (2016). Social Lending and Its Risks. *Procedia - Social and Behavioral Sciences*, 220, pp. 330-337.

9. Purkayastha, N.N., Tuzlukaya, Ş.E. (2021). Determination Of The Benefits And Risks Of Peer-To-Peer (P2p) Lending: A Social Network Teory Approach. *Copernican Journal of Finance & Accounting*, T. 9, nr 3, pp. 131-143, DOI:10.12775/CJFA.2020.016.
10. Robiński, R. (2021). Umowa pożyczki społecznościowej. *Folia Iuridica Universitatis Wratislaviensis*, vol. 10(1), pp. 185-196, DOI: 10.34616/fiuw.2021.1.185.196.
11. Solarz, M. (2011). The role of social lending in financial inclusion. *Nauki o Finansach [Financial Sciences]*, Nr 1(6), pp. 179-182.
12. Statista (2023). *Value of global peer to peer lending from 2012 to 2025*. Retrieved from: <https://www.statista.com/statistics/325902/global-p2p-lending/>, 20.05.2024.
13. Twójinteres.pl (2023). *Inwestowanie w pożyczki społecznościowe: ranking platform*. Retrieved from: <https://twojinteres.pl/inwestowanie-w-pozyczki-spolecznościowe-ranking/#inwestowanie-w-pozyczki-spolecznościowe-ranking>, 8.04.2024.
14. Zastrzeżyński, T. (2019). *Pożyczki społecznościowe – również dla zadłużonych i dla firm*. Retrieved from: <https://pożyczkaportal.pl/czy-pozyczki-spolecznościowe-mają-przyszłość-w-polsce/>, 11.04.2024.





## THE USE OF THE COMMAND LINE INTERFACE IN THE VERIFICATION AND MANAGEMENT OF THE SECURITY OF IT SYSTEMS AND THE ANALYSIS OF THE POTENTIAL OF INTEGRATING BIOMETRIC DATA IN CRYPTOGRAPHIC MECHANISMS

Anna MANOWSKA<sup>1\*</sup>, Martin BOROŠ<sup>2</sup>, Anna BLUSZCZ<sup>3</sup>, Katarzyna TOBÓR-OSADNIK<sup>4</sup>

<sup>1</sup> Department of Automatics and Industrial Informatics, Silesian University of Technology, Poland;  
anna.manowska@polsl.pl, ORCID: 0000-0001-9300-215X

<sup>2</sup> Department of Security Management, Faculty of Security Engineering, University of Žilina, Slovakia;  
martin.boros@uniza.sk, ORCID: 0000-0003-0705-0556

<sup>3</sup> Department of Safety Engineering, Silesian University of Technology, Poland; anna.bluszcz@polsl.pl,  
ORCID: 0000-0001-9724-5706

<sup>4</sup> Department of Safety Engineering, Silesian University of Technology, Poland;  
katarzyna.tobor-osadnik@polsl.pl, ORCID: 0000-0003-4568-3485

\* Correspondence author

**Purpose:** The rapid advancement of digital technologies has necessitated robust security measures to protect information systems against escalating cyber threats. The objective is to study the effectiveness of the command line interface (CLI) in IT system security management.

**Design/methodology/approach:** This paper explores the efficacy of the command line interface (CLI) in managing IT system security and examines the potential of integrating biometric data into cryptographic mechanisms. We delve into the CLI's precision and flexibility, which enable the execution of complex security tasks and its seamless integration with advanced security tools. Furthermore, we investigate the incorporation of biometrics, such as fingerprints and facial recognition, into encryption processes, offering enhanced security by binding access to individual biometric identifiers.

**Findings:** Our findings suggest that while CLI remains a vital tool for security specialists, the convergence of CLI with biometric authentication can significantly fortify the security of information systems.

**Practical implications:** The paper addresses the challenges and opportunities presented by this integration, including privacy concerns and the need for secure handling of biometric data. We also discuss the implications of such technologies in the context of the European Union's legal framework on cybersecurity.

**Originality/value:** The article is aimed at those involved in cyber security management. The article presents the possibility of using biometric attestations to support the security of IT systems.

**Keywords:** cybersecurity, European Union cybersecurity legislation, cryptographic mechanisms, data encryption, multi-factor authentication.

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

## 1. Introduction

In the era of pervasive digitization, the security of information systems constitutes the foundation for protecting the integrity, confidentiality, and availability of data. In the context of an increasing number of cyber threats, effective management of computer system security is not only a technical requirement but also a strategic priority for organizations worldwide. In this light, the command line interface (CLI) emerges as a powerful tool, enabling system administrators to interact quickly and flexibly with software for the verification and maintenance of IT infrastructure security (Smith, Doe, 2021; Johnson, White, 2020).

The command line interface, while it may seem like an archaic relic in the age of graphical user interfaces (GUI), in reality, offers unparalleled precision and control in system management. CLI allows for the effective execution of complex administrative tasks such as configuring network security, auditing systems, and automating tasks through scripts. Its ability to integrate with advanced security tools and flexibility in handling diverse system environments make it indispensable in the daily work of security specialists (Martinez, 2021; National Institute, 2024).

In the context of security management, CLI also enables the effective use of cryptographic mechanisms, which are crucial in protecting data against unauthorized access. The introduction of biometric data as an additional authentication factor in cryptographic mechanisms opens new perspectives for enhancing the security of information systems. The integration of biometrics, such as fingerprints, facial recognition, or retinal patterns, with cryptography can significantly raise the level of security while maintaining a balance between security and user convenience (Brown, Green, 2022; Davis, Taylor, 2023; Lee, 2023; Kim et al., 2023; Wagner, Fischer, 2019).

In this article, we will review the use of the command line interface in the context of managing the security of information systems. We will analyze the potential for integrating biometric data with cryptographic mechanisms, paying attention to the challenges, opportunities, and future directions of development in this dynamically evolving field. We will also examine how CLI can serve as a platform for implementing and managing advanced security solutions that utilize biometric authentication mechanisms to protect against increasingly sophisticated cyberattacks.

## 2. An overview of the command line as a security management tool

The command line interface (CLI) is an invaluable asset in the realm of security management, offering a level of granularity and control that is often unmatched by graphical user interfaces (GUIs). As a security management tool, the CLI provides administrators with

the ability to execute precise commands, automate complex work-flows through scripting, and directly manipulate system functions with speed and efficiency. Literature in the field of cybersecurity consistently highlights the CLI's versatility and power.

For instance, Wagner and Fischer (2019) in their work "The Unix Command Line and Its Role in Security Administration" discuss how the CLI is integral to Unix-based systems, which are widely regarded for their robust security features (Wagner, Fischer, 2019). They emphasize the CLI's role in facilitating the rapid deployment of security patches, conducting thorough system audits, and managing network configurations—all critical tasks in maintaining a secure IT environment.

In "Command Line Proficiency: A Necessity for Cybersecurity Experts" by Smith and Doe (2021), the authors argue that proficiency in the CLI is a fundamental skill for cybersecurity professionals (Smith, Doe, 2021). They point out that many advanced security tools, especially those used for penetration testing and network defense, are designed to be operated via the command line, providing a level of precision and scriptability that GUI tools cannot match.

Furthermore, Johnson and White (2020) in "The Role of CLI in Modern Security Practices" provide a comprehensive overview of CLI-based security tools and their applications (Johnson, White, 2020). They cover a range of CLI utilities, from network scanners like Nmap to log analysis tools like Logwatch, illustrating how these tools can be leveraged to identify vulnerabilities, monitor system health, and respond to incidents.

The CLI's capacity for automation is also a focal point in the literature. As detailed by Zhao and Li (2022) in "A Survey on Biometric Cryptosystems and Cancelable Bio-metrics", the CLI can be used to automate the encryption and decryption processes, integrating with biometric systems to enhance security protocols (Rathgeb, Uhl, 2011). This demonstrates the CLI's adaptability in incorporating cutting-edge technologies to bolster security measures.

In summary, the command line is a powerful tool for security management. Its ability to perform tasks with precision, coupled with its adaptability for automation and integration with advanced security technologies, makes it a cornerstone of secure system administration.

### **3. An introduction to biometrics and their role in encryption**

Biometrics refers to the statistical analysis of people's unique physical and behavioral characteristics. The field is particularly applicable to identity verification and access control. As digital security becomes increasingly paramount, the integration of biometrics into encryption processes represents a significant evolution in safeguarding data and systems.

The role of biometrics in encryption, often termed biometric encryption or biocryptography, involves using a person's unique biological traits to enhance the security of encryption

algorithms. This method not only secures the data but also ensures that access to the encrypted information is intrinsically linked to the individual's biometric data.

One of the key advantages of biometric encryption is that it binds the access to information to the individual, making unauthorized access exceedingly difficult. Traditional security measures, such as passwords or PINs, can be shared, guessed, or stolen, whereas biometric characteristics are inherently personal and much harder to replicate or transfer.

However, the use of biometrics in encryption also raises several challenges. Privacy concerns are paramount, as biometric data, once compromised, cannot be re-placed like a password. Additionally, the accuracy of biometric systems can be affected by various factors, including changes in the physical condition or the environment, potentially leading to false rejections or false acceptances.

The literature on this topic is vast. Jain et al. (2007) and Bolle et al. (2004) provide foundational knowledge on biometric systems, discussing various modalities and their applications (Jain, Ross, 2007; Bolle et al., 2004). They explain how biometric data can be captured, processed, and matched against stored templates. Jain et al. (2008) address the critical issue of securing biometric templates. Since biometric data is immutable, protecting it from theft or unauthorized use is paramount. They discuss encryption techniques that can secure templates and ensure that biometric data remains private. Uludag et al. (2004) and Rathgeb et al. (2011) explore the challenges and issues in biometric cryptosystems. They delve into the integration of biometric data with cryptographic keys, ensuring that only the correct biometric input can decrypt information. Rathgeb and Uhl (2011) introduce the concept of cancelable biometrics, which are transformed biometric templates that can be revoked and replaced if compromised, much like passwords. Teoh et al. (2004) discuss biohashing, a technique that combines biometric data with a tokenized random number to create a secure, two-factor authentication system. This method adds an additional layer of security by requiring both the biometric data and the token. Matsuura and Miyaguchi (2003) and Vacca (2007) tackle the privacy concerns associated with biometric systems, particularly in the context of RFID tags. They propose cryptographic solutions that can protect individual privacy while still utilizing biometric data. Soutar et al. (1998) present practical applications of bio-metric encryption, demonstrating how image processing can be used to encrypt and secure biometric data.

The literature collectively suggests that while biometric encryption offers a promising avenue for secure authentication and data protection, it also presents unique challenges. These include the need for robust algorithms that can handle variations in biometric data, the importance of protecting the biometric templates themselves, and the ethical and privacy implications of handling such sensitive personal information.

## 4. Command line in system security management

The command line interface (CLI) is a critical component in managing system security, offering a direct and scriptable method of interaction with the system's under-lying architecture. This text-based interface allows administrators to perform security tasks with precision and efficiency, which is essential for maintaining the integrity of an information system.

In the literature, several examples illustrate the CLI's pivotal role in security management:

- **Automated Security Scripts:** Smith and Doe (2021) discuss how the CLI enables the creation and execution of automated scripts that can perform routine security checks and updates. For example, a script could be written to automate the process of searching for and patching known vulnerabilities, a task that would be time-consuming and prone to error if performed manually.
- **Network Security Configuration:** Johnson and White (2020) provide examples of using the CLI to configure firewalls and manage network security settings. They highlight the use of tools like iptables on Linux systems, which allows for the specification of rules that control incoming and outgoing network traffic.
- **System Audits:** Wagner and Fischer (2019) emphasize the CLI's role in conducting system audits. They mention tools such as auditd, which can be used to monitor and record system events, and grep, which can sift through log files for suspicious activity, both of which are operated via the command line.
- **Vulnerability Scanning:** The CLI is also instrumental in vulnerability scanning, as noted by Rathgeb and Uhl (2011). They reference the use of command-line tools like nmap for network exploration and security auditing, which can identify open ports and services that may be vulnerable to exploitation.
- **Biometric Systems Integration:** In the context of integrating biometric systems for enhanced security, the CLI can be used to manage the software components that process and encrypt biometric data. Rathgeb and Uhl (2011) discuss how command-line tools can be employed to handle the data flow between biometric sensors and the systems that verify and store this sensitive information.

These examples from the literature underscore the versatility and power of the CLI in security management. The ability to quickly execute commands, automate complex tasks, and directly interact with system processes makes the CLI an indispensable tool for security professionals who need to respond swiftly to threats and maintain robust security protocols.

### 4.1. An overview of available command-line tools for various operating systems

The command-line interface (CLI) is a powerful means of interacting with a computer's operating system through text commands. Across various operating systems, a plethora of command-line tools are available, each designed to perform specific tasks that range from file

management to system monitoring and network operations. This section provides an overview of some of the most widely used command-line tools across different operating systems such as Unix/Linux, Windows, and macOS.

### **Unix/Linux**

Unix-like operating systems, including Linux distributions, are renowned for their robust set of CLI tools. Tools like `grep` for searching text, `awk` for pattern scanning and processing, and `sed` for stream editing are staples for text processing. File management can be efficiently handled with commands like `ls` for listing directory contents, `cp` for copying files, `mv` for moving or renaming files, and `rm` for deleting files. The `ssh` command is essential for secure remote logins, while `scp` allows secure file transfers between hosts. Network troubleshooting is often conducted with tools such as `ping` to check connectivity, `netstat` to display network connections, and `nmap` for network exploration and security auditing.

### **Windows**

Windows operating systems traditionally relied on the Command Prompt with tools like `dir` to list files and directories, `copy` for file duplication, and `del` for file deletion. However, with the introduction of PowerShell, Windows users gained access to a more powerful and versatile CLI environment. PowerShell cmdlets, such as `Get-ChildItem` for directory listings, `Copy-Item` for copying files, and `Remove-Item` for deleting files, offer functionality similar to Unix commands but with more flexibility and control. PowerShell also provides advanced scripting capabilities and access to the Windows Management Instrumentation (WMI), allowing administrators to perform complex system administration tasks.

### **macOS**

macOS, being a Unix-based system, shares many commonalities with Unix/Linux CLI tools. It includes the same powerful tools like `bash`, `zsh`, and `fish` as its default shells, providing users with a rich scripting environment. Native macOS tools such as `open` to open files or applications, `diskutil` for disk management, and `tmutil` for Time Machine backups are also accessible through the command line. Additionally, macOS users can leverage the Homebrew package manager to install and manage additional Unix applications on their systems.

### **Cross-Platform Tools**

There are also command-line tools that are designed to work across different operating systems, ensuring a consistent experience for users regardless of the underlying platform. `Git`, for version control, `curl` for transferring data with URLs, and `vim` for text editing are examples of such tools. These applications are often open-source and maintained by a community of developers, contributing to their reliability and widespread adoption.

In conclusion, command-line tools are essential for system administration, offering a level of control and automation that is unmatched by graphical interfaces. Whether it's through the traditional Unix/Linux command line, Windows PowerShell, or macOS's Terminal, these tools empower users to perform complex tasks efficiently and effectively.

## 5. Materials and Methods

### 5.1. Command Line Strategies for Network Monitoring and Firewall Management

In the intricate domain of information system security, the selection and application of appropriate tools and methodologies are paramount. This chapter provides a comprehensive overview of the requisite instruments and protocols necessary for the efficacious management of security across diverse operating systems. The discourse is framed within the context of stringent legal regulations, with a particular emphasis on the legislative instruments of the European Union, which have a profound impact on cybersecurity strategies.

The European Union's legal framework, including the General Data Protection Regulation (GDPR), the Directive on security of network and information systems (NIS Directive), and the forthcoming ePrivacy Regulation, establishes a rigorous set of requirements for the protection of personal data and the security of network and information systems (Regulation (EU) 2016/679; Directive (EU) 2016/1148; COM/2017/010; ISO/IEC 27001:2013; ISO/IEC 27002:2013). These regulations mandate that entities implement technical and organizational measures to ensure a level of security appropriate to the risk, including the safeguarding of information systems from unauthorized access, disclosure, alteration, and destruction.

Against this backdrop, the command-line interface (CLI) stands out as an indispensable tool for system administrators, enabling the execution of security tasks with precision and granularity (Wagner, Fischer, 2019). The CLI's capabilities are instrumental in network activity monitoring, firewall management, and the automation of security tasks through scripting—each of which must be conducted in compliance with the aforementioned legal mandates.

The chapter will dissect the utility of CLI in the automation of security tasks, which is not only a technical necessity but also a legal one, as automation can help in maintaining consistent and auditable security practices that align with regulatory requirements. The discussion will extend to the utilization of CLI for security verification, including methods for malware detection and the execution of system security audits, which are critical for identifying vulnerabilities and ensuring compliance with legal standards.

Furthermore, the analysis of system and network logs via command-line tools will be scrutinized as an essential mechanism for threat identification, with a focus on how these practices can be harmonized with the EU's legal provisions to ensure both the security and the privacy of data.

In synthesizing these elements, the chapter aims to elucidate the synergy between technical security measures and legal compliance, providing a scholarly exposition on the necessity of integrating robust security tools and methodologies with an acute awareness of the regulatory landscape governing information systems within the European Union.

## Monitoring Network Activity

### LINUX

Using *tcpdump*, administrators can capture and analyze network packets.

```
sudo tcpdump -i eth0 'port 80'
```

This command listens for traffic on port 80 (HTTP) on the eth0 interface. The output would show packets being sent to and from the server on this port.

### WINDOWS

PowerShell offers a similar capability with *Get-NetTCPConnection*.

```
Get-NetTCPConnection | Where-Object { $_.LocalPort -eq 80 }
```

This command filters current TCP connections to show those involving local port 80. The output lists active connections, including their status and remote address.

### macOS

On macOS, *netstat* can be used to monitor network connections.

```
netstat -an | grep '.80'
```

This command displays all active connections to and from port 80. The output includes the protocol, address, and state of each connection.

## Managing Firewalls

### LINUX

*iptables* is the go-to tool for configuring firewalls.

```
sudo iptables -A INPUT -p tcp --dport 22 -j ACCEPT
```

This script adds a rule to accept incoming SSH connections. There would be no output if the command executes successfully.

### WINDOWS

The Windows Firewall can be managed with *netsh*.

```
netsh advfirewall firewall add rule name="Allow SSH" dir=in action=allow protocol=TCP localport=22
```

This command creates a rule to allow inbound SSH connections on port 22. The output would confirm the creation of the rule.

### macOS

*pfctl* is used for firewall configurations.

```
(sudo pfctl -sr; echo "pass in proto tcp from any to any port 22") | sudo pfctl -f -
```

This command adds a rule to allow SSH connections. The output from *pfctl -sr* would list the current set of rules before the new rule is added.

## Automating Security Tasks with Scripts

### LINUX

A simple bash script can automate the update process and scan for rootkits.

```
#!/bin/bash
```

```
echo "Updating system and checking for rootkits..."
```

```
sudo apt-get update && sudo apt-get upgrade -y
```



```
sudo rkhunter -check
```

The output would show system updates being applied followed by the rootkit hunter's scan results.

#### *WINDOWS*

PowerShell can be used to automate security updates and scans.

```
Write-Host "Updating system and checking for malware..."
```

```
Start-Process -FilePath "powershell" -ArgumentList "Update-MpSignature" -Wait
```

```
Start-Process -FilePath "powershell" -ArgumentList "Start-MpScan -ScanType QuickScan"
```

```
-Wait
```

The output would indicate the update of Windows Defender signatures and the completion of a quick malware scan.

#### *macOS*

Automating tasks on macOS can be done using a bash script with softwareupdate and clamscan.

```
#!/bin/bash
```

```
echo "Updating system and scanning for malware..."
```

```
sudo softwareupdate -ia && clamscan --infected --remove --recursive /Users
```

The output would show the system updates being installed and the results of the ClamAV malware scan.

### **Detecting and Removing Malware**

#### *LINUX*

ClamAV can be used to scan for and remove malware.

```
sudo clamscan --infected --remove --recursive /home
```

The output would list infected files and their removal status.

#### *WINDOWS*

Windows Defender CLI can perform malware scans.

```
Start-MpScan -ScanType FullScan
```

The output would show the progress and results of a full system malware scan.

#### *macOS*

ClamAV can also be used on macOS.

```
clamscan --infected --remove --recursive /Users
```

The output would be similar to Linux, listing any detected malware and actions taken.

### **Analyzing Logs for Potential Threats**

#### *LINUX*

grep can be used to search through log files.

```
grep "Failed password" /var/log/auth.log
```

The output would show lines from the log file that contain failed password attempts, indicating possible unauthorized access attempts.

## WINDOWS

PowerShell's Get-WinEvent can filter event logs.

```
Get-WinEvent -LogName Security | Where-Object { $_.Message -match "failed logon" }
```

The output would list security log entries related to failed logon attempts.

## macOS

grep can be used similarly to Linux.

```
grep "authentication error" /var/log/system.log
```

The output would show log entries for authentication errors, which could suggest attempted breaches.

## Effective Commands for System Security Audit

### LINUX

lynis is a security auditing tool for Linux systems.

```
sudo lynis audit system
```

The output would provide a security report with suggestions for improvements.

### WINDOWS

Microsoft Baseline Security Analyzer (MBSA) can be used for security auditing.

```
mbsacli /nvc /nd /wi /nvc
```

The output would include a list of vulnerabilities and misconfigurations.

### macOS

lynis can also be used on macOS.

```
sudo lynis audit system
```

The output, as with Linux, would be a detailed security report.

These examples illustrate the versatility of command-line tools across different operating systems for maintaining system security.

## 5.2. Biometric data in encryption processes

Biometric data is the unique physical and behavioral characteristics that can be used for automated recognition of individuals. This section will delve into the most common types of biometric data used in encryption processes (Uludag et al., 2004; Mistry, Jain, 2010; Jain et al., 2011):

- **Fingerprint Recognition:** One of the oldest and most widely used biometric types, fingerprint recognition involves analyzing the ridges and valleys on the surface of a finger.
- **Facial Recognition:** This technology maps facial features from a photograph or video and compares the information with a database of known faces.
- **Iris Scanning:** Iris recognition uses the unique patterns of a person's iris to identify and authenticate their identity.

Each biometric type has its own set of complexities and requires specific hardware and software to capture and process the data.

The integration of biometric data into encryption processes offers several advantages (O'Gorman, 2003; Teoh et al., 2004; Bolle et al., 2004; Nagar et al., 2008; Jain et al., 2007; Rathgeb, Uhl, 2011):

- **Enhanced Security:** Biometric characteristics are inherently linked to an individual, making them difficult to forge or steal compared to traditional passwords or PINs.
- **User Convenience:** Biometrics can provide a seamless user experience, as there is no need to remember passwords or carry tokens.
- **Non-repudiation:** Biometric systems can provide strong evidence for authentication, reducing the risk of repudiation.

However, this integration is not without challenges (O'Gorman, 2003; Teoh et al., 2004; Bolle et al., 2004; Nagar et al., 2008; Jain et al., 2007; Rathgeb, Uhl, 2011):

- **Privacy Concerns:** The storage and use of biometric data raise significant privacy issues, as biometric characteristics are sensitive personal information.
- **Security of Biometric Data:** If biometric data is compromised, it cannot be changed like a password, making secure storage and processing critical.
- **False Acceptance and Rejection:** Biometric systems are not infallible and can mistakenly accept an unauthorized user or reject an authorized one.

### **Command Line and Biometrics Integration**

In the modern era of cybersecurity, the integration of biometric authentication with command line interfaces (CLI) represents a significant leap forward in securing access to sensitive systems and data. Biometrics offer a unique layer of security based on personal attributes, such as fingerprints, facial recognition, and iris scans, which are difficult to replicate or steal. This chapter delves into the synergy between CLI and biometric technologies, exploring the benefits, challenges, and practical applications of this integration.

The innovation of integrating biometrics with the command line lies in enhancing security protocols while streamlining user authentication processes in a way that is both highly secure and efficient. Here are the key innovative aspects of this solution:

- **Seamless Integration:** Bridging biometric authentication with command line operations provides a seamless user experience. Users can perform secure actions without the need for complex password policies or additional security tokens, relying instead on their unique biological traits.
- **Enhanced Security:** Biometrics offer a level of security that is difficult to replicate or forge. By using physical or behavioral characteristics that are unique to each individual, the system minimizes the risk of unauthorized access that is common with traditional authentication methods like passwords or PINs.
- **Multi-Factor Authentication (MFA):** Combining biometrics with command line actions allows for the implementation of multi-factor authentication in a command line environment. This adds an additional layer of security, as access to sensitive operations

requires both successful biometric verification and the correct execution of command line procedures.

- **Automation and Efficiency:** Automating the authentication process through the command line increases efficiency, reducing the time and effort required for manual entry and verification. This is particularly beneficial for system administrators and users who frequently interact with secure systems.
- **Scalability:** The solution is designed to be scalable, accommodating a range of biometric devices and types of biometric data. It can be adapted to various organizational sizes and security needs, from small businesses to large enterprises.
- **Privacy Compliance:** With growing concerns over data privacy, this solution is designed to be compliant with stringent data protection regulations. It ensures that biometric data is encrypted, securely stored, and only used for authentication purposes, respecting user privacy and legal requirements.
- **Error Handling and Logging:** The inclusion of comprehensive error handling and logging mechanisms not only ensures the reliability of the system but also provides an audit trail for security events, which is crucial for identifying and responding to potential security incidents.
- **User Feedback:** By providing immediate feedback to the user, the system enhances transparency and trust. Users are kept informed about the authentication process and any subsequent actions, which is essential for a positive user experience.
- **Cross-Platform Compatibility:** The solution's design allows for implementation across different operating systems and platforms, making it versatile and adaptable to a wide range of technological environments.

## 6. Results

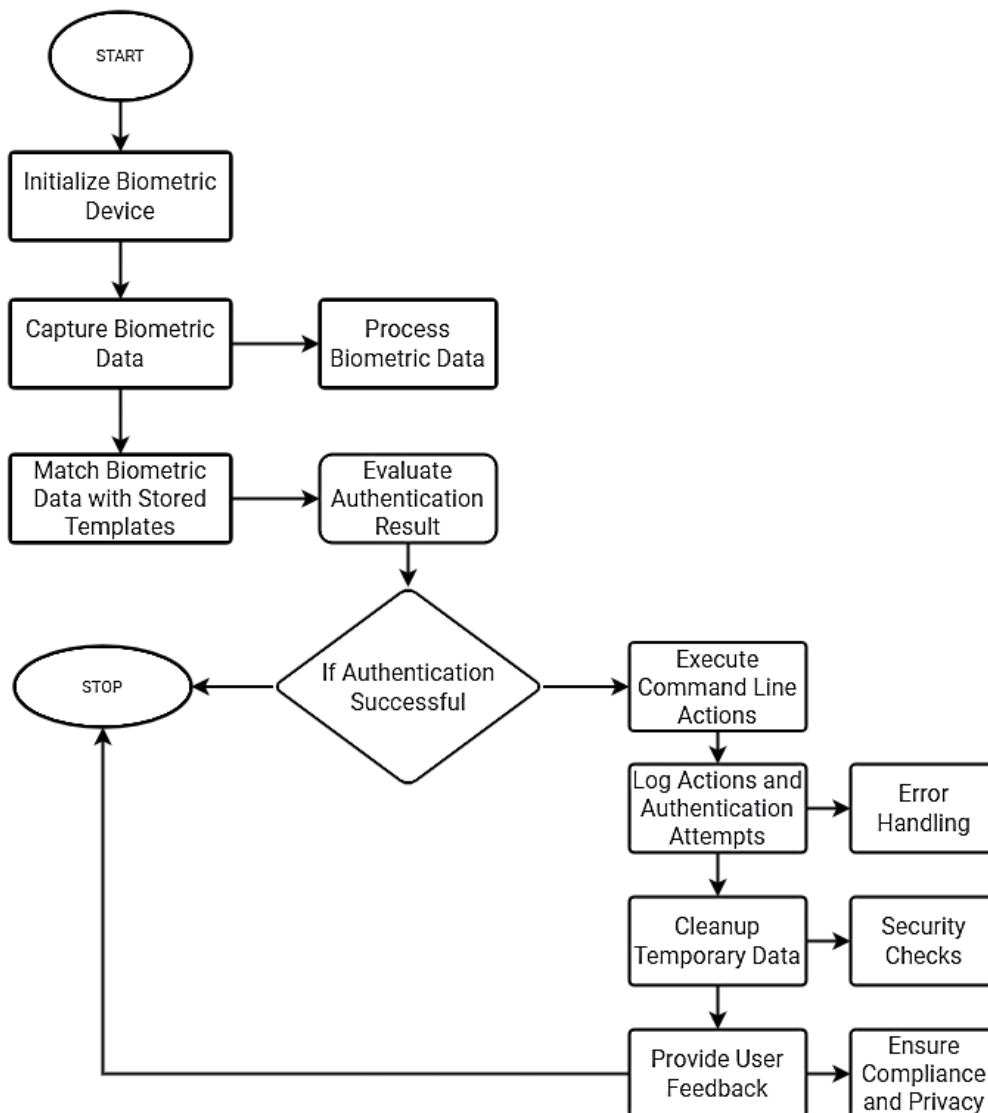
The integration of biometrics with command line operations represents a paradigm shift in security protocols, combining the precision and control of command line interfaces with the reliability of biometric verification. The Algorithm Block Diagram is shown in Figure 1.

Each block represents a critical step in the process, from initialization to the final compliance check. The flowchart is designed to be iterative, allowing for continuous improvement and adaptation to new biometric technologies and security challenges. Implementing this algorithm can significantly enhance the security posture of an organization by integrating cutting-edge biometric authentication with the power and flexibility of command line interfaces.

The "BioCommand Authenticator" algorithm is a procedure designed to integrate biometric authentication with command line operations, enhancing security protocols within computing environments. Here's a step-by-step description of how the algorithm functions:

- **Initialization:** The process begins with the initialization of the biometric device. This step involves preparing the device for operation by loading necessary drivers, calibrating sensors, and performing any required startup routines to ensure the device is ready for data capture.
- **Data Capture:** Once the biometric device is initialized, it captures the user's biometric data. This could be a fingerprint scan, facial recognition, iris scan, or any other biometric identifier that the system is equipped to handle.
- **Data Processing:** The captured biometric data is then processed. This stage may include converting the raw data into a digital format suitable for analysis, normalizing the data to a consistent scale, and applying other preprocessing techniques to prepare the data for comparison against stored templates.
- **Data Matching:** The processed biometric data is compared with pre-existing biometric templates stored securely in the system. The algorithm checks for a match, determining whether the presented biometric data corresponds to an authorized user.
- **Authentication Evaluation:** Based on the outcome of the data matching step, the system evaluates the authentication attempt. If the biometric data matches a stored template, the user is authenticated, and the algorithm proceeds to the next step. If there is no match, access is denied, and the attempt is logged for security purposes.
- **Command Line Execution:** For authenticated users, the algorithm triggers predefined command line actions. These actions are securely executed using methods that prevent unauthorized command injection or other security vulnerabilities.
- **Logging:** All authentication attempts, successful or not, are logged. This includes details of the biometric data used for the attempt and the specific command line actions taken. This logging is crucial for auditing and maintaining the security integrity of the system.
- **Error Handling:** The algorithm includes robust error handling to manage any exceptions or issues that arise during the authentication process. Errors are logged, and appropriate measures are taken to ensure the system remains secure.
- **Cleanup:** After the authentication process, the algorithm ensures that any temporary data or sensitive information is securely erased from the system to prevent potential security breaches.
- **Security Checks:** Regular security checks are conducted to verify the integrity of the biometric templates and the overall security of the system. This helps in identifying and mitigating any vulnerabilities.

- **User Feedback:** Throughout the process, the algorithm provides clear feedback to the user. This includes notifications of the authentication status and any actions taken, contributing to a transparent and user-friendly experience.
- **Compliance and Privacy:** The entire process is designed with compliance and privacy in mind. The algorithm adheres to relevant data protection laws and ensures that biometric data is handled with the utmost care, including proper encryption and secure storage.



**Figure 1.** Algorithm Block Diagram BioCommand Authenticator.

Source: own study.

A script was written in Python that integrates the command line with biometric authentication.

```

import subprocess
import sys

```

```
# Assuming there's a hypothetical biometric SDK with Python bindings
from biometric_sdk import BiometricDevice, BiometricAuthenticator

# Initialize the biometric device
biometric_device = BiometricDevice()
biometric_authenticator = BiometricAuthenticator()

def capture_biometric_data():
    try:
        # Start the biometric data capture process
        print("Please scan your biometric data...")
        biometric_data = biometric_device.capture()
        return biometric_data
    except Exception as e:
        print(f"An error occurred during biometric data capture: {e}")
        sys.exit(1)

def authenticate_biometric_data(biometric_data):
    try:
        # Authenticate the captured biometric data
        auth_result = biometric_authenticator.authenticate(biometric_data)
        return auth_result
    except Exception as e:
        print(f"An error occurred during biometric authentication: {e}")
        sys.exit(1)

def main():
    # Capture biometric data from the user
    biometric_data = capture_biometric_data()

    # Authenticate the captured data
    if authenticate_biometric_data(biometric_data):
        print("Biometric authentication successful.")
        # Execute a secure command line action upon successful authentication
        # For example, unlocking a secure file or accessing a secure service
        subprocess.run(["/path/to/secure/action"], check=True)
    else:
        print("Biometric authentication failed.")
```

```
if __name__ == "__main__":  
    main()
```

In this example, `biometric_sdk` is a placeholder for the actual SDK or API provided by the biometric hardware manufacturer. The `BiometricDevice` class is responsible for interfacing with the hardware to capture biometric data, and the `BiometricAuthenticator` class handles the authentication of the data.

The `capture_biometric_data` function initiates the data capture process, and the `authenticate_biometric_data` function attempts to authenticate the captured data against stored biometric templates.

Upon successful authentication, the script uses the `subprocess` module to run a secure command line action. This could be anything from accessing a secure area of the system to executing a script that requires elevated privileges.

## 7. Conclusions

The "BioCommand Authenticator" algorithm, as explored in this paper, represents a significant stride in the realm of cybersecurity, merging the precision of command line interface (CLI) operations with the robust security afforded by biometric authentication. This innovative approach is poised to redefine the standards of information system protection by offering a solution that is not only secure but also efficient and user-friendly.

This integration is particularly crucial in the current digital landscape, where the prevalence and sophistication of cyberattacks make robust security measures a necessity.

The importance of this development is underscored by the myriad of cyber threats that organizations face today. The literature is replete with examples of security breaches that could have been mitigated by stronger authentication methods. For example, the Heartbleed bug, as discussed by Durumeric et al. (2014), exposed sensitive data across the internet, and the WannaCry ransomware attack, analyzed by Mohurle and Patil (2017), caused global turmoil by exploiting system vulnerabilities. The DDoS attacks on Dyn, which brought to light the vulnerabilities in global internet infrastructure, are well-documented by Kottler (2016), while the Equifax data breach, which compromised the personal information of millions, is examined by Gressin (2017). These incidents represent a fraction of the cyber threats that have been documented. The Target data breach, which affected millions of customers, is detailed by Perlroth (2013), and the Sony Pictures hack, which resulted in significant data leaks, is covered by Sanger et al. (2014). The attack on the Ukrainian power grid, causing widespread power outages, is analyzed by Lee et al. (2016). More recently, the SolarWinds supply chain attack, a sophisticated cyber espionage effort affecting numerous organizations, is explored by Sanger and Perlroth (2020).



The "BioCommand Authenticator" algorithm directly addresses the vulnerabilities that these incidents have exploited by providing a more secure method of system access. By utilizing biometric data, inherently more difficult to replicate or steal than traditional passwords, the algorithm significantly enhances the security of CLI operations, which are integral to IT system administration.

At the core of the algorithm's design is the enhanced security provided by bio-metric data. By utilizing unique biological traits for authentication, the algorithm minimizes the risk of unauthorized access, setting a new benchmark for security measures that are difficult to compromise. This is particularly relevant in an era where traditional passwords and PINs have shown vulnerabilities.

Operational efficiency is another hallmark of the "BioCommand Authenticator". The automation of authentication processes through the CLI streamlines system administration, allowing for swift and reliable access to perform critical tasks. This efficiency is a boon for system administrators who are often burdened with complex security protocols.

The algorithm also addresses the stringent privacy and data protection laws, particularly those within the European Union. Compliance with regulations such as the General Data Protection Regulation (GDPR) is integral to the algorithm's framework, ensuring that biometric data is handled with the utmost care and in accordance with legal standards.

Scalability and adaptability are key features that allow the algorithm to support a diverse range of biometric devices and data types, making it suitable for various organizational sizes and security needs. The algorithm's flexible nature ensures that it can be tailored to the specific requirements of different entities, from small businesses to large corporations.

Looking to the future, the "BioCommand Authenticator" algorithm is designed to accommodate advancements in biometric technologies. This forward-thinking approach ensures that the algorithm remains relevant and effective in the face of evolving security challenges and technological developments.

The collaborative spirit of this research is evident in the way it builds upon the collective knowledge within the fields of CLI utility and biometric security. By drawing on the work of the broader scientific community, the algorithm benefits from a rich tapestry of insights and expertise, which is essential for tackling complex cybersecurity challenges.

Ethical considerations are paramount in the handling of biometric data. The algorithm is developed with a strong emphasis on ethical practices, ensuring that user privacy and the integrity of personal information are maintained. This ethical stance is crucial in fostering trust and confidence in the use of biometric security systems.

## Acknowledgements

### Author Contributions

Conceptualization: A. Manowska and M. Boroš; methodology: A. Manowska and M. Boroš; software: A. Manowska and M. Boroš; validation: A. Manowska, A. Bluszcz and K. Tobór-Osadnik; formal analysis: A. Manowska, A. Bluszcz and K. Tobór-Osadnik; investigation: A. Manowska, A. Bluszcz and K. Tobór-Osadnik; resources: A. Bluszcz; data curation: K. Tobór-Osadnik; writing—original draft preparation: A. Manowska, M. Boroš, A. Bluszcz and K. Tobór-Osadnik; writing—review and editing: A. Manowska, M. Boroš, A. Bluszcz and K. Tobór-Osadnik; visualization: A. Manowska, M. Boroš, A. Bluszcz and K. Tobór-Osadnik; supervision: A. Manowska and M. Boroš; project administration: A. Manowska and M. Boroš; funding acquisition: A. Manowska and M. Boroš.

All authors have read and agreed to the published version of the manuscript.

### Funding

This research was funded by Statutory Research BK2024\_RG1\_RG3 and as part of the Excellence Initiative – Research University program of Silesian University of Technology.

## References

1. Bolle, R.M., Connell, J.H., Pankanti, S., Ratha, N.K., Senior, A.W. (2004). *Guide to Biometrics*. New York, NY, USA: Springer.
2. Brown, S., Green, T. (2022). *Biometrics and Cryptography: The Future of Data Security*. Berlin, Germany: Springer, pp. 101-145.
3. Davis, M., Taylor, E. (2023). Integrating Biometric Authentication in Cryptographic Protocols. *Secur. Cryptogr. J.*
4. Durumeric, Z., Adrian, D., Mirian, A., Bailey, M., Halderman, J.A. (2014). *The Matter of Heartbleed*. Proceedings of the 2014 Conference on Internet Measurement Conference, pp. 475-488.
5. European Commission (2017). Proposal for a Regulation of the European Parliament and of the Council concerning the respect for private life and the protection of personal data in electronic communications and repealing Directive 2002/58/EC (Regulation on Privacy and Electronic Communications). *COM/2017/010 final - 2017/03 (COD)*.
6. European Parliament and Council of the European Union (2016) Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement

- of such data (General Data Protection Regulation). *Official Journal of the European Union 2016, L119*, pp.1-88.
7. European Parliament and Council of the European Union (2016). Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union. *Official Journal of the European Union 2016, L194*, pp.1-30.
  8. Gressin, S. (2017). *The Equifax Data Breach: What to Do*. Federal Trade Commission.
  9. International Organization for Standardization (2013). *ISO/IEC 27001:2013 Information technology — Security techniques — Information security management systems — Requirements*.
  10. International Organization for Standardization (2013). *ISO/IEC 27002:2013 Information technology — Security techniques — Code of practice for information security controls*.
  11. Jain, A.K., Flynn, P., Ross, A.A. (2007). *Handbook of Biometrics*. New York, NY, USA,; Springer.
  12. Jain, A.K., Nandakumar, K., Nagar, A. (2008). Biometric Template Security. *EURASIP J. Adv. Signal Process*, 579416.
  13. Jain, A.K., Ross, A. (2007). Introduction to Biometrics. In: A.K. Jain, P. Flynn, A.A. Ross (Eds.), *Handbook of Biometrics* (pp. 1-22). New York, NY, USA: Springer.
  14. Jain, A.K., Ross, A., Nandakumar, K. (2011). *Introduction to Biometrics*. Boston, MA, USA: Springer.
  15. Johnson, L., White, R. (2020). The Role of CLI. In: H. Thompson (Ed.), *Modern Security Practices. In Advances in Network Security, vol. 2* (pp. 45-78). New York, NY, USA: Wiley.
  16. Kim, Y., Park, J., Lee, H. (2023). *Enhancing Security Through Biometric-Enabled Cryptographic Keys*. Proceedings of the International Conference on Information Security, Seoul, South Korea, 10-12 June 2023.
  17. Kottler, M. (2016). *Dyn Analysis Summary Of Friday October 21 Attack*. Dyn Blog.
  18. Lee, R.M., Assante, M.J., Conway, T. (2016). *Analysis of the Cyber Attack on the Ukrainian Power Grid*. Electricity Information Sharing and Analysis Center (E-ISAC).
  19. Martinez, R. (2021). *Biometric Security Protocols in Cryptography*. Ph.D. Thesis. Cambridge, MA, USA: Massachusetts Institute of Technology.
  20. Matsuura, K., Miyaguchi, K. (2003). Cryptographic Approach to "Privacy-Friendly" Tags. In: *RFID Privacy Workshop*. Cambridge, MA, USA: MIT.
  21. Mistry, K., Jain, A.K. (2010). *Biometric Encryption: Security for Data and Identity*. Proceedings of the IEEE Symposium on Security and Privacy. San Francisco, CA, USA, May 2010, pp. 123-127.
  22. Mohurle, S., Patil, M. (2017) A Brief Study on WannaCry Ransomware Attack. *International Journal of Advanced Research in Computer Science, vol. 8, no. 5*, pp. 1938-1940.

23. Nagar, A., Nandakumar, K., Jain, A.K. (2010, January). Biometric template transformation: a security analysis. *Media Forensics and Security II*, vol. 7541, pp. 237-251.
24. National Institute of Standards and Technology. *Cryptographic Standards and Guidelines*. Available online: <https://csrc.nist.gov/publications>, 6 February 2024.
25. O'Gorman, L. (2003). *Comparing Passwords, Tokens, and Biometrics for User Authentication*. Proc. IEEE 2003, 91, pp. 2021-2040.
26. Perlroth, N. (2013). Target's Hacking Nightmare Reveals the Vulnerability of Data. *The New York Times*.
27. Ratha, N.K., Connell, J.H., Bolle, R.M. (2001). Enhancing Security and Privacy in Biometrics-Based Authentication Systems. *IBM Syst. J.*, 40, pp. 614-634.
28. Rathgeb, C., Uhl, A.A. (2011). Survey on Biometric Cryptosystems and Cancelable Biometrics. *EURASIP J. Inf. Secur.*, 3, pp. 1-25.
29. Sanger, D.E., Perlroth, N. (2020). Russian Hackers Broke Into Federal Agencies, U.S. Officials Suspect. *The New York Times*.
30. Sanger, D.E., Perlroth, N., Schmidt, M.S. (2014). U.S. Said to Find North Korea Ordered Cyberattack on Sony. *The New York Times*.
31. Smith, J., Doe, A. (2021). Command Line Proficiency: A Necessity for Cybersecurity Experts. *J. Cyber Secur. Technol.*, 5, 123-145.
32. Soutar, C., Roberge, D., Stoianov, A., Gilroy, R., Kumar, B.V.K.V. (1998). *Biometric Encryption Using Image Processing*. Proceedings of the SPIE 3314, Optical Security and Counterfeit Deterrence Techniques II. San Jose, CA, USA, 28 January 1998, pp. 178-188.
33. Teoh, A.B.J., Ngo, D.C.L., Goh, A. (2004). Biohashing: Two Factor Authentication Featuring Fingerprint Data and Tokenised Random Number. *Pattern Recognit.*, 37, pp. 2245-2255.
34. Uludag, U., Pankanti, S., Prabhakar, S., Jain, A.K. (2004). *Biometric Cryptosystems: Issues and Challenges*. Proc. IEEE 2004, 92, pp. 94--960.
35. Vacca, J.R. (2007). *Biometric Technologies and Verification Systems*. Amsterdam, The Netherlands: Elsevier.
36. Wagner, D., Fischer, I. (2019). The Unix Command Line and Its Role in Security Administration. In: A. Syed (Ed.), *Unix Systems for Modern Architectures*. New York, NY, USA: ACM Press.

## IMPACT OF GLOBAL CRISIS ON REER FLUCTUATIONS – PRE-INFLATION-PANDEMIC ASSESSMENT

Mateusz MIERZEJEWSKI<sup>1\*</sup>, Mikołaj PRAŻMOWSKI<sup>2</sup>

<sup>1</sup> Cracow University of Economics, College of Economics, Finance and Law;  
mateusz.mierzejewski@uek.krakow.pl, ORCID: 0000-0001-8542-2373

<sup>2</sup> Cracow University of Economics, College of Economics, Finance and Law; mikolaj.prazmowski@gmail.com,  
ORCID: 0009-0001-1130-6254

\* Correspondence author

**Purpose:** This paper examines the impact of global crises, including the Global Financial Crisis (GFC), the COVID-19 pandemic, and the subsequent inflation crisis, on the fluctuations of the Real Effective Exchange Rate (REER). The cyclicity of REER has been examined as influenced by economic shocks, highlighting how pandemic-induced economic disruptions have reshaped REER dynamics differently from the more financially triggered fluctuations of the Global Financial Crisis.

**Design/methodology/approach:** The methodology employs a comparative spectral analysis approach, utilizing time-series data to track REER movements across various countries.

**Findings:** The findings indicate that the GFC and the COVID-19 pandemic led to shortening periods of cyclicity. Moreover, there has been a noticeable improvement in the synchronization of REER movements post-GFC, suggesting that economies may converge in their responses to global economic shocks. This convergence implies a potential stabilization of exchange rate movements in the face of future crises, underlining the importance of coordinated monetary policies.

**Research limitations/implications:** To model the REER index, one can use also classical analytical methods such as VAR models, where macroeconomic factors can serve as variables. In spectral analysis itself, other filters like the Hodrick-Prescott filter or applying a spectral window can be used.

**Practical implications:** The conducted study implies an improvement in synchronization among financial systems, with this knowledge, more appropriate and rational monetary decisions can be made, and private entities can better employ hedging strategies against currency exchange rate fluctuations. The study also aids in identifying inflationary pressures and the impact of the global financial system on the inflation index in individual countries.

**Originality/value:** The methods used in the article represent an innovative approach to modeling the REER index, providing new insights into the cyclicity of the index and the shortening periods of its occurrence. The article is addressed both to researchers in this field and to individuals involved with the monetary system and those working in the financial industry.

**Keywords:** REER, Cyclicity, Global Financial Crisis, COVID-19 pandemic.

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

## 1. Introduction

The Global Financial Crisis (GFC), which began in 2007, marked a turning point for the global economy, sparking profound transformations in the financial system (Adrian, Shin, 2010; Firlej, 2011) affecting monetary policy (ECB & Stark, 2009), and exchange rates worldwide (Tsangarides, 2012). In the years leading up to it, there was an increase in financial globalization (Mendoza, Quadrini, 2010), capital market liberalization (Semmler, Young, 2010; Roy, Kemme, 2020), and an intensification of international trade (Saracco et al., 2016), which led to increased volatility in currency exchange rates (Coudert et al., 2011) and a diversity of economic paths. Initiated by the crash in the U.S. real estate market and spreading through the globalized banking system, the crisis caused significant turbulence in financial markets (Verick, Islam, 2010), resulting in a drastic drop in the value of many currencies and an increase in economic uncertainty (Helleiner, 2011). In response, measures were taken to stimulate the economy and stabilize markets, such as lowering interest rates (Helleiner, 2011) and implementing unconventional monetary policy programs (Cecioni et al., 2018). Concurrently, over the following years, a series of regulations and standards were introduced at the supranational level (Anginer et al., 2019; Porter, 2014), aimed at reducing the risk of a financial crisis recurrence, which simultaneously leads to an increased role of global financial markets for individual economies, and may lead to synchronization of selected elements of monetary and fiscal policies (Nanto, 2010).

In the context of the presented global economic integration, an important element at the European level is the progressing synchronization of the real effective exchange rate (REER), which on one hand reflects similar reactions of national economies to global events and challenges (Baghestani, 2021), enabling more effective and consistent political actions at the supranational level, and in the context of the European System of Central Banks, contributes to improving the coherence of monetary policy (Pistoiesi et al., 2017), thereby enhancing the stability of the entire region. On the other hand, REER synchronization improves its predictability, facilitating entrepreneurs' determination of future exchange rate trends, which improves the precision of decisions regarding, among others, foreign investments (Goldberg, Klein, 1997), pricing products for export (Grennes, 2019), and currency risk hedging strategies (Bernoth, Herwartz, 2021), which become less exposed to adverse currency fluctuations (Mierzejewski et al., 2019). In the context of the impact of financial globalization, it can be assumed that both the cyclicity of the REER index, resulting from following changes in economic cycles, and the impact of regulations implemented in the economic-financial system on the synchronization of the index between countries, may occur. As a result, the occurrence of economic crises may change the shaping of this index, which the perspective of the global post-pandemic crisis, which has significantly translated into the shaping of global monetary policies (Wei, Han, 2021) and the functioning of economies (Akbulaev et al., 2020),

may signify the beginning of a new phase in the REER index's time cycle, and thus a change in the functioning of enterprises operating in the real economy.

The significance of this work lies in its ability to provide new insights into the behavior of REER during periods of global economic turbulence. By employing an innovative comparative spectral analysis approach, this research contributes to the existing body of knowledge on exchange rate economics and offers valuable information for policymakers and financial industry stakeholders. The findings of this study are crucial for making informed decisions regarding monetary policies and for understanding the synchronization of REER movements among different economies during crises. The significance of this work lies in its ability to provide new insights into the behavior of REER during periods of global economic turbulence. By employing an innovative comparative spectral analysis approach, this research contributes to the existing body of knowledge on exchange rate economics and offers valuable information for policymakers and financial industry stakeholders. The findings of this study are crucial for making informed decisions regarding monetary policies and for understanding the synchronization of REER movements among different economies during crises.

The current state of research in the field of exchange rate economics includes significant contributions from various scholars. Key publications have examined the effects of financial globalization (Mendoza, Quadrini, 2010), capital market liberalization (Semmler, Young, 2010; Roy, Kemme, 2020), and international trade intensification (Saracco et al., 2016) on currency exchange rates. The volatility of exchange rates during the GFC and its aftermath has been documented extensively (Coudert et al., 2011), highlighting the importance of understanding these dynamics. Recent studies have also focused on the impact of the COVID-19 pandemic on economic indicators and financial markets (Akbulaev et al., 2020; Wei, Han, 2021). The novelty of the results presented in this study lies in the use of spectral analysis to model the cyclicity of the REER index, providing new insights into the synchronization of REER movements during and after major economic crises. The study's innovative approach and its focus on the comparative analysis of different crisis periods contribute to the originality and value of the findings. These results are expected to be of interest to researchers, policymakers, and practitioners in the field of exchange rate economics and monetary policy. According to what we were able to find, no studies are referring and reporting on the comparative spectral analysis of REER fluctuations specifically addressing the simultaneous impacts of the Global Financial Crisis, the COVID-19 pandemic, and the subsequent inflation crisis on the synchronization of REER movements across various European countries. This lack of existing research highlights the novelty of our approach and underscores the importance of our findings. By filling this research gap, we have demonstrated that the issue is relevant, and we have also proven that our study does indeed fill a research gap.

This research involves a comparative spectral analysis of time-series data to track REER movements across various countries. The analysis utilizes the Fourier Transform to identify cyclical behaviors in the REER index and employs the Dickey-Fuller and Philips-Perron tests

to confirm the stationarity of the series. Additionally, the study examines the synchronization of REER fluctuations by comparing the spectral density indices of individual countries.

The research is guided by the following hypotheses:

H1: The Global Financial Crisis (GFC) and the COVID-19 pandemic have shortened cyclical periods in REER movements.

H2: There is an improvement in the synchronization of REER movements post-GFC, suggesting a convergence in economic responses to global shocks.

H3: The synchronization of REER indices among European countries has increased, indicating a stabilization of exchange rate movements in response to coordinated monetary policies.

## 2. Literature Review

With the end of the COVID-19 pandemic in 2022, global inflation began to rise (Słomba, Palac, 2023), driven by a series of factors including demand-related shocks (Giovanni et al., 2022), global supply (Giovanni et al., 2022), oil prices (Ha et al., 2023a), and global changes in interest rates (Pallotti et al., 2023). Particularly, shocks in oil prices and global demand play a key role in the movements of global inflation (Ha et al., 2023b). As a result, many European countries lost competitiveness (Kotkowski, 2020) compared to countries where this problem did not occur, or which dealt with it better and faster. The real effective exchange rate, which is already adjusted for inflation (Economic Governance Support Unit, 2017), is a tool that allows for the comparison of competitiveness between countries. Apart from the impact of inflation itself, this index also depends on the value of a country's currency compared to an index or basket of other major currencies, one of the tools used for this is the average level of bilateral exchange rates (Chinn, 2006). Weights are assigned to account for the trade allocation of each partner. The REER formula is weighted to consider the relative importance of each trade partner to the home country (Economic Governance Support Unit, 2017). An increase in REER indicates that a country's exports become more expensive and imports cheaper. This may mean a loss of trade competitiveness (Chinn, 2006). Cyclical factors influencing the level of the index include Consumer Price Index (CPI) (Stock, Watson, 2019), Producer Price Index (PPI) (Zapata et al., 2023), GDP deflator (Kanago, 2023), and unit labor costs (ULC) (Gu et al., 2020; Darvas, 2012). They are cyclical, meaning they exhibit regular fluctuations in each of the studied cycles, and their lengths are determined in similar time intervals, e.g.: 1998-2015 (Stavárek, Miglietti, 2015), 1994-2007 (Comunale, 2015), 1981-2008 (Asif, Rashid, 2010), 1955-1990 (Mendoza, 1995). Historically studied periods of cyclicity lasted between 12 and 27 years. Currently, we can observe shortening periods of cyclicity, the last analyzed period falls between the Global Financial Crisis and the Pandemic-Inflation Crisis, i.e., from 2011 to 2020.



The Consumer Price Index (CPI) shows synchronization with real GDP and wage dynamics in the euro area, suggesting a strong correlation between macroeconomic indicators and the fluctuation of the index (Misztal et al., 2020). This means that movements in the index are not isolated but impact higher economic activities such as production costs. There is a unidirectional causality between the Producer Price Index (PPI) and CPI, through wavelet analysis it can demonstrate clear cyclical effects (Tiwari et al., 2013). However, the PPI itself may indicate changes in the CPI in advance as an indicator of inflationary pressure in the economy. This relationship underscores PPI's reaction to changes in raw material costs and production processes before these cost adjustments impact consumer prices (Fan et al., 2009). Similarly, the consumer price index shows synchronization with fluctuations in real GDP, but also with its deflator. The cyclicity of the producer price index is closely related to the phases of the economic cycle, intensifying during periods of economic expansion, and moderating during recessions (Berry et al., 2019). Studies emphasize the cyclicity of economic indicators, particularly the GDP deflator, which reflects cyclical patterns like CPI and PPI, but with unique nuances due to its comprehensive range. The GDP deflator often shows a stable long-term relationship with the CPI and a less stable relationship with the PPI, highlighting its wide coverage of goods and services produced in the country (Becsi, 1994). The interrelated dynamics of economic indicators and labor market situations illustrate unit labor costs (ULC), which measure the average labor cost per unit of production (Firlej, Matras, 2022). It has a naturally cyclical nature and undergoes fluctuations in response to changes in labor productivity and wage rates. Unit labor cost tends to be procyclical and shows significant synchronization with CPI and PPI, reflecting changes in labor costs passed on to consumer and producer prices (Herwartz, Siedenburg, 2013; Firlej et al., 2023).

The breakthrough event in the process of synchronization of indicators was the Global Financial Crisis, which impacted not only national economies but also the global financial system causing its synchronization, through the occurrence of intensified systemic financial risk. Particularly global risk shocks and the domino effect on financial markets were key in strengthening the synchronization of financial cycles across different markets (Cha, 2012). Additionally, the impact of market volatility and information during the crisis played a significant role, where volatility often overshadowed the impact of information on market correlations. However, as the crisis progressed, the impact of information became increasingly clear, indicating a dynamic interaction between these factors (Mun, Brooks, 2012). Moreover, domino effects, especially from the USA to global markets, were characterized by significant synchronization during the GFC, highlighted by the transmission mechanisms among international banks (Mollah et al., 2016). This highlights the complex mechanisms of risk transmission and market behaviors, which contribute to the global synchronization of financial markets during times of economic crisis.

Cyclical measurements of macroeconomic indicators are crucial for understanding the real effective exchange rate (REER) as they highlight turning points in the economy, which are essential for policy adjustment and strategic planning. Cyclical fluctuations in REER reflect changes in a country's economic competitiveness, influenced by performance, labor costs, and economic policies. REER appreciation during periods of economic growth may indicate improved competitiveness or higher inflation rates compared to trading partners, while depreciation during downturns may suggest the opposite. The cyclicity, which both influences and responds to global economic dynamics, is essential for making informed decisions regarding trade, monetary policy, and international market strategies, thereby supporting economic stability and growth.

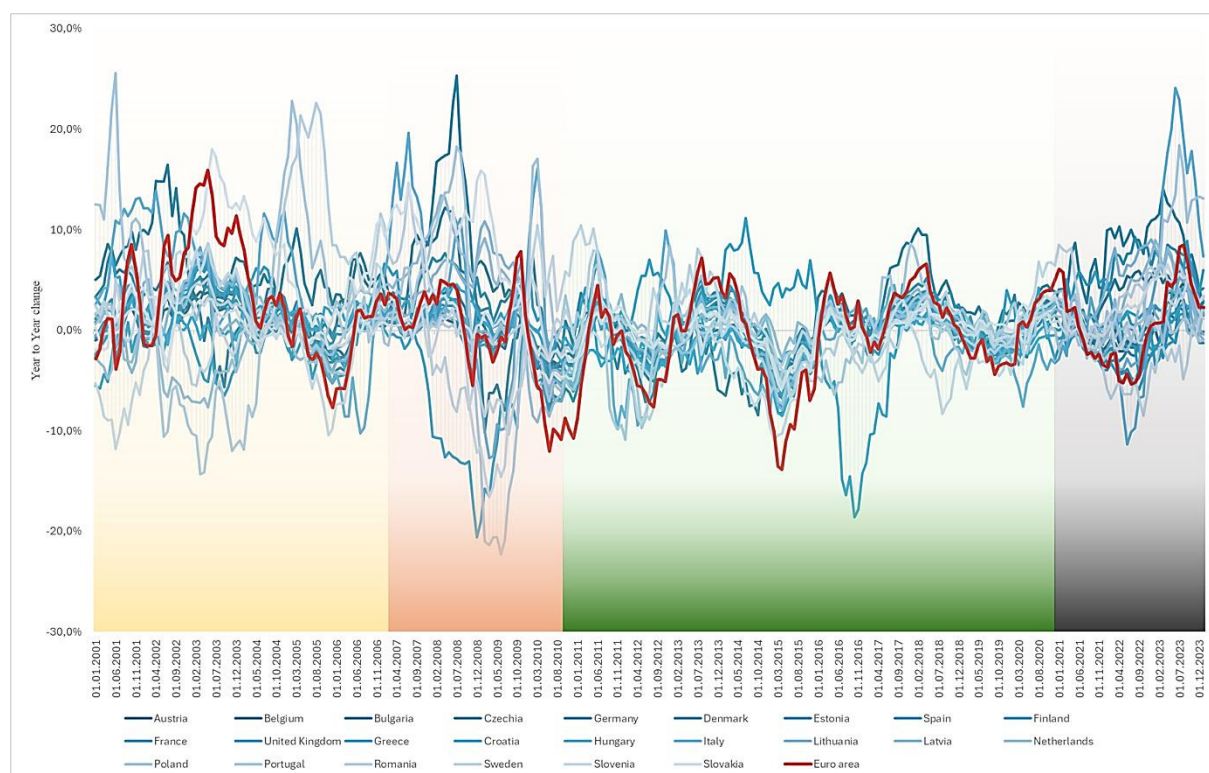
### 3. Materials & Methods

The article aimed to determine the possibility of a cyclical component in the shaping of the behavior patterns of the real effective exchange rate (REER), as well as to study the impact of the financial crisis (GFC) on its European synchronization and the subsequent emergence of a new cyclical path in the period between crises (GFC and the post-pandemic crisis) as a result of changes implemented in global financial systems, by identifying economies with similar fluctuations of the index during this period. The analysis was conducted using the Fourier Transform (Maruyama, 2018; Pollock, 2009), which allows for the extraction of cyclical behaviors of a time series for stationary series (to confirm the stationarity of the series, the Dickey-Fuller and Philips-Perron tests were used (commonly applied in the field, including by Leybourne & Newbold (Leybourne, Newbold, 1999; Wolters & Hassler (Wolters, Hassler, 2006))). To determine the synchronization of the lengths of fluctuations in the cyclicity of individual series, the spectral density index was used, which offers a more detailed view of the power distribution of the signal at different frequencies. The values of this index enabled the comparison of the similarity of structures of individual cycles, for which a measure of the correlation between individual time series was used.

The study utilized monthly data from January 2000 to January 2024, for 24 European countries (Austria, Belgium, Bulgaria, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, United Kingdom, Greece, Croatia, Hungary, Italy, Lithuania, Latvia, Netherlands, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia) and the eurozone (a group of countries that share the euro as their common currency), sourced from the Bank for International Settlements database (BIS, <https://data.bis.org/topics/EER/data>).

#### 4. Result and discussion

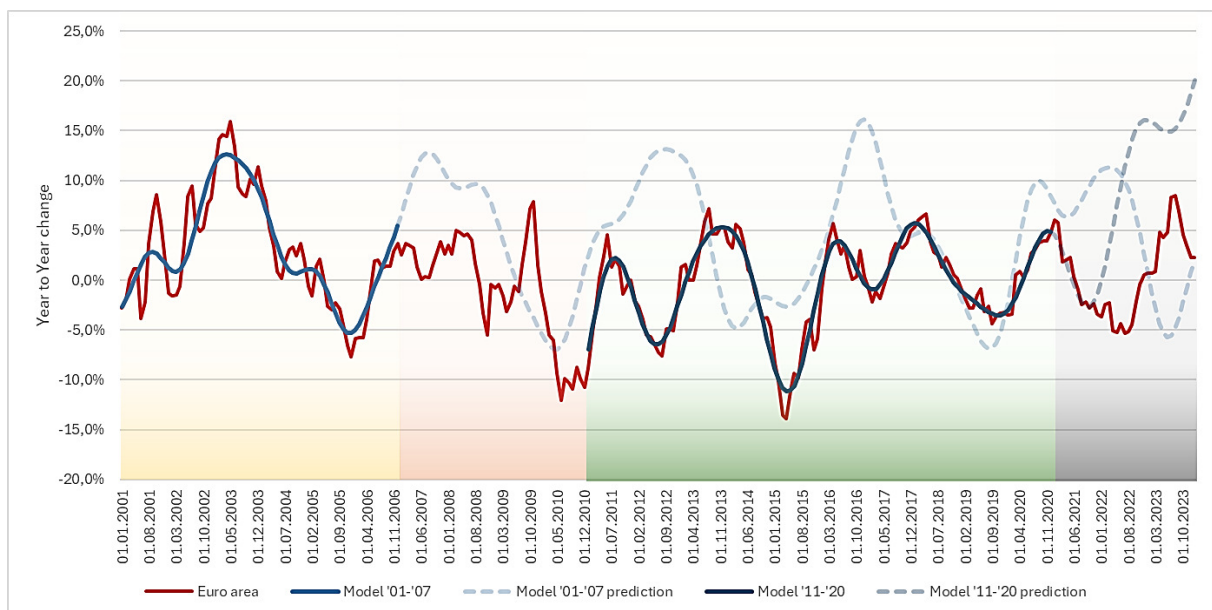
Defining cycles in the structures of individual time series of the REER index began with determining the time intervals of individual phases: I. REER Cycle Phase, which covered the time from the beginning of the study to the Global Financial Crisis (GFC), and II. REER Cycle Phase, after the GFC period. Based on the literature, it was assumed that the GFC period ranged from the beginning of 2007 to the end of 2010 (Merrouche, Nier, 2010; Shahrokh, 2011; Tekin, 2020; Olbrys, 2021). Additionally, it was indicated that the post-pandemic crisis, which contributed to changes in the cyclical structure of the REER index, began in 2021 (Bank of Greece & Catiforis, 2022; Prokopowicz, 2022). This is related to the occurrence of global inflation caused by rising commodity prices and changes in monetary policy. During the crisis, stimulus packages were introduced to support the liquidity of economic entities disrupted by rising production prices and to maintain aggregate supply at the pre-crisis level. International organizations launched financial programs such as the European Regional Development Fund, the European Social Fund+ and the Fund for a Just Transition to support the global financial system and economic recovery (Masseti, Exadaktylos, 2022).



**Figure 1.** Development of the real effective exchange rate values in European countries, indicating the REER Cycle Phases.

Source: own study based on BIS data.

For each phase (in figure 1: Phase I of the REER Cycle in yellow; Phase II of the REER Cycle in green), series were isolated for examination of basic statistics, followed by determination of cyclical structures using the Fourier Transform (Figure 1 also marks the GFC period and the post-pandemic crisis). Preliminary results of the variance (dispersion of values around the mean, with an increase indicating greater dispersion and a decrease indicating less, thereby increasing consistency) for the REER index during Phases I and II of the REER Cycle indicated a change of approximately 42.34 pp in Phase I and 12.55 pp in Phase II. Before the GFC, the range between the highest value (Slovakia – 235.77) and the lowest (Slovenia – 3.91) was 232.76, while after the crisis it was 49.40. The highest REER value was recorded for the Czech Republic (51.27) and the lowest for Slovenia (1.87). Between the phases, an average decrease of 29.80 pp was observed, indicating the impact of the GFC on reducing the variability of the REER index. Only for three of the countries studied was an increase in variance noted between periods, namely Sweden, Lithuania, and the United Kingdom. After the GFC, the variance decreased, meaning it reduced differences in currency rate volatility among countries, thereby increasing the synchronization of the REER index among the countries studied.



**Figure 2.** Development of the REER index for the Euro area with markings of cyclical components.

Source: own study based on BIS data.

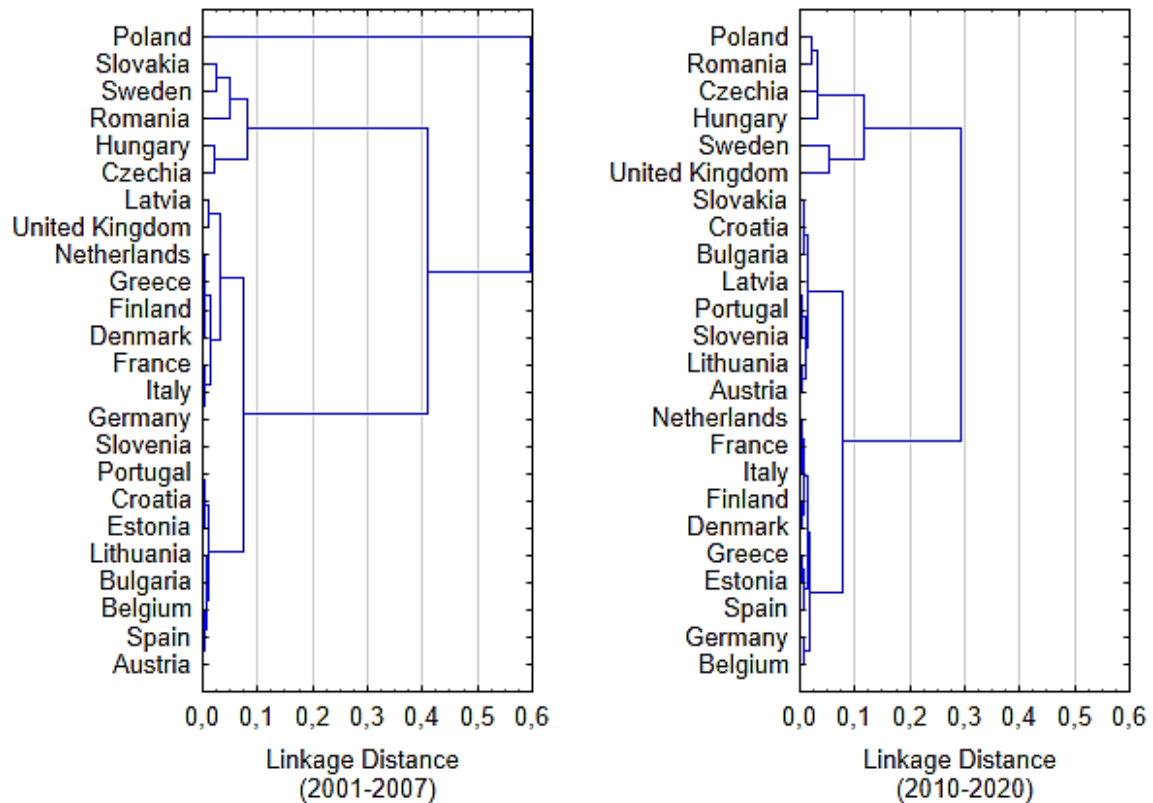
Based on the series of changes in the REER index value (year-over-year) for the Euro area and the results of the cycle structure analysis in the respective Phases, two models describing the cyclical parameter of the index were determined. The equations describing these models (where  $t$  denotes successive observations over time) took the form:

$$\begin{aligned}
y_{01-07} = & 0.04 - 3.34(0.02 \cos(0.11t) - 0.005 \sin(0.11t)) \\
& - 2.65(-0.0001 \cos(0.12t) + 0.008 \sin(0.12t)) \\
& - 6.2(0.003 \cos(0.27t) - 0.004 \sin(0.27t)) \\
& + 3.85(-0.001 \cos(0.29t) - 0.0003 \sin(0.29t)) \\
& - 14.31(-0.002 \cos(0.44t) - 0.002 \sin(0.44t))
\end{aligned} \tag{1}$$

$$\begin{aligned}
y_{11-20} = & -0.0026 + 4.46(-0.006 \cos(0.141t) - 0.003 \sin(0.141t)) \\
& + 25.5(-0.002 \cos(0.225t) - 0.006 \sin(0.225t)) \\
& + 1.8(-0.002 \cos(0.216t) + 0.001 \sin(0.216t)) \\
& + 6.7(-0.002 \cos(0.108t) - 0.002 \sin(0.108t)) \\
& + 9.7(0.026 \cos(0.025t) - 0.017 \sin(0.025t)) \\
& + 5.8(-0.002 \cos(0.325t) - 0.001 \sin(0.325t)) \\
& - 9.68(0.001 \cos(0.208t) - 0.001 \sin(0.208t)) \\
& - 934(-0.0007 \cos(0.158t) - 0.004 \sin(0.158t)) \\
& - 44.79(-0.02 \cos(0.041t) - 0.007 \sin(0.041t))
\end{aligned} \tag{2}$$

The described models illustrate the change in the share of the cyclical factor in the dynamics of the NEER index in the Euro area (the model fit for Phase I is measured by the determination coefficient  $R^2 = 0.83$ , while for Phase II, following the GFC, it is  $R^2 = 0.92$ ). Thus, the models indicate not only a change in the temporal dynamics of the index (changes in the contributions of various cycle lengths) but also greater synchronization over time (a decrease in residuals resulting from the mismatch to the cycle). Consequently, the consequence of the policies implemented in the financial space was an improvement in the predictability of the NEER index formation after the crisis.

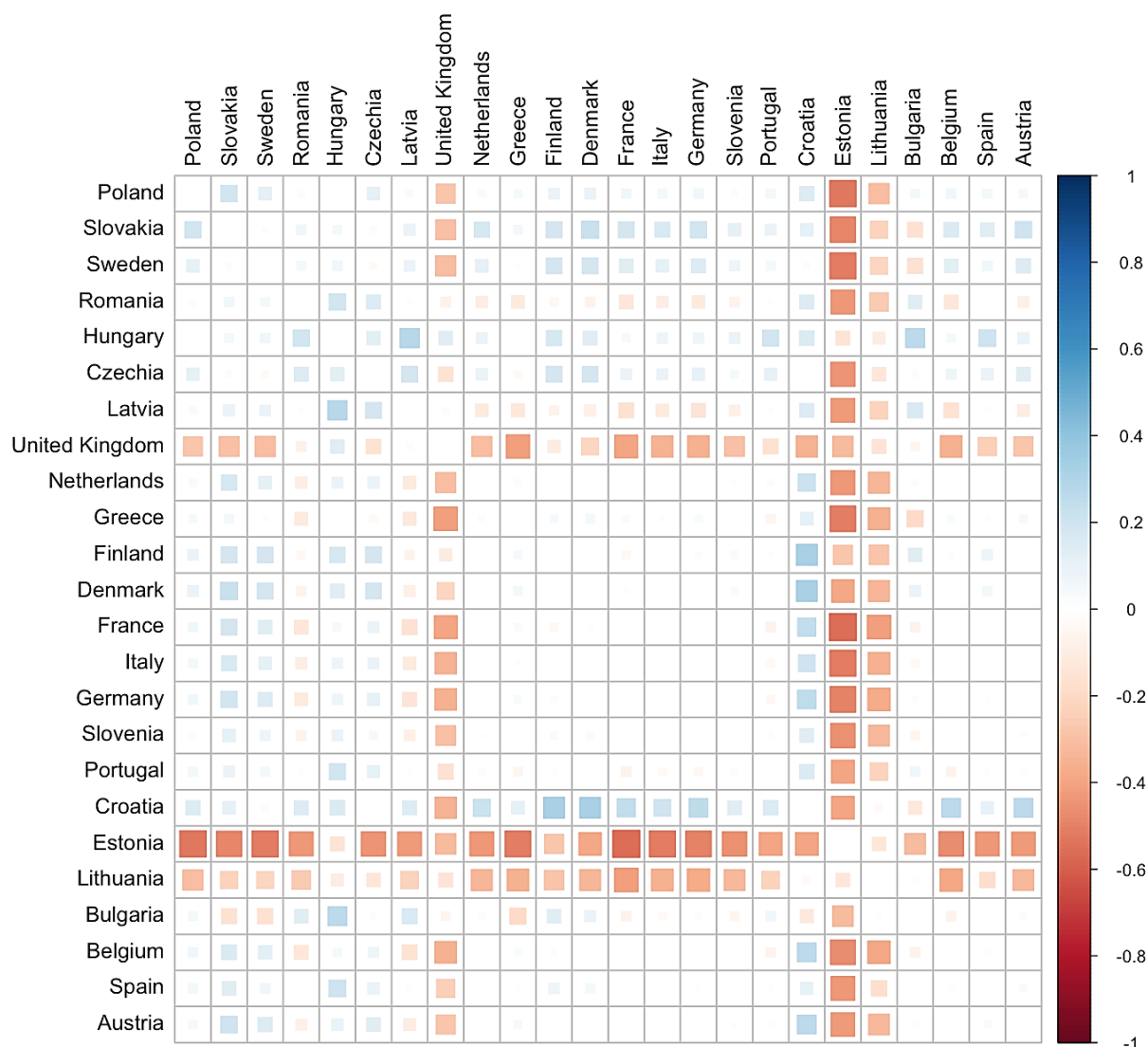
Similarly, for the individual time series of individual countries' NEER indices, a cycle decomposition was conducted for periods of Phase I and Phase II, followed by a comparison of the spectral density index (which describes the contribution of various cycle lengths to the dynamics of the entire series) between countries using Ward's categorization method.



**Figure 3.** Classification of countries based on the cyclical structure of the NEER index during Phases I and II.

Source: own study based on BIS data.

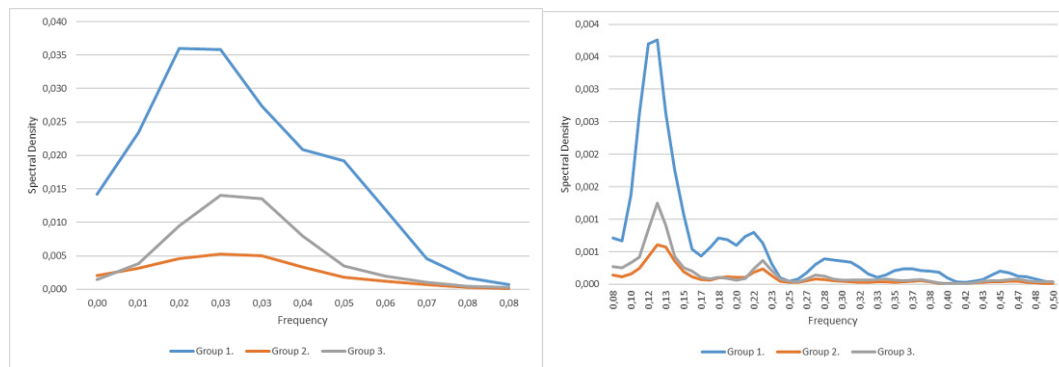
As a result, countries were grouped based on similar characteristics of the cyclical element in the dynamics of the REER index during Phases I and II (as shown in figure 3 above). In the pre-crisis period, four distinct groups of countries with similar cycle characteristics can be identified: 1. Poland; 2. Slovakia, Sweden, Romania, Hungary, Czechia; 3. Latvia, United Kingdom, Netherlands, Greece, Finland, Denmark, France, Italy, Germany; 4. others. In the categorization of countries in Phase II, there is a reduction in the number of groups (three distinct groups of countries with similar structures of the cyclical element can be identified), as well as a decrease in the Euclidean distance between the groups of countries, which indicates not only a convergence of cyclical dynamics within the groups but also between the groups.



**Figure 4.** Differences in correlation structure between the spectral density indices of the REER index for individual countries during Phases I and II.

Source: own study based on BIS data.

As presented in Chart 4 the changes in the correlation structure (that indicates the extent to which two variables move concerning each other and how it contributes to participation) REER indices of various countries are correlated across two distinct periods, highlighting that during Phase I, there is a broader range of correlation values indicating more variability in the cyclical behaviors and economic interactions among the countries, while in Phase II, there is a noticeable shift towards stronger and more consistent positive correlations, as evidenced by the clustering of blue squares, suggesting that post-crisis economic conditions and policies have led to greater synchronization and alignment of REER fluctuations across these nations. However, some countries still exhibit unique or negative correlations for example Estonia, Lithuania, United Kingdom, reflecting divergent economic conditions or responses to global economic events.



**Chart 5.** Average values of the spectral density of the REER index in individual country groups during Phase 2.

Source: own study based on BIS data.

In Phase II, the cycle structure in the three country groups was primarily based on a long-term cycle (frequencies of 0.02-0.03, corresponding to approximately four-year cycles) and three short cycle lengths (less than a year). These are the frequencies: 0.12 (eight-month cycles), 0.22 (four-month cycles), and 0.28 (quarterly cycles). At the same time, it can be noted that the strongest impact of the cyclical component on the dynamics of the observed series is found in the first group of countries, indicating that these are the countries with the most predictable dynamics of the REER index behaviors during the studied period.

## 5. Conclusion

The study presented in this article focuses on analyzing the impact of the Global Financial Crisis (GFC) on the synchronization of the real effective exchange rate (REER) and on identifying cyclical changes in its behavior in the context of global financial integration. A detailed assessment of REER dynamics indicates increased synchronization and predictability of the index in response to global and regional events. The analysis results clearly show that the GFC significantly impacted the structure and dynamics of REER, enhancing its synchronization on a European scale. The variance between Phase I and Phase II decreased by 29.80 percentage points, and the correlation between countries increased by 3.60 percentage points. In Phase II, the cycle structure in the three country groups was primarily based on a long-term cycle with frequencies of four-year cycles, and three shorter cycle lengths of less than a year. As a result of the crisis the first group of countries showed the strongest cyclical impact, indicating the most predictable REER index dynamics during the period studied.

Based on the grouping of countries according to similarities in the dynamics of REER, it was found that after the GFC, there was a convergence of economic cyclical behavior among different economies, suggesting that policies introduced in response to the crisis contributed to increasing global economic cohesion. At the same time, it was indicated that due to the crisis,



there was a change in the cyclical structure of individual time series describing the REER index, which has also been evolving since 2021. This observation indicates that the post-pandemic crisis may have a real impact on the dynamics of the formation of the real effective exchange rate index, leading to the creation of a new dynamic structure and REER levels after the crisis ends, leading to a new, Phase III of the REER Cycle. Based on the research results, it can be concluded that the Global Financial Crisis (GFC) and the COVID-19 pandemic have indeed shortened the cyclical periods in REER movements, confirming H1. Additionally, there has been a noticeable improvement in the synchronization of REER movements post-GFC, suggesting that economies are converging in their responses to global shocks, thereby confirming H2. Furthermore, the synchronization of REER indices among European countries has increased, indicating a stabilization of exchange rate movements in response to coordinated monetary policies, thus confirming H3.

While this research provides significant insights into the behavior of REER during major global crises, it is important to acknowledge its limitations and weaknesses. Firstly, the study is constrained by the availability and quality of data, which may affect the accuracy of the findings. The reliance on spectral analysis, although innovative, may also introduce biases, especially if the underlying assumptions of stationarity are not fully met. Additionally, the focus on European countries limits the generalizability of the results to other regions with different economic structures and policy responses. Despite these limitations, the research offers valuable new knowledge and several key lessons. It demonstrates that global crises, such as the GFC and the COVID-19 pandemic, have a significant impact on the synchronization and cyclicity of REER. The study's findings suggest that post-GFC, there is a noticeable improvement in the synchronization of REER movements, indicating that economies are increasingly converging in their responses to global economic shocks. This convergence implies a potential stabilization of exchange rate movements, which is crucial for policymakers and financial market participants. The importance of this research lies in its contribution to understanding the dynamics of exchange rates in response to global crises. By highlighting the increased synchronization of REER movements, the study provides a basis for more coordinated monetary policies among European countries. This coordination can lead to more effective and consistent policy actions at the supranational level, enhancing the stability of the entire region. The findings have practical implications for financial industry stakeholders, including better-informed decisions regarding hedging strategies against currency exchange rate fluctuations and improved forecasting of future exchange rate trends. The theoretical implications extend to the broader field of international economics, where this research fills a critical gap in understanding the interplay between global crises and exchange rate dynamics. The information obtained from this study can be further used to explore the impact of other types of economic shocks on REER and examine REER's synchronization in other regions. Future research could also investigate the long-term effects of coordinated monetary policies on the stability and predictability of exchange rates. Additionally, the methodology and findings

could be applied to other economic indicators to assess their cyclicity and synchronization in response to global events.

## Acknowledgements

The publication/article present the result of the Project no 023/EER/2023/POT financed from the subsidy granted to the Krakow University of Economic.

## References

1. Adrian, T., Shin, H.S. (2010). The Changing Nature of Financial Intermediation and the Financial Crisis of 2007-2009. *Annual Review of Economics*, 2(1), 603-618. <https://doi.org/10.1146/annurev.economics.102308.124420>
2. Akbulaev, N., Mammadov, I., Aliyev, V. (2020). Economic Impact of COVID-19. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3649813>
3. Anginer, D., Bertay, A.C., Cull, R., Demirguc-Kunt, A., Mare, D.S., Mare, D.S. (2019). *Bank Regulation and Supervision Ten Years after the Global Financial Crisis*. World Bank, Washington, DC. <https://doi.org/10.1596/1813-9450-9044>
4. Asif, M., Rashid, K. (2010). Time Series Analysis of Real Effective Exchange Rates On Trade Balance in Pakistan. *Journal of Yaşar University*.
5. Baghestani, H. (2021). Real exchange rate synchronization in the NAFTA region. *Journal of Economic Studies*, 49(7), 1212-1224. <https://doi.org/10.1108/JES-04-2021-0207>
6. Bank of Greece, Catiforis, C. (2022). Post-pandemic inflation: Phillips curve, trends, drivers and lessons. *Economic bulletin*, 43-66. <https://doi.org/10.52903/econbull20225502>
7. Becsi, Z. (1994). Indicators of the general price level and inflation. *Economic and Financial Policy Review*, 27-39.
8. Bernoth, K., Herwartz, H. (2021). Exchange rates, foreign currency exposure and sovereign risk. *Journal of International Money and Finance*, 117, 102454. <https://doi.org/10.1016/j.jimonfin.2021.102454>
9. Berry, F., Graf, B., Stanger, M., Ylä-Jarkko, M. (2019). Price Statistics Compilation in 196 Economies: The Relevance for Policy Analysis. *IMF Working Papers*, 19(163). <https://doi.org/10.5089/9781513508313.001>
10. Cecioni, M., Ferrero, G., Secchi, A. (2018). Unconventional Monetary Policy in Theory and in Practice. In: D.D. Evanoff, G.G. Kaufman, A.G. Malliaris, *World Scientific-Now*

- Publishers Series in Business*, vol. 15 (pp. 1-36). World Scientific/NOW Publishers. [https://doi.org/10.1142/9789813236592\\_0001](https://doi.org/10.1142/9789813236592_0001)
11. Cha, Z. (2012). *The Global Risk Shock and Financial Cycle Synchronization*. *Financial Regulation Research*. <https://consensus.app/papers/global-risk-shock-financial-cycle-synchronization-cha/3ca9808d9a1853c4b1c0b6307ecc3356/>
  12. Chinn, M.D. (2006). A Primer on Real Effective Exchange Rates: Determinants, Overvaluation, Trade Flows and Competitive Devaluation. *Open Economies Review*, 17(1), 115-143. <https://doi.org/10.1007/s11079-006-5215-0>
  13. Comunale, M. (2015). Current Account and REER Misalignments in Central Eastern EU Countries: An Update Using the Macroeconomic Balance Approach. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2677122>
  14. Coudert, V., Couharde, C., Mignon, V. (2011). Exchange rate volatility across financial crises. *Journal of Banking & Finance*, 35(11), 3010-3018. <https://doi.org/10.1016/j.jbankfin.2011.04.003>
  15. Economic Governance Support Unit. (2017). *Effective Exchange Rate in Euro Area Member States PE* (PE 602.099). European Parliament. [https://www.europarl.europa.eu/RegData/etudes/ATAG/2017/602099/IPOL\\_ATA\(2017\)602099\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/ATAG/2017/602099/IPOL_ATA(2017)602099_EN.pdf)
  16. Fan, G., He, L., Hu, J. (2009). CPI vs. PPI: Which drives which? *Frontiers of Economics in China*, 4(3), 317-334. <https://doi.org/10.1007/s11459-009-0018-z>
  17. Firlej, K. A. (2011). Źródła i przebieg kryzysu finansowego w Stanach Zjednoczonych i Europie Zachodniej.
  18. Firlej, K.A., Matras, M. (2022). Makroekonomiczne i mikroekonomiczne koszty i metody przeciwdziałania bezrobociu. *Problems of Economics and Law*, 7(1), 1-15. <https://doi.org/10.55225/pel.411>
  19. Firlej, K.A., Firlej, C., Luty, L. (2023). Economic growth and decent work as a goal of sustainable development in the European Union in the pre-pandemic and pandemic period. *International Entrepreneurship Review*, 9(1), 61-76.
  20. Giovanni, J.D., Kalemlı-Özcan, Şebnem, Silva, A., Yildirim, M. (2022). *Global Supply Chain Pressures, International Trade, and Inflation*, w30240. National Bureau of Economic Research. <https://doi.org/10.3386/w30240>
  21. Goldberg, L., Klein, M. (1997). *Foreign Direct Investment, Trade and Real Exchange Rate Linkages in Developing Countries*, w6344. National Bureau of Economic Research. <https://doi.org/10.3386/w6344>
  22. Grennes, T. (2019). *International Financial Markets and Agricultural Trade*. CRC Press. <https://doi.org/10.1201/9780429044106>
  23. Gu, G.W., Prasad, E., Moehrlé, T. (2020). New Evidence on Cyclical Variation in Average Labor Costs in the United States. *The Review of Economics and Statistics*, 102(5), 966-979. [https://doi.org/10.1162/rest\\_a\\_00863](https://doi.org/10.1162/rest_a_00863)

24. Ha, J., Kose, M.A., Ohnsorge, F., Yilmazkuday, H. (2023a). Understanding the global drivers of inflation: How important are oil prices? *Energy Economics*, 127, 107096. <https://doi.org/10.1016/j.eneco.2023.107096>
25. Ha, J., Kose, M.A., Ohnsorge, F., Yilmazkuday, H. (2023b). *What Explains Global Inflation*. The World Bank. <https://doi.org/10.1596/1813-9450-10648>
26. Helleiner, E. (2011). Understanding the 2007-2008 Global Financial Crisis: Lessons for Scholars of International Political Economy. *Annual Review of Political Science*, 14(1), 67–87. <https://doi.org/10.1146/annurev-polisci-050409-112539>
27. Herwartz, H., Siedenburg, F. (2013). To converge or not converge: Unit labor cost inflation in the Euro area. *Empirical Economics*, 44(2), 455-467. <https://doi.org/10.1007/s00181-011-0535-3>
28. Kanago, B. (2023). The Comovement Between Forecast Errors for Real GDP and Its Deflator in Six OECD Countries: Did Supply Shocks Become Less Dominant During the Great Moderation? *Journal of Business Cycle Research*, 19(2), 149-169. <https://doi.org/10.1007/s41549-023-00086-0>
29. Kotkowski, D. (2020). Szanse i zagrożenia dla pozycji Unii Europejskiej jako gracza na arenie międzynarodowej w perspektywie krótkookresowej. *Przegląd Geopolityczny*, 34, 103-118.
30. Leybourne, S.J., Newbold, P. (1999). The behaviour of Dickey–Fuller and Phillips–Perron tests under the alternative hypothesis. *The Econometrics Journal*, 2(1), 92-106. <https://doi.org/10.1111/1368-423X.00022>
31. Maruyama, T. (2018). *Fourier Analysis of Economic Phenomena (vol. 2)*. Springer Singapore. <https://doi.org/10.1007/978-981-13-2730-8>
32. Massetti, E., Exadaktylos, T. (2022). From Crisis to Crisis: The EU in between the Covid, Energy and Inflation Crises (and War). *JCMS: Journal of Common Market Studies*, 60(S1), 5-11. <https://doi.org/10.1111/jcms.13435>
33. Mendoza, E.G. (1995). The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations. *International Economic Review*, 36(1), 101. <https://doi.org/10.2307/2527429>
34. Mendoza, E.G., Quadrini, V. (2010). Financial globalization, financial crises, and contagion. *Journal of Monetary Economics*, 57(1), 24-39. <https://doi.org/10.1016/j.jmoneco.2009.10.009>
35. Merrouche, O., Nier, E. (2010). *What caused the global financial crisis? Evidence on the drivers of financial imbalances, 1999-2007*. International Monetary Fund.
36. Mierzejewski, M., Garncarz, J. (2019). Impact of Exchange Rates and Oil Prices on the Valuation of Companies From The TSL Sector. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 137. Cracow University of Economics, Department of Organisation Development, 115-131. <https://doi.org/10.29119/1641-3466.2019.137.8>

37. Misztal, P. (2020). Cyclical or countercyclical nature of prices and wages in the euro area. *Journal of Economics and Management*, 41. Kielce: Department of Economics and Finance, Faculty of Law and Social Sciences, & Jan Kochanowski University, 25-46. <https://doi.org/10.22367/jem.2020.41.02>
38. Mollah, S., Quoreshi, A.M.M.S., Zafirov, G. (2016). Equity market contagion during global financial and Eurozone crises: Evidence from a dynamic correlation analysis. *Journal of International Financial Markets, Institutions and Money*, 41, 151-167. <https://doi.org/10.1016/j.intfin.2015.12.010>
39. Mun, M., Brooks, R. (2012). The roles of news and volatility in stock market correlations during the global financial crisis. *Emerging Markets Review*, 13(1), 1-7. <https://doi.org/10.1016/j.ememar.2011.09.001>
40. Nanto, D.K. (b.d.). *The Global Financial Crisis: Analysis and Policy Implications. The Global Financial Crisis*.
41. Olbrys, J. (2021). The Global Financial Crisis 2007-2009: A Survey. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3872477>
42. Pallotti, F., Paz-Pardo, G., Slacalek, J., Tristani, O., Violante, G. (2023). *Who Bears the Costs of Inflation? Euro Area Households and the 2021-2022 Shock*, w31896. National Bureau of Economic Research. <https://doi.org/10.3386/w31896>
43. Pistoresi, B., Cavicchioli, M., Brevini, G. (2017). Central Bank Independence, Financial Instability and Politics: New Evidence for OECD and Non-OECD Countries. *International Journal of Economics and Finance*, 9(7), 179. <https://doi.org/10.5539/ijef.v9n7p179>
44. Pollock, S.D.S.G. (2009). Statistical Fourier Analysis: Clarifications and Interpretations. *Journal of Time Series Econometrics*, 1(1). <https://doi.org/10.2202/1941-1928.1004>
45. Porter, T. (ed.) (2014). *Transnational financial regulation after the crisis*. Routledge & Taylor & Francis Group.
46. Prokopowicz, D. (2022). *The postcovid rise in inflation: Coincidence or the result of misguided, excessively interventionist and monetarist economic policies*. <https://doi.org/10.13140/RG.2.2.21398.22081>
47. Roy, S., Kemme, D.M. (2020). The run-up to the global financial crisis: A longer historical view of financial liberalization, capital inflows, and asset bubbles. *International Review of Financial Analysis*, 69, 101377. <https://doi.org/10.1016/j.irfa.2019.101377>
48. Saracco, F., Di Clemente, R., Gabrielli, A., Squartini, T. (2016). Detecting early signs of the 2007–2008 crisis in the world trade. *Scientific Reports*, 6(1), 30286. <https://doi.org/10.1038/srep30286>
49. Semmler, W., Young, B. (2010). Lost in temptation of risk: Financial market liberalization, financial market meltdown and regulatory reforms. *Comparative European Politics*, 8(3), 327-353. <https://doi.org/10.1057/cep.2010.10>

50. Shahrokhi, M. (2011). The Global Financial Crises of 2007-2010 and the future of capitalism. *Global Finance Journal*, 22(3), 193-210. <https://doi.org/10.1016/j.gfj.2011.10.010>
51. Słomba, A., Palac, P. (2023). Wpływ pandemii COVID-19 oraz wojny rosyjsko-ukraińskiej na wskaźnik kondycji gospodarstw domowych w Polsce. *Problems of Economics and Law*, 8(1), 57-68. <https://doi.org/10.55225/pel.511>
52. Stark, J. (2009). *Monetary Policy before, During and After the Financial Crisis*, <https://www.ecb.europa.eu/press/key/date/2009/html/sp091109.en.html>
53. Stavárek, D., Miglietti, C. (2015). Effective Exchange Rates in Central and Eastern European Countries: Cyclicity and Relationship with Macroeconomic Fundamentals. *Review of Economic Perspectives*, 15(2), 157-177. <https://doi.org/10.1515/revecp-2015-0015>
54. Stock, J., Watson, M. (2019). *Slack and Cyclically Sensitive Inflation*, w25987. National Bureau of Economic Research. <https://doi.org/10.3386/w25987>
55. Tekin, H. (2020). How optimal cash changed by the global financial crisis? A multi-country analysis. *Economics and Business Letters*, 9(2), 114. <https://doi.org/10.17811/ebl.9.2.2020.114-123>
56. Tiwari, A.K., Mutascu, M., Andries, A.M. (2013). Decomposing time-frequency relationship between producer price and consumer price indices in Romania through wavelet analysis. *Economic Modelling*, 31, 151-159. <https://doi.org/10.1016/j.econmod.2012.11.057>
57. Tsangarides, C.G. (2012). Crisis and recovery: Role of the exchange rate regime in emerging market economies. *Journal of Macroeconomics*, 34(2), 470-488. <https://doi.org/10.1016/j.jmacro.2012.01.005>
58. Verick, S., Islam, I. (2010). The Great Recession of 2008-2009: Causes, Consequences and Policy Responses. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.1631069>
59. Wei, X., Han, L. (2021). The impact of COVID-19 pandemic on transmission of monetary policy to financial markets. *International Review of Financial Analysis*, 74, 101705. <https://doi.org/10.1016/j.irfa.2021.101705>
60. Wolters, J., Hassler, U. (2006). Unit root testing. *Allgemeines Statistisches Archiv*, 90(1), 43-58. <https://doi.org/10.1007/s10182-006-0220-6>
61. Zapata, H.O., Betanco, J.E., Bampasidou, M., Deliberto, M. (2023). A Cyclical Phenomenon among Stock & Commodity Markets. *Journal of Risk and Financial Management*, 16(7), 320. <https://doi.org/10.3390/jrfm16070320>

## ENERGY AND CLIMATE POLICY AS A DETERMINANT OF FUEL POVERTY IN POLAND

Rafał NAGAJ<sup>1\*</sup>, Bożena GAJDZIK<sup>2</sup>

<sup>1</sup> Institute of Economics and Finance University of Szczecin; rafal.nagaj@usz.edu.pl,  
ORCID: 0000-0002-9410-7663

<sup>2</sup> Department of Industrial Informatics, Silesian University of Technology; bozena.gajdzik@polsl.pl,  
ORCID: 0000-0002-0408-1691

\* Correspondence author

**Purpose:** The aim of the study is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland.

**Design/methodology/approach:** The paper applies the method of regression analysis to assess the impact of climate and energy policy factors on fuel poverty in Poland. For this purpose, a literature review was carried out on the factors influencing fuel poverty and the development of climate and energy policy, particularly decarbonisation in the European Union, in order to identify potential determinants of fuel poverty. An empirical analysis was carried out of electricity and gas price developments and decomposition analysis of these prices in Poland in the studied period, and it was assessed using regression analysis which factors, among the instruments of energy and climate policies, determine fuel poverty in Poland.

**Findings:** The main finding is that climate and energy policies influence fuel poverty in Poland, especially share of renewable energy sources in energy mix and expenditures on environment protection. It was also found that macroeconomic policy instruments, which determine the level of income per capita and thus disposable income, have a statistically significant impact on fuel poverty in Poland. In addition, it was found that such instruments as taxes and social transfers are worth using for this purpose.

**Research limitations/implications:** It is recommended to deepen long-term research on the impact of these policies on fuel poverty. For the time being, the lack of long-term data limits the possibility for long-term analysis.

**Practical implications:** Unfortunately, there is a lack of detailed data on income decomposition in decile groups, which limits the possibility to accurately estimate the long-term level of fuel poverty in Poland.

**Social implications:** The regulation of fuel poverty would make it possible to constantly monitor the phenomenon and to apply instruments that would precisely limit this social phenomenon.

**Originality/value:** The paper provides information on the impact of climate and energy policy on fuel poverty in Poland. So far there have only been analyses of the scale of the phenomenon, not of the factors. It is addressed to fuel poverty practitioners and policy makers in the field of social and energy policy.

**Keywords:** fuel poverty, energy policy, climate policy, decarbonisation, Poland.

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

## 1. Introduction

The year 2022 represents a period of sharp increases in global energy prices and draws attention to the problem of societies' inability to consume energy at an adequate level. It should be noted, however, that the issues of energy poverty and fuel poverty have been addressed in the literature for a long time (Moore, 2012). Unfortunately, economic practice and policy makers, but also the literature, do not distinguish between these concepts, and in addition, in many countries, including Poland, this topic is either not regulated or is regulated indirectly through other socio-economic phenomena, i.e. social policy, energy policy, construction. Meanwhile, the war in Ukraine and the energy crisis have highlighted the problem of being unable to pay energy bills. Meanwhile, the literature on the subject has dealt with the phenomena of energy poverty and fuel poverty for many years. Furthermore, a distinction is made between energy poverty and fuel poverty, which is analysed in this paper (Moore, 2012). Energy poverty is the lack of access to energy carriers or the inability to consume energy due to either technical or network problems or a lack of an energy commodity or a purchasable good (Day, Walker, Simcock, 2016). Fuel poverty, meanwhile, is the difficulty to consume enough energy or to heat one's residence for financial reasons, i.e. either lack of sufficient income to cover energy expenses or because prices of energy carriers are too high (González-Eguino, 2015).

In addition, especially since the Energy and Gas Directive came into force, the European Union has been making numerous changes to the energy market, liberalising it. In addition, recent years have seen a strong emphasis on the decarbonisation of economies through climate policy. According to climate policy and the European Green Deal (European Commission), Member States are obliged to achieve zero carbon emissions by 2050. However, this involves several measures, such as gradually increasing the share of renewable energy sources (RES) in energy consumption, cutting energy consumption to increase energy efficiency, reducing greenhouse gas emissions (Gajdzik et al., 2024a). All these measures involve increasing state spending on environmental protection and passing on charges to end users in the bills they pay for electricity, gas or oil.

All these measures are accompanied, on the one hand, by an improvement in air quality, but, on the other, by a change in the amount that society, including households, must pay for energy carriers. All of this is linked to the phenomenon of the inability of some members of the public to pay their energy bills, i.e. fuel poverty. As the literature highlights (Kyprianou et al., 2019), not all EU member states, indeed most, including Poland, do not have and do not have policies directly aimed at reducing and monitoring fuel poverty. Moreover, it is often not known exactly how much fuel poverty there is in a country. Analyses are already appearing in the literature indicating how fuel poverty should be measured (Day, Walker, Simcock, 2016; Sałach, Lewandowski, 2018). In the case of Poland, however, there is extraordinarily little



research on fuel poverty (Nagaj, 2022a), and if there is any it concerns energy poverty (Górska, 2022). Similarly, when it relates to energy and climate policy, there is an extensive literature on the analysis of these policies (Gajdzik et al., 2023b; Leeuwen, Monios, 2022), whereas there is a lack of research on its impact on fuel poverty, including in Poland. The authors of this paper have therefore decided to fill this existing research gap in the literature.

The aim of this manuscript is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland. This objective is guided by three research tasks (RTs):

RT1: to estimate the fuel poverty rate in Poland in the studied period,

RT2: to review the literature concerning potential factors that may determine fuel poverty and how fuel poverty has been measured in Poland so far,

RT3: to analyse the impact of energy and climate policies on the level of fuel poverty in Poland by assessing the impact of the basic instruments associated with these two policies.

The research tasks formulated in this way are accompanied by the following research questions (RQs):

RQ1: What is the share of energy expenditure in household income and what is the fuel poverty rate in Poland in 2005-2022?

RQ2: What are determinants of the fuel poverty rate in Poland?

RQ3: Does energy and climate policy have an impact on fuel poverty in Poland?

The analysis covers the period 2005-2022, i.e., after accession to the EU. Climate and energy policy is mainly determined by EU policies and directives, which justifies this time horizon.

The work structure is as follows: first section presents the background of analysis based on narrative literature review about fuel poverty in Poland, and determinants of fuel poverty; second section concerns the materials and methods used during empirical analysis, it presents the methodology of the research, while the next section presents the research results for Poland. The last section of this paper is a set of conclusions and recommendations.

## **2. Background for analysis**

The issue of energy poverty has been in the public debate since the 1970s. (since the oil crisis) but in recent years, energy poverty has increased in many countries, i.e. reducing their own energy consumption, mainly for financial reasons (PEI Report 2023; Schumacher, 1985; Ulucak et al., 2021). The determinants of energy poverty vary in their causes, societal reach and dynamics of changes in energy crisis. Energy poverty is affected by many factors, both objective and subjective, economic and financial, as well as other factors, including factors that are

dependent on and independent of the contributors to poverty. Thus, energy poverty is the result of the overlapping of various global, regional and local trends, as well as the effects of overlapping policies, including energy, fiscal, credit (banking), financial, etc. The determinants of energy poverty can be positive or negative, e. g. the energy crisis, which became apparent strongly after the COVID-19 pandemic (Gajdzik et al., 2024b). Many trends require monitoring and action by the public sector to address energy poverty. According to Shonali Pachauri and Narasimha D. Rao (2013), there is no generally accepted definition of energy poverty. For these authors energy poverty is “a term of a lack of access to adequate, reliable, affordable and clean energy carriers and technologies for meeting energy service needs for cooking and those enabled by electricity to support economic and human development”. According to Day et al. (2016), energy poverty is “a situation of inability to realize the essential capabilities as a result of insufficient access to affordable, reliable and safe energy services, and taking into account the alternative means of realizing these capabilities reasonably”. Another study defined energy poverty as “when the amount of energy used is lower than the minimum need to sustain a livelihood” (Barners et al., 2011). According to the IEA (2002), energy poverty is defined as a lack of access to commercial and clean fuels, electricity, efficient equipment, and high dependence on biomass, causing pollution. Energy Poverty Observatory 2021 defines energy poverty as the absence of vital energy services to individuals and households. Górska (2022) assumes that energy poverty is understood as a situation where heating costs exceed 10% of income. Winkler et al. (2011) define energy poverty as a state in which households spend a large share of income on energy-related expenditures. The EPEE (European Fuel Poverty and Energy Efficiency Project) defines energy poverty as “the lack of funds to maintain adequate heating at a fair price”. Energy poverty refers to people who experience a lack of thermal comfort in their homes or who must limit their consumption of basic goods to pay their energy bills (Boardman, 1991; Hills, 2011). Boardman 2010, and Walker et al. 2012 assume that household income is one of the most important determinants of energy poverty. There are two key areas that need to be distinguished, the first is energy poverty and the second is fuel poverty. The former mostly concerns developing economies and is associated with the inability to consume energy or no energy access. On the other hand, fuel poverty mostly affects wealthier countries and is associated with the inability to consume enough energy carriers for financial reasons (Primc, Dominko, Slabe-Erker, 2021). Income is important for both energy poverty and fuel poverty. In the context of income, GDP per capita in a given country is more important for energy poverty, while for fuel poverty the macroeconomic policy pursued in a given country (Nagaj, 2022a), as it determines the economic situation and the even distribution of income in a country. In addition to macroeconomic policy factors, fuel poverty is determined by energy prices, including fuel prices, and thus the situation on the fuel and energy markets. These two segments are considered crucial, and it is assumed that if fuel prices rise faster than incomes, this may be the cause of energy poverty. There are countries where low incomes and high energy prices, including fuels (gas, coal, oil) are key determinants of energy poverty, e.g. Poland.

This determinant is negatively reinforced by obsolete buildings, “black” energy carriers, coal heating, as well as by market conditions and economic and energy crises. Examples of countries where old buildings are energy inefficient, more exposed to cold spells and heat waves, Italy, Spain, Portugal, Greece, Malta (Górska, 2022). The problem of old buildings affects the entire world of Western Europe, especially historic buildings. Old buildings are also a problem in Poland, such buildings have inadequate sources of heating, and their modernization is expensive. All these measures are being counteracted in the context of the climate and energy policy, which may thus be a factor influencing the level of energy poverty in developing countries (Nagaj, 2020), and fuel poverty in developed countries (Hills, 2012).

Considering the different market and economic determinants of energy poverty, various categories of energy poverty and fuel poverty can be defined. The Polish Economic Institute (in Polish: PIE) singled out the four most important dimensions of energy poverty: fuel (income), structural, municipal and hidden (Report, Dec. 2023). The first (i) occurs when energy expenditure accounts for a large proportion of household expenditure; the second (ii) when poverty increases due to relatively high energy bills relative to income; (iii) when a household cannot meet its energy needs due to lack of access to adequate infrastructure, e. g. central heating, hot water from the network, or when dwellings and buildings require too much energy for modern construction; (iv) last the group concerns households that use coal-fired furnaces as their main source of heat in Poland. The European Observatory on Energy Poverty estimates that around 50 million households in the European Union live in conditions of energy poverty (Górska, 2022). Data for Poland (2022), according to the PRI report (December 2023), are as follows:

- income-related energy poverty: 16-30% of households,
- structural poverty affected 8-12% of households in Poland,
- communal poverty amounted to 3-5% of households,
- hidden poverty was between 13% and 16%.

Locally, the problem of energy poverty is more acute for rural dwellers than for urban dwellers. Most studies show that the problem of energy poverty is concentrated in rural areas due to lower incomes and lower energy efficiency of buildings (Baker et al., 2008; Rugkasa et al., 2007; Walker et al., 2012; Snell, Thomson, 2013; Illsley et al., 2007).

According to surveys – PEI Report (Dec., 2023), 68% of Polish households track fuel and energy prices, and 66% of saving households pointed to economic necessity as the reason for saving energy. In 2022, the proportion of EU citizens declaring that they are unable to heat their homes sufficiently increased from 6.9% to 9.3%. Subjective energy poverty in countries was: Bulgaria (22.5%), Cyprus (19.2%), Greece (18.7%), Lithuania (17.5%), Portugal (17.5%). Studying the relationship between social aggregates related to the national economy, such as income, consumption, investment, leads them to see energy poverty as a form of social consciousness. Ecological awareness has accompanied the development of humanity since time immemorial and its conditions are constantly changing, therefore it must be constantly built

(Gajdzik et al., 2023a). In a situation of energy poverty, there are attitudes (behaviors) that are not ecological, such as burning garbage. According to the PEI Report (Dec., 2023), about 7% of households in single-family homes in Poland admit to smoking garbage. The ecological awareness model can be a starting point for assessing energy poverty of individuals and social groups based on empirical knowledge. Therefore, from a sociological point of view, empirical research should capture the subjective determinants of energy poverty between different social categories and explain the reasons for this differentiation by determining the level of energy awareness of society, which may be e. g. coughing, occupation, age, etc.

Socio-economic determinants can be analysed in the study of energy poverty. The study (Lis et al., 2016) analysed the country's energy poverty in a multi-faceted way and concluded that high energy expenditure and low income (analysis of variance) are more determined by the socio-economic characteristics of households, and subjective energy poverty by the energy efficiency of buildings. As a result, the problem of excessive costs among the energy poor is concentrated in eastern Poland, and the problem of lack of thermal comfort in housing concerns residents of western voivodships. Differences in temperature and energy prices are an important determinant of regional differences in subjective energy poverty.

Recognising the importance of the determinants of energy poverty, which are both subjective and objective, actions are taken to, firstly, steer the actions of societies through support instruments, particularly financial and social (Nagaj, 2022b), and secondly, to make society aware of the importance of the problem and to promote an ecological culture and, consequently, to instill a sense of responsibility for global warming.

Fuel poverty, often called in the EU policy as energy poverty (understood as the share of households experiencing energy poverty in the total number of households measured on the basis of different indicators) has increased policy interest. Energy poverty has been enshrined in EU legislation. In its 2020 Recommendations to Member States, the European Commission presented a legislative package focusing on the diagnosis of energy poverty in Member States and its potential causes and consequences. Energy poverty was also an essential element of the EC Recommendation, 28.09.2021, on the implementation of the "energy efficiency first" principle and the Fit for 55 packages. Within the structures of EU organisations there is a Commission for the Protection of Energy Poverty and operates the Advisory Centre. In addition, energy poverty has been included in the European Green Deal as part of the renovation wave, the EU's 2030 building modernisation policy. In the Energy Efficiency Directive (2023), the European Commission committed Member States to improve energy efficiency in social housing and households of people affected by energy poverty. The programmes are funded by the Social Climate Fund (€86 billion foreseen for the period 2026-2032). More than 75% of the Fund's budget comes from emissions trading for buildings and road transport and fuels for ancillary sectors, which is to apply from 2027.

One of the determinants of energy poverty is recent global initiatives and refocused efforts towards widening access to modern energy carriers and technologies (related to cooking and electricity) for households in developing countries (Cordes, 2011; GEA, 2012). Traditional energy, i.e. “black” is replaced by new energy, i.e. “green” from RES. Regarding the Kyoto Protocol implementation, it was found for EU-27 that an increase in the share of renewable energy sources by one percentage point was related to a decrease of one percentage point in the greenhouse gases index. GDP per capita appeared to be an insignificant driver for reductions in per capita CO<sub>2</sub> emissions, while it proved to be important for economic efficiency models. Thus, increasing GDP per capita by 1000 USD reduces greenhouse gases by 7.1 g per EUR of GDP in EU-27 (Wang et al., 2023). In the last decade, the renewable energy share in the EU (%) has been growing year by year. In 2010, EU countries received slightly less 15% of energy from RES, now more than 20% of energy comes from RES (Eurostat). The increasing share of RES in energy sources is important for climate policy because it helps prevent global warming and the world (EU countries policy and other aware threats) is moving towards a “Net Zero” strategy. In each country, the energy consumption of households would, in general, increase CO<sub>2</sub> emissions, so the net zero strategy is the important and key direction of politics in many countries (Myszczyzyn, Suproń, 2022). Implementing this strategy requires investment in new industrial and energy technologies and new techniques for building and heating homes. The general tendency toward fast technological transformations could create the expectations that CO<sub>2</sub> emissions would be reduced on a global level and the consequences of climate change would be mitigated. Strongly popularized for more than a decade, the industry development concept called Industry 4.0, through technologies included in the pillars of Industry 4.0, can improve energy consumption and air quality. For example, Wolniak et al. (2020), analyzing on the energy efficiency in the steel sector in Poland, stated that there is a link between investment in modern technologies and energy efficiency in steel production. Gajdzik, Sroka, and Vveinhardt (2021) argue that increasing the technological investment in electric steel plants results in an energy consumption decrease in steel electric furnaces produced. The general tendency toward fast technological transformations could create the expectations that CO<sub>2</sub> emissions would be reduced on a global level and the consequences of climate change would be mitigated. However, the speed of the development of these technological transformations (such as renewable energy) must be examined in detail and whether those processes are sufficient to improve the environmental situation must be evaluated.

Climate policy, in its current radical form, is needed because, unfortunately, the climate is changing. This is particularly evident in the average annual temperature, which has risen by 1.3°C over the last 35 years. The European Union wants to ensure coherence between the “net zero” strategy and social problems, including energy poverty. The EU is working towards a reliable, affordable, and sustainable energy system, but there are still too many factors that vary from country to country. World equality and fairness politics aim to deliver sustainable

energy for all. The problem of energy poverty is amongst the United Nations Sustainable Development Goals (UN-SDGs). Goal seven of UN-SDGs mainly targets energy poverty through “ensuring access to affordable, reliable, sustainable and modern energy for all”.

Studies on the determinants of poverty are important for climate policy. At the macro-level of economies, energy poverty increases income poverty (Vera et al., 2005) and reduces the social and economic progress of societies (Acharya, Sadath, 2019; Sadath, Acharya, 2017; Khandker et al., 2012) and may constitute a barrier to the development of renewables (Gajdzik et al., 2023). At the micro-level, energy poverty is a barrier to education, a threat to health and well-being of the household members (Kanagawa, Nakata, 2006; Day et al., 2016; Hill, 2012).

### 3. Materials and Methods

In the previous section authors studied the nature of fuel poverty, how it is measured and how the phenomenon has been analysed in the literature. Many factors were found to influence energy poverty, but less so fuel poverty. Of those which, on the other hand, determine fuel poverty, we can divide into those which shape the level of costs of energy carriers and those which shape household incomes, especially disposable incomes. Furthermore, it was found that fuel poverty, depending on how it is measured, can be defined in diverse ways. Bearing in mind that the aim of this paper is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland, it is therefore important to specify the measurement methodology. For this purpose, the following stages of the study will be carried out:

The following stages of the study will be carried out:

1. Analysis of spending on energy carriers in Poland.
2. Estimation of the fuel poverty rate in Poland.
3. Development of a model to analyse the impact of energy and climate policies on fuel poverty.
4. Selection for analysis of factors influencing fuel poverty.
5. Searching data in databases.
6. Analysis of the impact of energy and climate policy (including macroeconomic policy instruments) on fuel poverty.

For the purposes of the analysis, the authors adopted the definition proposed by Boardman (2010), according to which fuel poverty concerns those people in households who spend at least 10% on the energy supplied. Based on this definition, the authors analyzed household expenses on energy carriers in Poland in the first stage of the research process. To determine this, the authors will calculate the average share of expenditure on energy carriers per person in households, and what this share is for each of the income quintile groups in households (per person).

The development of the average level of expenditure will allow us to assess how the burden on the entire society caused by expenditure on energy carriers has changed in the studied period.

However, additional analysis in income quintile groups will allow us to assess how the share of energy expenditure varied depending on income. The research period was 2005-2022, i.e., from the full year of Poland's functioning in the structures of the European Union. 2022 is because complete data is available until this year.

In the second stage of the research process, the fuel poverty rate in Poland was estimated. For the purposes of this analysis, it will be examined, based on the adopted definition of fuel poverty, in which income groups of society the share of expenditure on energy carriers exceeds 10%. The authors will be supported here by the distribution of the income structure for decile groups. Such income groups, in which the share of expenditure on energy carriers is above 10%, will be considered fuel poor. The calculation of fuel poverty will consist in summing up those fuel poor income groups. The authors will calculate fuel poverty for 36 periods in the studied period. This number of observations will guarantee the reliability of the statistical analysis in regression analysis.

The third stage of the research process is the developing model to analyse the impact of energy and climate policies on fuel poverty. As mentioned earlier, the aim of this study is to assess the impact of energy and climate policies on fuel poverty in Poland. For this reason, the model developed considers both energy and climate policies and the instruments associated with them, which can shape household spending on energy carriers. However, the literature review indicated that the level of fuel poverty is also influenced by macroeconomic policies and factors that affect the rate of GDP growth and its even distribution across society. Figure 1 shows a model for analysing the impact of energy and climate policies on fuel poverty.

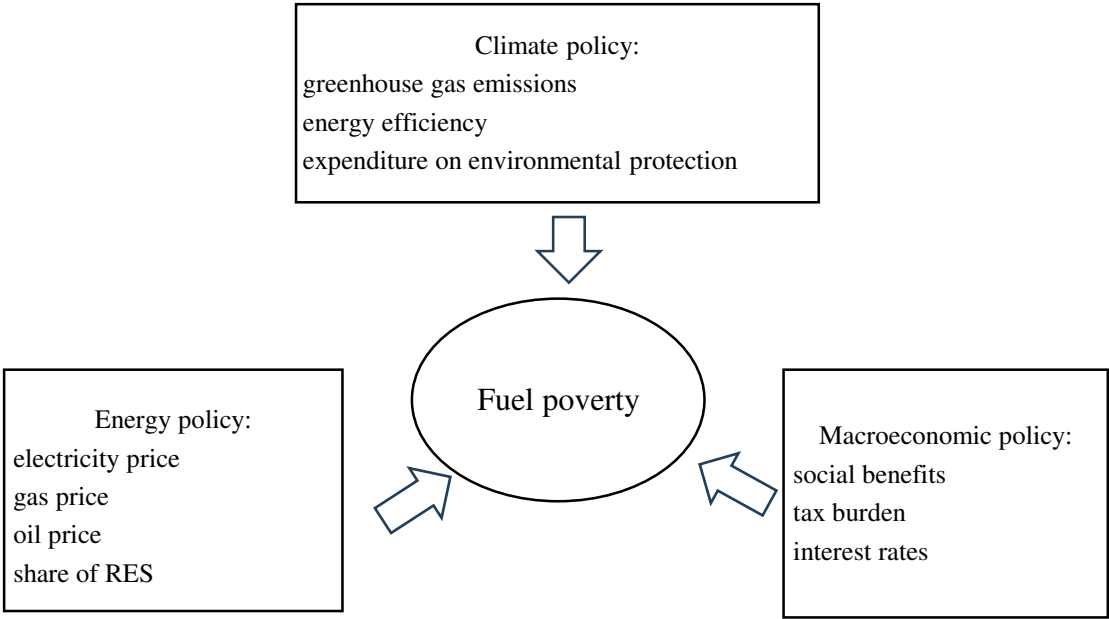


Figure 1. Model for analysing the impact of energy and climate policy on fuel poverty. Source: own method of analysis.

The next stage of the research process is the identification of factors influencing fuel poverty for regression analysis. The factors were divided into 3 groups of factors, i.e. related to energy policy, climate policy and macroeconomic policy. The literature review indicated that among the factors that may determine the level of fuel poverty are the level of expenditure on energy carriers and the level of income. Therefore, within the group belonging to climate policy, four factors have been identified that can influence fuel poverty. These are: electricity prices, gas prices, oil prices and the share of renewables in electricity consumption. The issue of the role of energy prices was highlighted by Recalde et al. (2019) and Górska (2022), indicating that they have an increasing effect on fuel poverty. Similarly, the role of the share of renewables is most often pointed out, although in this case the cases of countries with a large share of RES in the energy mix indicate that a large share of renewables acts negatively on energy prices. The next group of factors are those grouped under climate policy. In this group, the authors considered three factors: greenhouse gas emissions, energy efficiency and expenditure on environmental protection. In the case of the first factor, a lower level of this factor should have a negative impact on the cost of energy carriers and thus the level of fuel poverty. Meanwhile, in the case of energy efficiency, as pointed out by Snell and Thomson (2013) and Górska (2022). The higher it is, the lower the costs for heating should be, which should translate into lower levels of fuel poverty. In the case of expenditure on environmental protection, they have a similar effect to subsidies. The higher they are, the higher the charges passed on to end users' bills, which should increase the number of people susceptible to fuel poverty. The last group of factors are those affecting income and economic growth, i.e. relating to macroeconomic policy. As indicated by Sharma et al. (2019), fostering economic growth or pursuing macroeconomic policies (Nagaj, 2022a) that increase income should have a downward effect on the level of fuel poverty. Therefore, active fiscal policy instruments, i.e. an increase in social benefits and a reduction in taxes (Nagaj, 2022b), as well as expansionary monetary policy instruments, i.e. an increase in the money supply or a reduction in interest rates to finance investments, should theoretically stimulate a reduction in the level of fuel poverty in the country.

The authors then proceeded to search for data in databases, which are Eurostat, the Central Statistical Office and the OECD. Considering the availability of data and ensuring an equal time range for all variables, the authors decided on the period 2005-2022.

The final step in the research process is the analysis of the impact of energy and climate policy on fuel poverty. Having developed a model for analysing the impact of energy and climate policy on fuel poverty, it is necessary to proceed to the creation of a multiple regression model. In the model for analysing fuel poverty in Poland (independent variable Y), the authors proposed 10 independent variables, of which the first four relate to the impact of energy policy, the next three to the impact of climate policy and the last three to the impact of macroeconomic policy. These include:



- $X_1$  – Electricity prices for household consumers in Poland - Consumption from 1000 kWh to 2499 kWh (Data source: Eurostat: *Electricity prices for household consumers - bi-annual data*).
- $X_2$  – Gas prices for household consumers in Poland - band D2 (Data source: Eurostat: *Gas prices for household consumers - bi-annual data*).
- $X_3$  – Price of Euro 95 petrol in Poland (Data source: Bankier.PL: *Wskaźniki makroekonomiczne: Euro 95 (Polska)*).
- $X_4$  – Share of renewable energy in gross final energy consumption in Poland (Data source: Eurostat: *Share of renewable energy in gross final energy consumption by sector*).
- $X_5$  – Total net greenhouse gas emissions in Poland - excluding memo items and including international aviation – tonnes per capita (Data source: Eurostat: *Net greenhouse gas emissions*).
- $X_6$  – Final energy efficiency in Poland - million tonnes of oil equivalent (Data source: Eurostat: *Energy efficiency*).
- $X_7$  – General government expenditure on environmental protection in Poland - in mln euro (Data source: Eurostat: *General government expenditure by function*).
- $X_8$  – Social benefits to households as % of GDP in Poland (Data source: OECD: *Social benefits to households (indicator)*).
- $X_9$  – Tax revenue as % of GDP in Poland (Data source: OECD: *Tax revenue (indicator)*).
- $X_{10}$  – Interest rate of 10-years government bonds in Poland (Data source: OECD: *Long-term interest rates (indicator)*).

Based on the proposed model, a multiple regression equation was developed:

$$Y = a + b_i \cdot X_n + \varepsilon, \quad (1)$$

where:

$Y$  – fuel poverty rate in Poland (dependent variable);

$a$  – constant parameter,  $Y$  intercept;

$b_i$  – coefficients of the regression function for independent variables ( $i = 1, \dots, 10$ );

$X_1, X_2, \dots, X_n$  – independent variables affecting the dependent ( $n = 1, \dots, 10$ ).

$\varepsilon$  – random error component.

Statistical verification will be counted at a statistical significance coefficient of 0.05, and calculations will be made using Statistica 13.3 software (TIBCO Software, Dublin, Ireland).

## 4. Results

The authors' first calculation activity in this section was to calculate what the average share of expenditure on energy carriers and in various income groups of households in Poland is and based on it the level of fuel poverty in the studied period. The results of these calculations are presented in Table 1.

**Table 1.**

*Share of expenditure on energy carriers in disposable income per person in households and the fuel poverty rate in Poland in 2005-2022*

Specification	For average income	Share of expenditure on energy carriers in disposable income (in %)					Fuel poverty rate (in %)
		in Quintile groups					
Year		1	2	3	4	5	
2005	10.36	31.02	16.96	12.32	9.08	4.99	34.9
2006	10.74	32.14	17.58	12.77	9.41	5.17	35.1
2007	9.46	27.44	15.32	11.29	8.43	4.54	35.7
2008	9.57	28.08	15.27	11.29	8.45	4.66	35.9
2009	10.04	29.90	16.02	11.81	8.79	4.90	35.9
2010	10.30	29.62	16.63	12.26	9.13	4.98	35.7
2011	10.49	31.91	16.79	12.37	9.25	5.08	35.6
2012	10.32	31.78	16.65	12.16	9.07	4.98	35.5
2013	10.34	33.08	16.73	12.12	9.08	4.97	35.5
2014	9.56	29.60	15.19	11.04	8.27	4.71	36.1
2015	9.30	27.99	14.58	10.70	8.08	4.61	36.4
2016	8.55	22.40	12.74	9.72	7.49	4.42	28.9
2017	8.10	19.64	11.97	9.26	7.21	4.23	29.8
2018	7.46	18.73	10.98	8.49	6.64	3.87	21.4
2019	6.93	17.75	10.10	7.80	6.12	3.63	21.4
2020	6.62	19.13	9.64	7.37	5.81	3.42	13.3
2021	6.97	22.32	10.23	7.81	6.11	3.52	19.9
2022	7.64	25.58	11.21	8.49	6.64	3.86	19.5

Source: own calculations based on GUS, *Budżety gospodarstw domowych [Household budgets]*, GUS, Warszawa. Publications in 2006-2022.

Analysing the average level of expenditure on energy carriers, it should be noted that, apart from short periods of growth in 2008-2011 and 2021-2022, their share in household income is declining. On average over the whole period, this share has fallen by 2.72 percentage points. In general, the trends are similar in all income groups in Poland and these declines in successive income decile groups (increasing) were (in percentage points) respectively: 5.44, 5.76, 3.83, 2.44, 1.12. It should also be noted that greater variations in the weight of these expenditures in the household budget were observed for those with lower incomes than for those with the highest incomes. Among those in the first income decile group, the difference between the highest share of expenditure on energy carriers and the lowest in the period under study was as much as 15.33 percentage points, while in the second income decile group it was 7.93 percentage points, in the third decile group 5.40 percentage points, in the fourth and fifth decile groups 3.60 and 1.75 percentage points respectively. The results also indicate that fuel

poverty, i.e., the share of expenditure above 10 per cent of disposable income, in the studied period affected all those with the lowest incomes, i.e. from the 1st and 2nd decile groups and, until 2015, also from the third income quintile group. This was reflected with the fuel poverty rate in Poland, which increased with minor fluctuations until 2015, and from 2016 onwards a decrease in the rate was observed, after which the fuel poverty rate in Poland increased again in 2021-2022. It is worth noting that 2016 coincides with the period when new social benefits were introduced in Poland for people with children, the so-called '500+ programme'. This state aid mainly concerned the poorest people. This is reflected in a comparison of the amount of the share of expenditure on energy carriers in income among the poorest (first decile group) and the richest (fifth decile group). Between 2005 and 2015, this ratio among the poorest was 6.0-6.7 times higher than for the richest. In 2016, however, it fell to 5.1, and by 2019 it had fallen to 4.9. From 2020, it rose again to reach 6.6 in 2022. This means that spending on energy in the period under review was a decreasing burden on household budgets, but the poorest section of the population was less affected by these decreases. For this reason, the fuel poverty rate in Poland has been increasing faster again in the recent period, although it has not approached the levels of the 2005-2015 period.

Knowing how the fuel poverty rate evolved over the period under study (Table 1), we proceeded to analyse the impact of energy and climate policies on this phenomenon. For this purpose, before starting the regression analysis, a correlation analysis of the dependent variable with the independent variable was analysed. This will allow us to determine which factors are statistically significantly correlated with the fuel poverty rate in Poland and thus can be subjected to regression analysis. Correlation results show Table 2.

**Table 2.**

*Correlation analysis between the dependent variable and potential determinants of fuel poverty level in Poland*

Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Y	-0.72*	-0.22	-0.30	-0.86*	-0.06	-0.88*	-0.57*	-0.80*	-0.81*	0.59*

\* independent variables that are statistically significantly correlated with the dependent variable at  $p < 0.05$ .

Source: own work.

The results of the correlation analysis showed that fuel poverty level in Poland is not statistically significantly correlated with gas price for household consumers, petrol price in Poland, and level of greenhouse gas emissions. On the other hand, in terms of energy policy, a negative strong correlation is observed with electricity price for household consumers and the level of share of renewable energy in gross final energy consumption in Poland. In terms of climate policy in Poland, a strong correlation is observed with the level of energy efficiency and an average strength of the relationship with general government expenditure on environmental protection. However, it is worth noting that all macroeconomic policy instruments that also determine income in Poland are also correlated with the fuel poverty level in Poland.

When proceeding to the regression analysis, co-correlation between the independent variables was also checked. It was found that there was a strong correlation between variables X1 and the other independent variables, so these variables were excluded from further analysis.

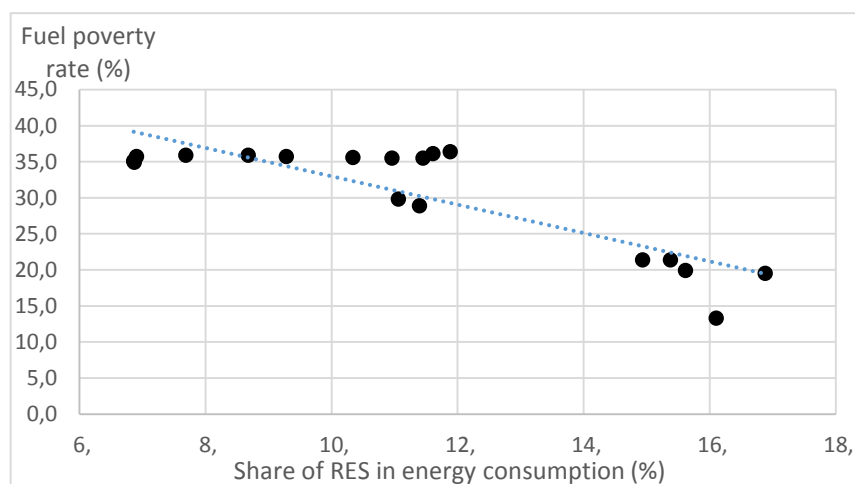
In addition, regression analysis indicated that variable X6 does not have a statistically significant effect at  $p < 0.05$  on fuel poverty level in Poland. For the remaining variables, i.e. X4, X7, X8, X9, X10, regression analysis was conducted to determine their impact on fuel poverty level in Poland. The results of the regression analysis are presented in Table 3.

**Table 3.**

*Results of regression analysis for the dependent variable fuel poverty level in Poland for semi-annual data over the period 2005-2022*

	<b>Coefficients <math>b^*_i</math></b>	<b>Standard Error of <math>b^*_i</math></b>	<b>Coefficients <math>b_i</math></b>	<b>Standard Error of <math>b_i</math></b>	<b>t-statistic</b>	<b>p-value</b>
N = 36	Regression statistics: R = 0.9830; R <sup>2</sup> = 0.9664; Adjusted R <sup>2</sup> = 0.9607; F(5,30) = 172.33; p < 0.0000; Standard error: 1.4921					
Constant			174.1891	8.9366	19.4917	0.0000
Variable X <sub>4</sub>	-0.8410	0.0967	-1.9381	0.2228	-8.6970	0.0000
Variable X <sub>7</sub>	0.2175	0.0747	0.0027	0.0009	2.9114	0.0067
Variable X <sub>8</sub>	-0.3719	0.0467	-3.9579	0.4971	-7.9622	0.0000
Variable X <sub>9</sub>	-0.3738	0.0444	-1.8577	0.2204	-8.4270	0.0000
Variable X <sub>10</sub>	-0.3343	0.0675	-1.6243	0.3282	-4.9488	0.0000

The results of regression analysis indicated that the fuel poverty rate in Poland was influenced by 5 variables, i.e. share of renewable energy in gross final energy consumption (X4), expenditures on environmental protection (X7), level of social benefits in Poland (X8), tax burden (X9), and interest rates in Poland (X10). It means that, in terms of energy policy, only the level of renewables has a statistically significant impact, while in terms of climate policy, expenditure on environmental protection. In the first case, the impact is negative, while in the second case it is positive. The positive impact of environmental expenditure is due to the fact that it is covered by energy charges. Macroeconomic policy instruments were also found to play a key role in stimulating revenues. Regression analysis indicated that when analysing the impact of energy and climate policies, with the additional impact of macroeconomic policies, renewables were found to play the most significant role. It is RES, through their expenditures and charges included in energy bills that have the greatest impact on fuel poverty in Poland.



**Figure 1.** Relationship between fuel poverty rate and the share of RES in the energy mix in Poland.

Source: own study.

As Figure 1 shows, the relationship between the two variables is negative, confirming the conclusions about the negative impact of RES on fuel poverty. This is the factor that most strongly determines the fuel poverty rate in Poland. However, it is worth noting that this impact is not uniform, which may suggest that this impact is not similar in all income groups.

Therefore, when analysing the relationships presented above, the authors decided to additionally investigate how the influence of the examined factors on the level of expenditure on energy carriers is shaped in the individual income decile groups. Table 4 presents the results of the regression analysis for these variables.

**Table 4.**

*Results of regression analysis for the share of expenditures on energy carriers in disposable income by income decile group in Poland*

	<b>Coefficients <math>b^*_i</math></b>	<b>Standard Error of <math>b^*_i</math></b>	<b>Coefficients <math>b_i</math></b>	<b>Standard Error of <math>b_i</math></b>	<b>t-statistic</b>	<b>p-value</b>
For Q1	Regression statistics: $R = 0.8871$ ; $R^2 = 0.7869$ ; Adjusted $R^2 = 0.7412$ ; $p < 0.0001$ ; Standard error: 0.0265					
Constant			0.8388	0.1613	5.2014	0.0001
Variable $X_4$	-0.8474	0.2166	-0.0133	0.0034	-3.9115	0.0016
Variable $X_7$	0.5998	0.1916	0.0001	0.0000	3.1313	0.0074
Variable $X_9$	-0.4809	0.1513	-0.0163	0.0051	-3.1786	0.0067
For Q2	Regression statistics: $R = 0.9356$ ; $R^2 = 0.8753$ ; Adjusted $R^2 = 0.8587$ ; $p < 0.0000$ ; Standard error: 0.0104					
Constant			0.4932	0.0620	7.9581	0.0000
Variable $X_4$	-0.5631	0.1110	-0.0047	0.0009	-5.0738	0.0001
Variable $X_9$	-0.4921	0.1110	-0.0089	0.0020	-4.4334	0.0005
For Q3	Regression statistics: $R = 0.9447$ ; $R^2 = 0.8925$ ; Adjusted $R^2 = 0.8782$ ; $p < 0.0000$ ; Standard error: 0.0065					
Constant			0.3393	0.0384	8.8337	0.0000
Variable $X_4$	-0.5766	0.1013	-0.0032	0.0006	-5.5956	0.0001
Variable $X_9$	-0.4886	0.1030	-0.0059	0.0012	-4.7412	0.0003
For Q4	Regression statistics: $R = 0.9443$ ; $R^2 = 0.8916$ ; Adjusted $R^2 = 0.8772$ ; $p < 0.0000$ ; Standard error: 0.0043					
Constant			0.2396	0.0257	9.3272	0.0000
Variable $X_4$	-0.5587	0.1035	-0.0021	0.0004	-5.3991	0.0001
Variable $X_9$	-0.5066	0.1035	-0.0041	0.0008	-4.8962	0.0002

Cont. table 5.

For Q5	Regression statistics: R = 0.8619; R2 = 0.7429; Adjusted R2 = 0.7268; p < 0.0000; Standard error: 0.0030					
Constant			0.1540	0.0161	9.5754	0.0000
Variable X <sub>9</sub>	-0.8619	0.1267	-0.0032	0.0005	-6.7993	0.0000

The results of the regression analysis for the share of expenditure on energy carriers in the income of individual income groups of households in Poland indicated that the more affluent households, the more crucial factor is the tax burden. On the other hand, the lower the income of households, the more key role is played by energy policy in the form of the share of RES in the energy mix and, among the poorest people, expenditure on environmental protection. Thus, the results of the analysis indicate that energy and climate policies influence the level of fuel poverty in Poland, while when analysed from the perspective of the share of expenditures on energy carriers in household's income, it was found that this influence occurs mainly among those with the lowest income. The higher the income, the more important the role of taxes related to macroeconomic policy.

## 5. Conclusions

The aim of the article was to assess the importance of climate and energy policy in reducing fuel poverty on the example of Poland. The authors examined factors of climate and energy policy influencing the fuel poverty rate in Poland. To achieve this objective, the authors attempted to answer three research questions. Within the framework of RQ1, the authors estimated the share of expenditure on energy carriers in household income and what is the fuel poverty rate in Poland in 2005-2022. The analysis indicated that, despite fluctuations, fuel poverty in Poland falls over the period studied. Admittedly, this phenomenon has increased in the last two years, but the maximum levels of the pre-2016 period have still not been reached. By conducting a literature review, the authors also selected the basic determinants of fuel poverty and thus proceeded to answer RQ2, which reads as follows: What are determinants of the fuel poverty rate in Poland? To this end, an analysis model was developed and a multiple regression analysis was carried out. The analysis indicated that these factors are: renewable energy sources, or more precisely their share in the energy-mix, the scale of energy efficiency, the next is the size of expenditures on environmental protection, the scale of social expenditures realised by the government and the tax burden, which generate revenues for the realisation of social policy, and the last is interest rates in Poland, which are one of the instruments of macroeconomic policy. Thus, the results of the analysis confirmed the findings indicated in the literature (Rodriguez-Alvarez, Llorca, Jamasb, 2021), that income and income growth policies are one of the most important determinants of the scale of fuel poverty in a country.

By answering the last RQ3, the authors gave an answer to the main objective of the study. It was found that energy and climate policy have an impact on fuel poverty in Poland, however, the lowest income earners are most affected. It can be presumed that the reason for this is that the effects of these policies are implemented in the form of fixed charges included in household energy bills.

The article has some research limitations. The main one is the lack of more detailed data on household incomes, i.e. by deciles, which would allow for more accurate estimates of fuel poverty. However, despite this limitation, the authors succeeded in accurately estimating the phenomenon under study and identifying the impact of climate and energy policies. In the future, it would be worthwhile to carry out similar analyses for other European countries.

## References

1. Acharya, R.H., Sadath, A.C. (2019). Energy poverty and economic development: household level evidence from India. *Energy Building*, Vol. 183, 785-91. <https://doi.org/10.1016/j.enbuild.2018.11.047>.
2. Baker, W., White, V., Preston, I. (2008). *Quantifying rural fuel poverty. Report of Centre for Sustainable Energy for Eaga Partnership Charitable Trust*. CSE, Bristol.
3. Bankier.PL, *Wskaźniki makroekonomiczne: Euro 95 (Polska) [Macroeconomic indicators: Euro 95 (Poland)]*. Retrieved from: <https://www.bankier.pl/gospodarka/wskazniki-makroekonomiczne/eu-95-pol>, 1.06.2024.
4. Barnes, D.F., Khandker, S.R., Samad, H.A. (2011). Energy poverty in rural Bangladesh. *Energy Pol.*, 39, pp. 894-904, <https://doi.org/10.1016/j.enpol.2010.11.014>.
5. Boardman, B. (1991). *Fuel Poverty: From Cold Homes to Affordable Warmth*. London: Belhaven Press.
6. Boardman, B. (2010). *Fixing fuel poverty: challenges and solutions*. London/New York: Earthscan, pp. 1-272.
7. Cordes, L. (2011). *Igniting Change: A Strategy for Universal Adoption of Clean Cookstoves and Fuels*. Global Alliance for Clean Cookstoves (GACC).
8. Day, R., Walker, G., Simcock, N. (2016). Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy*, Vol. 93, pp. 255-264.
9. EREE. *European Fuel Poverty and Energy Efficiency Project*, [https://www.prekarite-energie.org/IMG/pdf/EPEE\\_Project\\_presentation.pdf](https://www.prekarite-energie.org/IMG/pdf/EPEE_Project_presentation.pdf)
10. European Commission. *European Green Deal*. [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal\\_en](https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en), 8.02.2024.

11. Eurostat. *Electricity prices for household consumers - bi-annual data*. Retrieved from: [https://ec.europa.eu/eurostat/databrowser/view/nrg\\_pc\\_204/default/table?lang=en&category=nrg.nrg\\_price.nrg\\_pc](https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_204/default/table?lang=en&category=nrg.nrg_price.nrg_pc), 30.05.2024.
12. Eurostat. *Energy efficiency*. Retrieved from: [https://ec.europa.eu/eurostat/databrowser/view/nrg\\_ind\\_eff\\_\\_custom\\_9531378/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_eff__custom_9531378/default/table?lang=en), 26.01.2024.
13. Eurostat. *Gas prices for household consumers - bi-annual data*. Retrieved from: [https://ec.europa.eu/eurostat/databrowser/view/nrg\\_pc\\_202/default/table?lang=en&category=nrg.nrg\\_price.nrg\\_pc](https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_202/default/table?lang=en&category=nrg.nrg_price.nrg_pc), 30.05.2024.
14. Eurostat. *General government expenditure by function (COFOG)*. Retrieved from: [https://ec.europa.eu/eurostat/databrowser/view/gov\\_10a\\_exp\\_\\_custom\\_11105433/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/gov_10a_exp__custom_11105433/default/table?lang=en), 28.04.2024.
15. Eurostat. *Net greenhouse gas emissions*. [https://ec.europa.eu/eurostat/databrowser/view/sdg\\_13\\_10\\_\\_custom\\_11104852/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10__custom_11104852/default/table?lang=en), Retrieved from: 28.04.2024.
16. Eurostat. *Share of renewable energy in gross final energy consumption by sector*. Retrieved from: [https://ec.europa.eu/eurostat/databrowser/view/sdg\\_07\\_40/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en), 26.04.2024.
17. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W.W., Romanyshyn, T. (2023b). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies*, Vol. 16, No. 21, 7364. <https://doi.org/10.3390/en16217364>.
18. Gajdzik, B., Wolniak, R., Nagaj, R., Žuromskaitė-Nagaj, B., Grebski, W.W. (2024b). The Influence of the Global Energy Crisis on Energy Efficiency: A Comprehensive Analysis. *Energies*, Vol. 17, No. 4, 947. <https://doi.org/10.3390/en17040947>.
19. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W.W. (2023a). Energy Behaviors of Prosumers in Example of Polish Households. *Energies*, 16, 3186.
20. Gajdzik, B., Nagaj, R., Wolniak, R., Bałaga, D., Žuromskaite, B., Grebski, W.W. (2024a). Renewable Energy Share in European Industry: Analysis and Extrapolation of Trends in EU Countries. *Energies*, 17, 2476. <https://doi.org/10.3390/en17112476>.
21. Gajdzik, B., Sroka, W., Vveinhardt, J. (2021). Energy Intensity of Steel Manufactured Utilising EAF Technology as a Function of Investments Made: The Case of the Steel Industry in Poland. *Energies*, Vol. 14, 5152.
22. GEA (2012). *Global Energy Assessment. Toward a Sustainable Future*. Cambridge, UK / New York, NY, USA / Laxenburg, Austria, Cambridge University Press, International Institute for Applied Systems Analysis; ISBN 9781 10700 5198 hardback; 9780 52118 2935 paperback, [www.globalenergyassessment.org](http://www.globalenergyassessment.org).
23. González-Eguino, M. (2015). Energy poverty: an overview. *Renewable & Sustainable Energy Reviews*, Vol. 47, No. C, pp. 377-385. <https://doi.org/10.1016/j.rser.2015.03.013>.
24. Górská, A. (2022). Wpływ pandemii COVID-19 na ubóstwo energetyczne w UE. Impact of the COVID-19 Pandemic on Energy Poverty in the EU. *PP*, 1(23), 109-127, DOI : 10.14746/pp.2022.28.1.8



25. GUS. *Macroeconomic indicators*. Retrieved from: <https://stat.gov.pl/wskazniki-makroekonomiczne/>, 30.05.2024.
26. Hills, J. (2011). Fuel poverty. The problem and its measurement. *CASE report, 69*. London: Department of Energy and Climate Change.
27. Hills, J. (2012). *Getting the measure of fuel poverty: final report of the fuel poverty review*. London.
28. IEA (2002). *World energy outlook. Policy model in energy use*, 21. <https://iea.blob.core.windows.net/assets/11bc7b29-db2a-46fb-a515-1f5e7d2c7dfd/WorldEnergyOutlook2002.pdf>
29. Illsley, B., Jackson, T., Lynch, B. (2007). Addressing Scottish rural fuel poverty through a regional industrial symbiosis strategy for the Scottish forest industries sector. *Geoforum*, 38, pp. 21-32.
30. Kanagawa, M., Nakata, T. (2006). *Socio-economic impacts of energy poverty alleviation in rural areas of developing countries*. Proc. 26th USAEE/IAEE North Am. Conf 2006, 24-7. Ann Arbor, MI, USA.
31. Khandker, S.R., Barnes, D.F., Samad, H.A. (2012). Are the energy poor also income poor? Evidence from India. *Energy Policy*, vol. 47, 1-12. <https://doi.org/10.1016/j.enpol.2012.02.028>.
32. Kyprianou, I., Serghides, D.K., Varo, A., Gouveia, J.P., Kopeva, D., Murauskaite, L. (2019). Energy poverty policies and measures in 5 EU countries: A comparative study. *Energy & Buildings*, Vol. 196, pp. 46-60. <https://doi.org/10.1016/j.enbuild.2019.05.003>
33. Leeuwen, J. van, Monios, J. (2022). Decarbonisation of the shipping sector – Time to ban fossil fuels? *Marine Policy*, vol. 146, 105310, <https://doi.org/10.1016/j.marpol.2022.105310>.
34. Lis, M., Miazga, A., Sałach, K. (2016). Zróżnicowanie ubóstwa energetycznego w Polsce. *IBS Working paper, 19*. Warszawa.
35. Moore, R. (2012). Definitions of fuel poverty: implications for policy. *Energy Policy*, Vol. 49, pp. 19-26. <https://doi.org/10.1016/j.enpol.2012.01.057>.
36. Myszczyżyn, J., Suproń, B. (2022). Relationship among Economic Growth, Energy Consumption, CO<sub>2</sub> Emission, and Urbanization: An Econometric Perspective Analysis. *Energies*, 15, 9647.
37. Nagaj, R. (2020). Polityka klimatyczno-energetyczna a ubóstwo energetyczne w Polsce [Climate and energy policies and its impact on energy poverty in Poland]. *Rynek Energii*, Vol. 146, No. 1, pp. 3-10.
38. Nagaj, R. (2022a). Macroeconomic Policy Versus Fuel Poverty in Poland—Support or Barrier. *Energies*, Vol. 15, No. 13, 4710. <https://doi.org/10.3390/en15134710>
39. Nagaj, R. (2022b). Polityka fiskalna a ubóstwo energetyczne w Polsce [Fiscal policy and fuel poverty in Poland]. *Rynek Energii*, Vol. 158, No. 1, pp. 3-10.

40. OECD (2021). *Social benefits to households (indicator)*. Retrieved from: <https://doi.org/10.1787/423105c6-en>, 30.05.2024.
41. OECD (2024). *Long-term interest rates (indicator)*. Retrieved from: <https://doi.org/10.1787/662d712c-en>, 30.05.2024.
42. OECD (2024). *Tax revenue (indicator)*. Retrieved from: <https://doi.org/10.1787/d98b8cf5-en>, 30.05.2024.
43. Pachauri, Sh., Rao, N.D. (2013). Gender impacts and determinants of energy poverty: are we asking the right questions? *Current Opinion in Environmental Sustainability*, No. 5, pp. 205-215, <http://dx.doi.org/10.1016/j.cosust.2013.04.006>.
44. Polish Economic Institute (Polski Instytut Ekonomiczny) (2023). *Raport 2023: Cztery oblicza ubóstwa energetycznego Polskie gospodarstwa domowe w czasie kryzysu 2021-2023. Ubóstwo energetyczne*. Warszawa. [https://pie.net.pl/wp-content/uploads/2024/02/PIE-Raport\\_Ubostwo\\_energetyczne\\_2023.pdf](https://pie.net.pl/wp-content/uploads/2024/02/PIE-Raport_Ubostwo_energetyczne_2023.pdf)
45. Primc, K., Dominko, M., Slabe-Erker, R. (2021). 30 years of energy and fuel poverty research: A retrospective analysis and future trends. *Journal of Cleaner Production*, Vol. 301, 127003. <https://doi.org/10.1016/j.jclepro.2021.127003>.
46. Recalde, M., Peralta, A., Oliveras, L., Tirado-Herrero, S., Borrell, C., Palencia, L., Gotsensb, M., Artazcoz, L., Mari-Dell'Olmo, M. (2019). Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health. *Energy Policy*, Vol. 133, No. C, 110869. DOI: 10.1016/j.enpol.2019.07.005.
47. Rodriguez-Alvarez, A., Llorca, M., Jamasb, T. (2021). Alleviating energy poverty in Europe: Front-runners and laggards. *Energy Economics*, Vol. 103, 105575. <https://doi.org/10.1016/j.eneco.2021.105575>.
48. Rugkasa, J., Shortt, N.K., Boydell, L. (2007). The right tool for the task: 'boundary spanners' in a partnership approach to tackle fuel poverty in rural Northern Ireland. *Health and Social Care in the Community*, 15(3), pp. 221-230.
49. Sadath, A.C., Acharya, R.H. (2017). Assessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: empirical evidence from households in India. *Energy Policy*, 102, 540-50. <https://doi.org/10.1016/j.enpol.2016.12.056>
50. Sałach, K., Lewandowski, P. (2018). *Ubóstwo energetyczne w Polsce 2012-2016: Zmiany w czasie i charakterystyka zjawiska [Energy poverty in Poland 2012-2016: Changes in time and characteristics of the phenomenon]*. Warszawa: IBS. <https://ibs.org.pl/publications/ubostwo-energetyczne-w-polsce-2012-2016-zmiany-w-czasie-i-charakterystyka-zjawiska/>, 12.06.2024.
51. Schumacher, D. (1985). *Energy: Crisis or opportunity? An Introduction to Energy Studies*. London: Palgrave Macmillan.

52. Sharma, V., Han, P., Sharma, V.K. (2019). Socio-economic determinants of energy poverty amongst Indian households: A case study of Mumbai, *Energy Policy*, Vol. 132, pp.1184-1190.
53. Snell C., Thomson H. (2013). Reconciling fuel poverty and climate change policy under the Coalition government: Green deal or no deal. *Social Policy Review*, Vol. 25, pp. 23-45.
54. Ulucak, R., Sari, R., Erdogan, S., Castanho, A.R. (2021). Bibliometric Literature Analysis of a Multi-Dimensional Sustainable Development Issue: Energy Poverty, *Sustainability*, No. 13, Vol. 9780.
55. Vera, I.A., Langlois, L.M., Rogner, H-H, Jalal, A.I., Toth, F.L. (2005). Indicators for sustainable energy development: an initiative by the international atomic energy agency. *Nat Resour Forum*, 29, pp. 274-83. Wiley Online Library.
56. Walker, R., McKenzie, P., Liddell, C., Morris, C. (2012). Area-based targeting of fuel poverty in Northern Ireland: An evidenced-based approach. *Applied Geography*, 34, pp. 639-649.
57. Wang, W., Melnyk, L., Kubatko, O., Kovalov, B., Hens, L. (2023). Economic and Technological Efficiency of Renewable Energy Technologies Implementation. *Sustainability*, 15, 8802. <https://doi.org/10.3390/su15118802>.
58. Winkler, H., Simões, A.F., Rovere, EL la, Alam, M., Rahman, A., Mwakasonda, S. (2011). Access and affordability of electricity in developing countries. *World Dev.*, Vol. 39, pp. 1037-50, <https://doi.org/10.1016/j.worlddev.2010.02.021>.
59. 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*, Vol. 13, 2867.



## IMPACT OF PHOTOVOLTAICS DEVELOPMENT ON ELECTRICITY GRIDS – POSSIBLE SCENARIOS ON THE EXAMPLE OF POLAND AND GERMANY

Kamil NAWROCKI<sup>1</sup>, Alfred BŁASZCZYK<sup>2</sup>, Alina MATUSZAK-FLEJSZMAN<sup>3\*</sup>

<sup>1</sup> SMA Solar Technology AG, Niestetal, Germany; nawrocki@sma.de, ORCID: 0009-0000-5711-9545

<sup>2</sup> Institute of Quality Science, Poznań University of Economics & Business, Poland;  
Alfred.Blaszczyk@ue.poznan.pl, ORCID: 0000-0001-5644-6210

<sup>3</sup> Institute of Quality Science, Poznań University of Economics & Business, Poland;  
Alina.Matuszak-Flejszman@ue.poznan.pl, ORCID: 0000-0001-5588-9343

\* Correspondence author

**Purpose:** The purpose of the article is to analyze the reduction of PV generation in Germany and Poland and possible ways to solve it.

**Design/methodology/approach:** The analysis was conducted using available secondary data and literature. The study's time scope is from Q1 2013 to Q1 2024.

**Findings:** The answer to the challenges is the continuous modernization of the power grid towards smart grids. A necessary element is increasing the flexibility of the power system through the development of energy storage and new grid services.

**Research limitations/implications:** Limitations apply to the Polish and German markets.

**Practical implications:** Based on the analysis of the Polish and German markets, the authors proposed possible scenarios for the development of PV networks and possible actions aimed at continuous modernization of the power grid towards smart grids by conducting programs to support the development of national network infrastructure.

**Social implications:** Reducing the negative impact on the environment and identifying opportunities to build smart grids.

**Originality/value:** Few studies have examined the effects of integrating RES into power grids. The research gap detailed the analysis of grid deactivation cases in Poland and Germany. The two markets were compared due to their geographical proximity and their significant differences.

**Keywords:** PV shutdown, grid forming, re-dispatch, Smart Grid, non-market reductions.

**Category of the paper:** Research paper; Viewpoint.

## 1. Introduction

In recent years, we have seen rapid photovoltaic (PV) growth in Europe, including Poland. The total installed PV capacity in Europe at the end of 2023 was 263 GW, and available scenarios forecast further growth. With the rapid growth of PV, there are side effects that are increasingly visible and felt by PV market participants. More broadly, PV systems and RES technologies significantly affect the reliability and quality of power supply because they are stochastic, uncontrolled, variable and primarily unpredictable. In addition, most of the commonly favored RES technologies do not provide inertial support, making the grid vulnerable to failures. Meeting these challenges requires additional auxiliary support systems and, more importantly, monitoring and communication networks. The current grid needs to be modernized in various operational aspects related to the network, from generation, transmission (Vita et al., 2016; Adewumi et al., 2022; Zafeiropoulou et al., 2022) and distribution, including operations, to power system planning. The above efforts are aimed at preserving the flexibility of the grid, including transformation and diversification (Ahmed et al., 2023; Ahmed et al., 2022; Salman et al., 2021) towards facilitating RES integration.

The modern electricity grid around the world has evolved over the past decades. It delivers electricity from a central generating unit through transformers and various levels of the transmission grid. In Poland, the electricity grid was mainly based on conventional coal-fired electrons. The rated capacity of such central generating units reaches thousands of megawatts (MW). The largest conventional power plant in Europe is 5102 MW in Belchatow. Conventional generating units are connected to the transmission grid with a good communication framework. This allows the power system to operate acceptably with sufficient security and reliability while maintaining a coordinated energy market (Kabalci, 2016). The distribution network built to serve central generating units has a high level of complexity but a relatively small number of integrated communication links. This makes it difficult to use modern distribution network control technologies at the local level. On the other hand, existing communication links mostly lack real-time monitoring to regulate the power quality of large loads realistically.

Modern technological advances in communication systems allow for much more monitoring and coordination. This, in turn, allows for better network monitoring, controllability, and flexibility while lowering operating costs, which aligns with the modern trend of RES integration.

Therefore, the concept of creating a Smart Grid (SG) provides an opportunity to implement information and communication technologies (ICT) to modernize the power grid system (Anjana, Shaji, 2018). However, the large-scale network of current power systems imposes the need to establish an optimized SG, which is justified given the network's multifaceted requirements in terms of communication, sustainability, interoperability and power quality in

order to maintain the technical and economic importance of the entire network (José de Castro Vieira, Tapia Carpio, 2020).

At the same time, the current transformation towards decarbonization to protect the environment requires the inclusion of RES in building a sustainable power system and meeting the ever-increasing demand for electricity. This transformation of the power system on the generation side requires a higher degree of communication networks to maintain grid integrity (Moslehi, Kumar, 2010). Most current RES technologies depend highly on topography and the environment, making them unpredictable and uncontrollable. This consequently limits their large-scale integration into electricity grids. In addition, this requires appropriate demand management and innovative strategies in renewable energy integration (Hossain et al., 2016). Modern grid control services, power electronic converters, smart meters and smart inverters require a state-of-the-art communications network (Phuangpornpitak, Tia, 2013). Therefore, creating an effective smart grid provides viable load management, significant reductions in system losses, reduced energy waste, accurate data monitoring, and flexibility for expansion and integration into the power system grid.

Similarly, SG consists of unidirectional communications, centralized generation, limited sensors, manual controls, and maintenance, which provides limited opportunities for customers to participate. A systematic change in the direction of SG development is being observed around the world, with simultaneous intensive innovations in each domain of SG considering their respective challenges (Lund et al., 2017; Alvi et al., 2022; Faheem et al., 2018; Ketter et al., 2018; Khan et al., 2023). Challenges facing European electricity grids due to the development of RES include the need to deliver flexibility, resilience and reliability to enable diversification and transformation while maintaining quality, stability and energy flow.

One of the new challenges in Europe related to the emergence of RES on the power grid is the emerging shutdown of PV installations by distribution grid operators on behalf of the national grid operator, known as non-market reduction of PV generation. These challenges are faced by countries where the share of RES in the national power system is increasing.

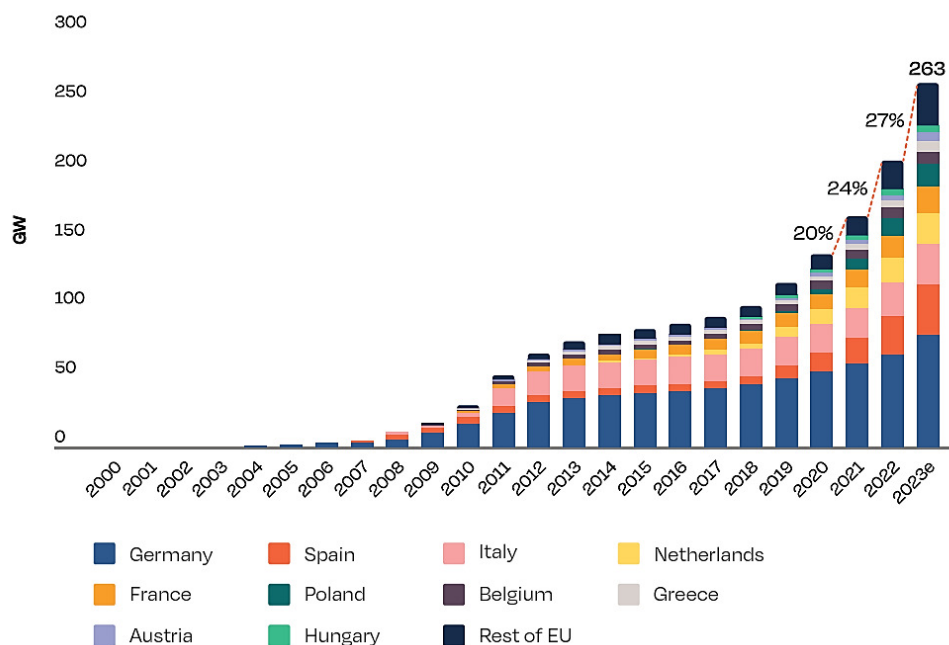
There are few studies on the effects of integrating RES into power grids. In contrast, there needs to be more scientific reports on the non-market reduction in the generation of photovoltaic sources due to their integration with electricity grids. Consequently, the research gap detailed the analysis of grid deactivation cases in Poland and Germany. A comparison was made between the two markets, on the one hand, due to the geographical proximity of the two countries and, on the other hand, due to the significant differences the two countries share. The German market is a mature and largest RES market in Europe with different legal, economic and technical conditions. On the other hand, the Polish photovoltaic market is still developing.

This article aims to analyze the reduction of PV generation in Germany and Poland and possible ways to solve it. The analysis was conducted using available secondary data and literature.

The research's time scope is from Q1 2013 to Q1 2024. The research methodology assumes that secondary data from Eurostat and other available statistical materials will be used.

## 2. Development of photovoltaic installations in EU countries

In 2023, installed solar capacity in the EU-27 member states increased by 27%, reaching 263 GW compared to 2022, when it was 207 GW (Solar Power Europe, 2023). After PV capacity in the European Union surpassed 100 GW in 2018 and reached the so-called 200 GW milestone in 2022, the upward trend was thus confirmed (Figure 1).



**Figure 1.** Cumulative solar PV installed capacity 2000-2023.

Source: (Solar Power Europe, 2023).

Against European countries' background, Poland's PV industry in 2019-2022 was characterized by significant dynamics. The total installed PV capacity in the EU at the end of 2022 was 198 GW, with an increase of 36 GW of new PV installations, an increase of 22% compared to 2021. From 2019 to 2022, Poland was among the top countries with increased PV capacity (Table 1). At the end of January 2024, Poland's total installed PV capacity was 17.07 GW.

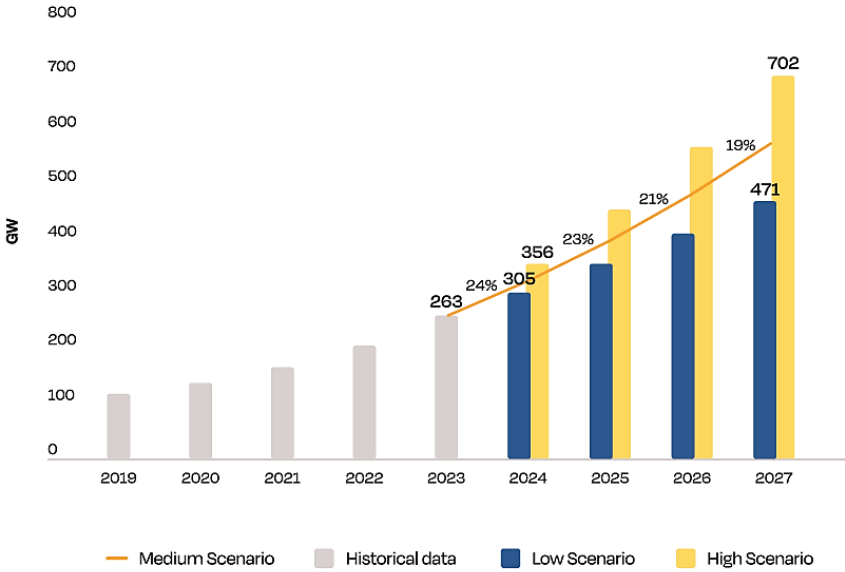


**Table 1.**  
*Total installed capacity in selected EU countries in 2022.*

Country	Total power 2021 [GW]	Total power 2022 [GW]	Increase 2022 [GW]	Average Increase [%]
Germany	59.371	66.662	7.291	12
Italy	22.594	25.077	2.483	11
Holland	14.911	18.849	3.938	26
Spain	13.715	18.214	4.499	33
France	14.810	17.410	2.600	18
Poland	7.416	12.422	5.006	68

Source: (IRENA, 2022).

However, Germany is the EU's largest and most mature PV market. Currently, Germany is the largest PV operator in the EU, with 82.1 GW of installed capacity. The country's rapid continuous growth of PV in recent years has widened the gap with Spain, second in this classification, with 35.6 GW of installed capacity. Analyzing the combined shares of the leading solar markets in the EU, Germany has slightly lost market share by two percentage points to 31% of the European market share, which still accounts for almost a third of the total installed PV capacity in the EU. Poland's share in the EU is 6.4% and has proliferated in recent years. Total installed PV capacity projections for the EU covering 2024-2027 show double-digit annual growth rates (Figure 2).



**Figure 2.** Scenarios for PV capacity growth in EU countries.

Source: (Solar Power Europe, 2023).

In the medium scenario, total capacity will reach growth rates of 24% in 2024 and 23% in 2025. According to Solar Power Europe experts, as PV grows in the EU, annual percentage growth will decrease significantly due to market saturation. The medium scenario predicts relative growth rates of up to 21% in 2026 and 19% in 2027. Thus, the upcoming growth rates will be lower than those achieved during Europe's 2022-2023 boom, when gains reached 24% and 27%, respectively. Regardless of the scenario, experts forecast further growth in

PV installation capacity in EU countries. Therefore, responding to the emerging side effects of such dynamic PV development is essential.

### **3. Challenges of power grid development in the context of RES developments**

The development of RES raises entirely new challenges for the electricity grid. The fluctuations in the integration of RES into the traditional power grid make it challenging to use renewables at the transmission level, which must handle the full range of rapidly fluctuating energy sources (Howlader et al., 2016; Cheung et al., 2010). This hinders the integration of RES into the electricity grid and vice versa, affecting the urgent global demand for a sustainable energy sector. The operational limitations of the power system are mainly due to the voltage and frequency limits set for the power system. Network insulation is damaged, leading to short circuits and equipment failures with system tripping due to overvoltage and undervoltage, respectively. These challenges have been mitigated by interconnection over a wide area at the national and international levels and solved with voltage regulation devices (Vaccaro et al., 2011; Andreotti et al., 2019).

Similarly, a slight deviation in system frequency causes desynchronization. Frequency stability is mainly maintained using automatic generation control (AGC) strategies. Offloading strategies are also recommended in emergencies.

Thus, given the dynamics of RES, which undergo unpredictable output power fluctuations, fast-response control strategies are needed. Unfortunately, most conventionally developed solutions are proving ineffective (Jamroen, Dechanupapritta, 2019; Lam et al., 2016; Keyhani, Chatterjee, 2012).

Based on the solutions presented for RES integration, it is mainly recommended that the forecasting of RES power production and the availability of energy storage systems be combined to increase the reliability and flexibility of the power system and maintain the techno-economic viability of the entire operation. However, most of these solutions require power system upgrades in the form of state-of-the-art communications for data acquisition, processing and optimization.

Electricity use has now been integrated into many critical areas and human welfare, classified as essential loads. Ensuring a reliable and safe power supply to these loads is necessary, and safety has been achieved by designing redundant circuits. In this perspective, establishing smart grids provides a structure that enables post-failure detection algorithms to use each power grid component optimally, thus eliminating the need for redundant circuits. As such, establishing a smart grid provides a transition from conventional grids to a modernized grid that facilitates collaboration and responsive interactions (Mahdad, Srairi, 2015).

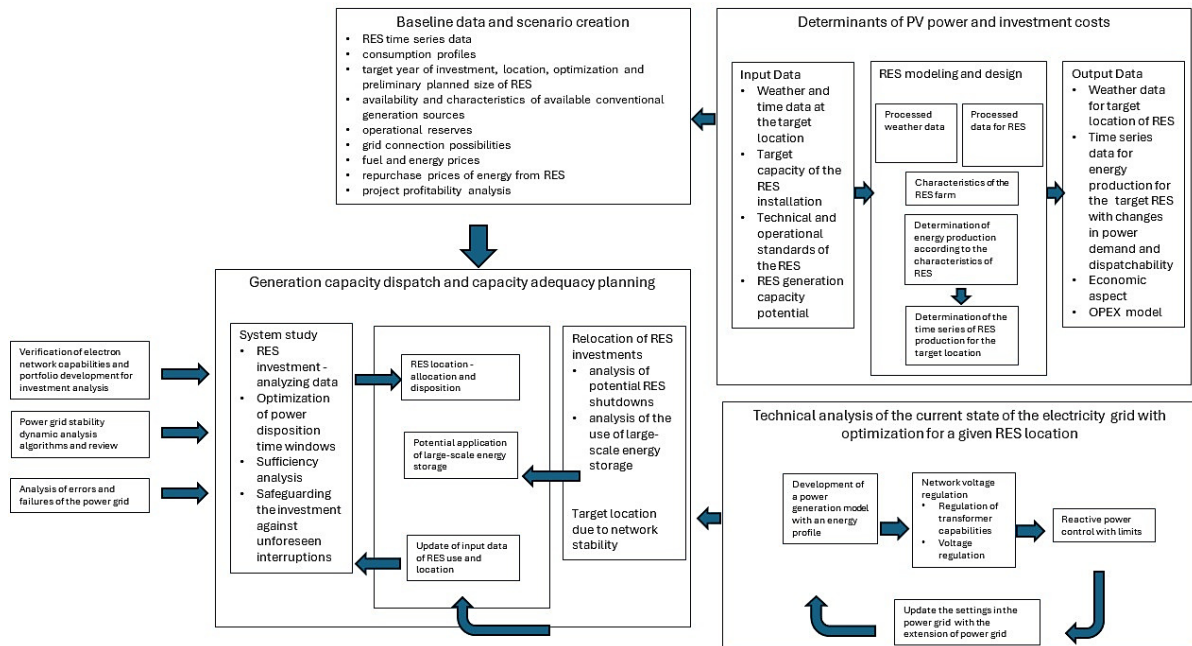
It also encourages introducing prosumer systems into the energy sector, allowing two-way interaction. This is integral to the creation of a deregulated electricity grid, which is necessary due to the constraints and demands that current RES technologies bring.

What is more, the activation of high-quality two-way communication in smart grids allows the incorporation of a complex, intelligent algorithm that enhances the reliability and self-repair capability of the power grid. Modern electricity sectors are being encouraged worldwide to move to smart grids. As the power grid slowly moves from a centralized architecture to a decentralized one, many new technologies are being proposed to support the systematic decentralization of the smart grid's communications and information infrastructure. These technologies are based on new and standard models successfully applied in other industries (Maddikunta et al., 2022).

Due to wind and solar power's uncontrollability, limited dispatch ability, and intermittent nature, dedicated ancillary services, such as regulation services, are needed to ensure reliability and operational needs.

One of the main reasons for RES integration is the potential rapid change in generated output. This, combined with the existing variability of this load, increases the stochastic nature of the entire power grid. RES at both the generation and distribution levels requires a coordinated power system upgrade for detailed monitoring, control and regulation. In particular, the current distribution level will require monitoring and control upgrades to optimize reliability and security and ensure the flexible operation of diverse RES-based small-scale generation systems (Manditereza, Bansal, 2016). The main idea is to optimize flow and power quality while reducing stochastic complexity.

While the existing power grid is adapted to cope with load variability, the available support provided by conventional power systems needs to be improved with the development of RES. Therefore, replacing or converting the output of synchronous generators will require systematic grid reinforcement, considering the variability of the time scale, i.e., the rapid fluctuations of renewable energy sources. Accurate wind and solar power forecasts are required to enable the specific tasks and additional services placed on RES generation sources. In addition to the generation forecast, local scheduling procedures for resources with unpredictable production characteristics must be refined to accommodate energy market requirements (Lee et al., 2022). The above elements should be taken into account when planning RES investments. Typical aspects of RES investment planning related to connecting new generation capacity to the electricity grid should consider power quality, contingencies and other necessary investment elements (Figure 3).



**Figure 3.** Typical planning aspects of connecting RES to the power grid, considering power quality, contingencies and investments.

Source: own elaboration based on (Khalid, 2024a).

Thus, it is essential to determine an effective model for RES sources and forecast their production. Wind and solar energy require much more intensive forecasting and scheduling due to their scope of application and intermittent and variable nature (Cheng et al., 2020). Therefore, short- and long-term renewable energy production and weather forecasts must be evaluated and studied (Sarshar et al., 2017; Hetzer et al., 2008; Naz et al., 2019). Unlike conventional generators, the unpredictability of RES sources limits their operation at total capacity, especially during peak hours. In addition, it satisfies additional load demands because it makes the system vulnerable to instability and power failures. As a result, grids that contain renewable energy sources need advanced energy management systems based on electricity availability, demand, energy unit prices, and storage and generation costs. In addition, the grid can consider renewable energy generation as a disruption from a power grid perspective if it represents less than 5-10% of total demand (Sgouridis et al., 2016). Likewise, the intermittent nature of renewable energy sources creates complications when planning the day-to-day operation of electric grids. Because renewables fluctuate over multiple time horizons, distribution grid operators must readjust system operations in real-time, for several hours or with day-ahead planning. Therefore, to meet load demand, the conventional generation system has to be constantly changed, as the RES output changes every minute. This cyclic operation hurts the system, putting pressure on the generators and reducing their efficiency. This problem becomes much more pronounced when combined with variable load demand. Rapid fluctuations in solar or wind power output affect the hourly load on the grid after the planning phase and even upset the balance between total demand and supply from second to second. Hence, the fundamental

problem is to reduce the cost of regulating intermittent renewable energy sources (Alhammad et al., 2021).

In conclusion, photovoltaic systems can replace conventional synchronous generation on the power grid if placed, sized, and functioning correctly. However, their unpredictable output fluctuations must be considered, as they will affect energy flow and how the grid operates. In this regard, four basic parameters of power system operation can be distinguished, namely:

- power balance,
- power quality,
- optimal power flow,
- grid stability.

Power balance challenges include issues related to the short- and long-term balance of power system generation and demand. Grid capacity must be coordinated on a large scale to achieve system-wide balance. This task is difficult due to the unpredictability and uncertainty of RES sources. End users have the most stringent requirements, the most important of which is adequate power quality. Uninterrupted power supply, stable voltage and current conditions, and safe conditions in power outages are considered for power quality challenges. Challenges related to optimal power flow concern the efficient transmission and distribution of electricity. Frequency and voltage regulation in the power system and system restoration after power outages are significant challenges related to stability issues. The modularity of RES generators and the fact that these generators are not synchronous are the most critical factors contributing to stability issues. A detailed summary of RES integration challenges and problems with basic parameters is presented in Table 2.

**Table 2.**  
*Challenges of RES integration*

Issue	Challenge	Description	Impact	Reliability	Resilience
Power balance	Limited availability of renewable energy sources of reproduction	According to the characteristics of most RES power generation technologies, grid frequency stability cannot be stabilized when RES generators are operating. This will lead to unforeseen power outages due to a mismatch between demand and generation.			x
	Inadequate forecasting of RES generators	Unplanned grid operation can be observed on the grid due to inaccuracies in forecasting RES output generation. The degree of losses can range from economic to technical and equipment damage.	x	x	
	Inadequacy in long-term generation operation	As the level of variable renewables on the power grid increases, the operational aspects of the grid in terms of seasonal and annual energy balancing will change, which will affect the timing of the synchronous generation system. As a result, the system may be susceptible to long-term system instability due to inaccuracies resulting from unpredictably variable RES output. Consequently, systematic generation deviations may prove economically challenging.		x	

Cont. table 2.

Power Quality	Voltage Flickering	Locally integrated RE through power electronics increases flicker, leading to shorter equipment life.			x
	Harmonics	The use of inverters in RES introduces additional harmonic distortion. This leads to shorter equipment life or equipment damage to end users.			x
	Low reliability during blackout	Renewable energy generators that continue to produce electricity in areas disconnected from the larger grid are susceptible to stability and power balance issues, leading to safety and operational concerns.	x	x	x
	Voltage overload at the distribution level	Connecting RES at low voltage on the grid leads to increased voltage impact. Excessive voltage at the peak of RES production or during periods of low power demand.	x	x	
Optimal Power Flow	Increased overall voltage profile	Connecting RES increases the overall voltage level, especially in impacted distribution areas.	x	x	x
	Limitation of network capacity	Existing grids may not be able to handle the power of renewable energy generators. If a RES shutdown is planned, it will result in power curtailment and losses for RES owners. An unplanned shutdown will leave the system vulnerable to failures and equipment damage.	x		x
	Increased potential instability and uncontrolled power at lower network levels	Uncontrolled connection of RES will result in increased unpredictability of power generation. This may result in increased curtailment of RES generators, stability requirements, and if unplanned, will lead to equipment damage.	x		x
	Low degree of controllability of RES	Connecting RES in the form of many unplanned capacities of small units will have an aggregate impact on power flow and system dynamics. This reduces the reliability of forecasting and planning, which can lead to systematic grid instability.	x	x	x
	Low level of RES monitoring	At low voltage levels of the grid, there is a lack of adequate metering equipment to complement the variability of renewable generation systems. As a result, there will be unobserved power flow, which can result in unscheduled grid operation that can be both technically and economically damaging.		x	x
	Limited network capacity	Connecting RES to the existing grid may require the construction of additional transmission lines. Otherwise, the grid will be exposed to RES capacity curtailment, reduced transmission capacity during planning phases, and capacity curtailment.	x	x	
Grid Stability	Limited ability to manage reactive power	Most renewable generation technologies have negligible reactive power input. According to grid standards and dynamics, transmission lines require reactive power support to maintain voltage standards. Therefore, the expansion of RES may be limited due to the resulting potential voltage violations. The lack of reactive power support will also affect power quality and stability, leading to curtailment or isolation of RES generators.	x	x	
	Reduced ability to detect faults	Fault detection and voltage instability may go undetected due to the relatively lower value of short-circuit currents in RES. This can cause complications in stable grid operation and isolation of RES microgrids.		x	x
	Reduce network inertia	An uncontrolled increase in grid frequency as a result of tripping an unstable RES source can lead to high grid instability. As a result, due to constraints related to the equality of demand and production, production curtailment or load reduction may be necessary to maintain the operational stability of the system.	x	x	

Source: own elaboration based on (Khalid, 2024b).

#### 4. Challenges of reducing grid power in Poland and Germany

The EU's 2030 climate and energy targets will be helped by the *National Energy and Climate Plans* (NECPs) enacted by individual EU countries. In Germany, according to the current NECP, a 40.4% share of RES is planned to be achieved in 2030, a significant increase from the 30% in the previous NECP and almost double the 2023 projections. In the electricity sector, Germany plans to achieve an 80% share of renewables by 2030, a significant increase from the 65% share by 2030 from the previous NECP. In photovoltaic development, the German government plans to install 22 GW of photovoltaics annually, translating into 215 GW of cumulative installed capacity by 2030 and 400 GW by 2040. The plans thus represent a massive leap from the current capacity of 82 GW and the previous NECP target of 98 GW. The area of support in Germany is regulated by the *Renewable Energy Sources Act* (EEG Erneuerbare-Energien-Gesetz). It allocates €300 million in 2023 for direct subsidies for photovoltaic installations installed on rooftops with electric vehicles and energy storage.

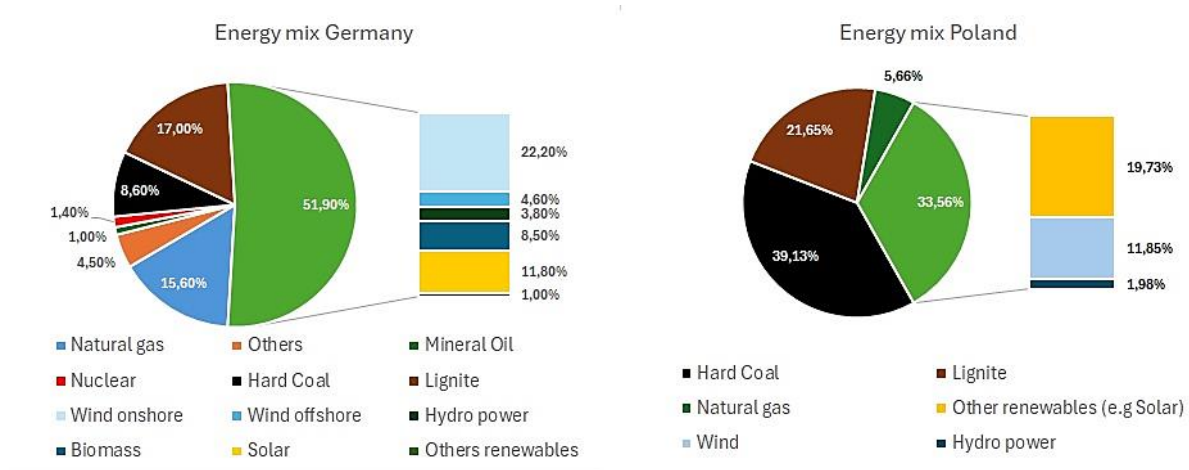
In Germany, to balance production and consumption in real-time, it is envisaged that RES will develop smoothly according to need and, in conjunction with actual demand at a given location, integrate the energy market and combine sectors, e.g., by expanding energy storage capacity. Great emphasis is placed on increasing self-consumption, i.e., increasing the consumption of the energy produced from PV without injecting surplus into the grid.

The National Energy and Climate Plan does not set specific targets to support demand-side management at the distribution or central levels. In grid development, the National Plan recognises the importance of expanding power grids for properly developing renewable energy sources. According to the NECP, the rapid growth of renewable energy sources in Germany requires an adequate expansion of interconnections, which will be implemented simultaneously with the expansion of the national grid. Regarding transmission infrastructure, about 14,000 km of lines are planned in Germany, including 1400 km interconnections (SolarPower Europe, 2024). However, there needs to be details on which member states will be connected as a priority and with what capacity. Regarding the distribution network, Germany plans to expand it.

A preliminary version of the NECP update was prepared in Poland and submitted to the European Commission on March 1, 2024. The document submitted to the European Commission is a draft update of the 2019 *National Energy and Climate Plan 2021-2030*. The draft NECP sets a target of 29.8% share of RES in gross final energy consumption in 2030. Projections by Polish market experts estimate much more, and Poland could reach about 50.1% RES share in final energy consumption in the electricity sector in 2030 and 59.1% in 2040 (Ministerstwo Klimatu i Środowiska, 2024). In the 2030 outlook, onshore wind power (with an installed capacity of about 15.8 GW), photovoltaic installations (about 29.3 GW) and offshore wind power (about 5.9 GW), which will operate in the NPS from about 2026,

will contribute most to the increase in electricity generation from RES. The document indicates the challenges that will arise as RES develops in Poland.

The increase in the share of RES in the national energy mix, mainly based on wind and solar, is variable over time. In Figure 5, you can see the energy mix of Germany (2023) and Poland (May 2024) for comparison. Noteworthy is the fact that Germany's RES is already more than 50%, and of this, the largest share is wind. In Poland, the share of RES is more than 33% of power, with the largest share being photovoltaics.



**Figure 4.** Energy Mix Germany (2023) and Poland (May 2024).

Source: own elaboration based on Clean Energy Wire and Rynekelektryczny.pl

This situation makes meeting the demand for electricity and power in the power system an increasing problem. One response to this challenge is to increase the flexibility of the power system. Currently, the flexibility of the power system is provided by conventional energy sources, particularly gas and coal-fired power generation units and pumped storage power plants. The ability to stabilise the grid depends on their technical parameters. The current rapid development of RES means that existing technologies need to be improved, and other flexible sources, including energy storage and appropriate Demand Side Response (DSR) management, should be used to stabilise the grid in the future. In the future, grid stabilisation will be achieved through greater cooperation between generators, consumers and operators, facilitated by the development of smart grids and smart metering. The National Plan envisages promoting greater participation of generators in future balancing and power markets. According to the NECP, the development of electricity system flexibility will be supported by the implementation of EU electricity market legislation, including the existing provisions of EU Regulation 2019/943 on redispatch (Article 13) or the formation of network tariffs (Article 18), and EU Directive 2019/944 on aggregation (Articles 13 and 17), active forms of market participation by the least active market participants (Articles 15 and 16) or flexibility services (Article 32). Accordingly, the goal of increasing the share of RES, energy storage, and DSR to ensure the flexibility of the electricity system has been defined. Adequate policies supporting the development of energy storage and the implementation of demand-side and supply-side mechanisms through the



introduction of dynamic pricing and tariffs or DSR aggregation will help ensure this goal's realisation. According to the draft NECP, priority will be given to the further expansion and modernisation of electricity grids (transmission and distribution) to improve the capacity to receive energy from generation sources and to ensure adequate energy flow in the power system. In the future, this infrastructure is also expected to provide the ability to continuously exchange energy with the power systems of neighbouring countries and the European power systems more broadly. In this area, the Polish NECP envisages the dynamic development of cross-border connections by increasing the availability and capacity of current cross-border power interconnections. At present, the key to the country's energy security is the connection of the electricity systems of the Baltic States (Lithuania, Latvia and Estonia) to synchronous operation, which is planned for February 2025.

With the development of photovoltaic and wind installations comes the shutdown of PV installations by distribution grid operators on behalf of the national grid operator PSE, known as non-market reduction of generation of PV sources. Such a situation occurs if three phenomena occur: very nice weather with high sunshine, strong wind and low electricity demand.

In Poland, such a situation occurs most often on Sundays before noon on sunny and windy days. The critical factor preventing such a situation is proper demand forecasting by the national power system, which PSE does in Poland. An erroneous forecast can affect the improperly prepared power system, resulting in larger power reductions than expected. Another reason for reductions in grid capacity is the low flexibility of coal-fired power plants, which still make up a significant part of Poland's energy infrastructure. The installed capacity of coal-fired power plants is 32.7 GW, accounting for 58.5% of the total capacity in the country's energy mix, and is steadily declining. Shutting down coal-fired power plants for a short period is problematic and very costly. As a result, PSE is taking advantage of the flexibility of renewables-based sources, leaving conventional power plants at minimum capacity levels.

The first non-market reduction in PV generation occurred on April 23, 2023 (Wysokienapiecie.pl, 2023). The event was later dubbed "Black Sunday" and began a PV and wind turbine shutdown period. To balance the power system on that day, transmission grid operator PSE reduced the output of PV sources by about 2.2 GW. A communique published by PSE declared a "threat to the security of electricity supply" so that it could issue an order to disconnect some power plants from the grid. It announced an excess electricity production over demand in the Polish power system. The main reason was the high generation of photovoltaic sources due to the sunny day. Wind farms also supply a relatively large amount of energy. This procedure allowed PSE to issue orders to reduce power plants connected to distribution networks with a voltage lower than 110 kV. These are mainly medium and small wind and solar power plants and micro photovoltaic installations, which currently constitute one of the largest power sources in the power system. However, for technical reasons, it is not possible to manage PV micro-installations (installations of less than 50 kWp) due to the lack of direct

communication with inverters. Currently, shutdown through inverter management is only possible for small and large installations built with a building permit under the obtained connection conditions. These installations, depending on the conditions notified by the DSO, have the appropriate telemechanics to enable remote management.

Considering the total installed PV capacity in Poland without micro-installations (capacity of 10.75 GW at the end of January 2024), the capacity of larger PV plants exposed to outages was 6.32 GW at the end of the first month of 2024. Before April 2023, PSE's actions to curtail RES generation included only wind farms. There were a few PV shutdowns in 2023, such as July 2 and October 8—later generation reductions involved only wind farms (December 25 and January 31, 2023). The first PV reduction in 2024 occurred on March 3. At that time, the non-market power reduction amounted to 815 MW from 12:00-13:00, 741 MW from 13:00-14:00 and 594 MW from 14:00- 15:00, covering larger PV power plants connected to the high and medium voltage grid. In addition to reducing the operation of photovoltaic systems, PSE also stabilised the Polish power system by, among other things, emergency power exports to neighbouring countries. Another reduction order took place on March 31, 2024, when PSE issued an order to shut down PV with a total installed capacity of 3.23 GW. The subsequent power reduction took place on April 15, 2024. On that date, a 2.5 GW reduction in PV capacity was ordered (against PSE's earlier forecast of 2 GW) and wind power curtailments. The curtailment peaked at 4.45 GW between 12:00 p.m. and 1:00 a.m. At that time, the total power demand was 17.4 GW. It is worth noting that the record for PV power generation in Poland occurred on April 9, 2024, at 10.65 GWh. The last recorded PV and wind power plant shutdowns occurred on May 1-5, 2024 (May long weekend). The most considerable PV capacity reduction was on May 1, 2024, at 12:00-13:00. It amounted to 4.749 GW against a planned 4.084 GW (Polskie Sieci Energetyczne, 2024), accounting for 75% of all PV capacity to be reduced in Poland. A parallel demand for wind capacity reduction of 0.862 GW was reported at the time. Table 3 shows the collected non-market reductions of PV generating units and wind turbines in the National Power System (NPS).

**Table 3.**

*Non-market reductions of PV generation units and wind turbines in the NPS*

LP	Date	Reduction PV [MW]	PV	Wind
1	23.04.2023	b.d.	Yes	bd
2	30.04.2023		2300	Yes
3	02.07.2023	b.d.	Yes	bd
4	08.10.2023	b.d.	Yes	bd
5	25.12.2023	b.d.	No	Yes
6	31.12.2023	b.d.	No	Yes
7	03.03.2024		815	Yes
8	31.03.2024		3230	Yes
9	15.04.2024		2500	Yes
10	01.05.2024		4749	Yes
11	02.05.2024		3851	Yes
12	03.05.2024		1602	Yes
13	04.05.2024		4415	Yes

14	05.05.2024	3387	Yes	No
15	09.05.2024	957	Yes	No
16	12.05.2024	2392	Yes	No
17	13.05.2024	1772	Yes	No
18	15.05.2024	3484	Yes	No
19	16.05.2024	4150	Yes	Yes
20	17.05.2024	3086	Yes	No
21	19.05.2024	2114	Yes	No
22	26.05.2024	2843	Yes	No

Source: PSE ( <https://www.pse.pl/komunikaty-osp>).

The reduction order notified by PSE entails the payment of appropriate compensation to owners of the affected generating units. The above situation is defined by Article 13 (7) of EU Regulation 2019/943, which specifies that the so-called non-market redispatch is subject to financial compensation paid to generators. Unfortunately, the current regulations do not define specific rates for reducing electricity generation. Generators are supposed to receive compensation covering lost revenues due to the reduction in electricity generation. Despite the relevant regulations, owners of photovoltaic installations subject to curtailment have received refusals from DSOs (Money.pl, 2024). Contracts containing a possible exclusion from compensation will be enforced by the DSOs as part of the connection agreement. In such a situation, DSOs will first limit capacity on a market basis, i.e., installations containing provisions allowing DSOs not to pay compensation. In the second place, excluders will be entitled to production limitations with a guarantee of compensation on a non-market basis.

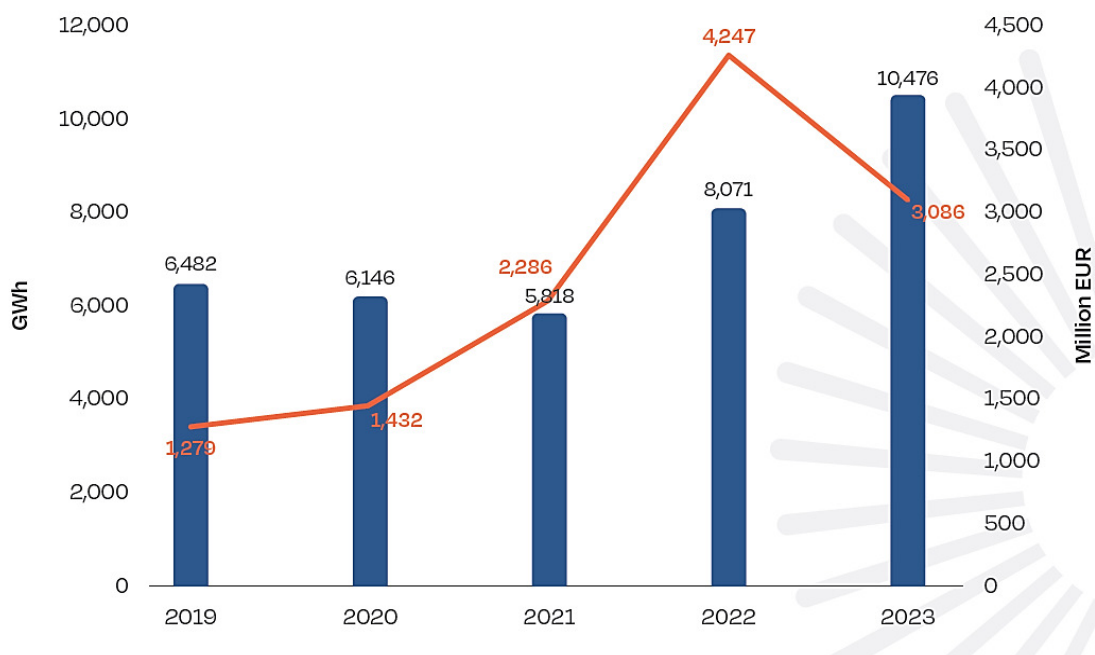
Due to the significant capacity volumes of wind and solar RES sources and the shutdown of nuclear power plants, the situation in Germany is much more complicated. The German power system increasingly relies on variable renewable energy sources, challenging the country's grid operators for many years. In Germany, special measures known as "re-dispatch" are used to achieve grid stability, which ensures a balance between supply and demand. A significant challenge in Germany is the specific distribution of RES, with wind power in the northern part of Germany and PV in the southern part, where there is more electricity demand due to the industry's location. Thus, from Germany's perspective, an adequate energy connection between the northern and southern parts of Germany is crucial. For grid stability, the electricity injected into the grid must equal the amount withdrawn from the grid at any given time. This is usually achieved through the energy market, where power plant operators produce enough electricity to meet demand, i.e., by supplying what has already been sold on the exchange. Grid operators receive a list of power plant "dispatches" based on market data one day in advance, which allows them to see if adjustments are needed to keep the grid running smoothly (Kerstine Appunn, 2016). Operators in Germany can use three different types of redispatch measures:

- ordering conventional power plants in northern Germany to reduce production to "make room" on the grid for a large influx of wind power,
- temporarily shutting down wind turbines (only as a last resort since renewables have priority on the grid),

- ordering conventional power plants in southern Germany to produce more electricity to meet demand from consumers in the south, whose suppliers have bought northern German wind power that cannot be supplied.

All of these actions result in additional costs for consumers. When grid operators order power plants to curtail production, they must compensate them for the price of the unsold electricity for which they would have been paid (minus the expenses that power plants save on fuel). When grid operators order renewable energy producers to disconnect from the grid, power producers must also be compensated for some of the lost profits.

In 2014, re-dispatch interventions were required for 330 days (232 days in 2013), affecting 5197 GWh and costing 186.7 million euros (132.6 million in 2013). The redispatch costs are passed on to consumers as part of the grid charge that households pay in their electricity bills. Re-dispatch costs in Germany continue to rise. For example, about 10.5 TWh of electricity was lost due to curtailment in 2023, compared to 8 TWh in 2022, and nearly doubled in two years. However, the cost of deliberately reducing production by some installations while implementing additional capacity in other regions was lower in 2023 than in 2022, falling from €4.2 billion in 2022 to €3.1 billion in 2023. The cost and level of congestion in Germany between 2019 and 2023 can be seen in Figure 5.



**Figure 5.** Cost and level of grid congestion in Germany 2019-2023.

Source: (SolarPower Europe, 2024).

The reduction of 10.5 TWh of electricity production by RES in 2023 corresponded to about 2.3% of Germany's total annual electricity production. At the same time that the operation of RES installations in some regions was reduced due to grid bottlenecks, fossil-fuel power plants in the other areas (in western and southern Germany) had to come online to cover the reduced production. Building wind turbines relatively far from energy consumption centres has

contributed to the high demand for redirection measures, as long-distance transmission lines are among the most congested parts of the power grid. The lower cost of maintaining grid stability in 2023, despite the increased demand for re-dispatch, is mainly due to the drop in energy prices after 2022 (Wehrmann, 2024).

## **5. Possible directions for regulatory and administrative action**

Due to the dynamic development of RES, grid capacity will continue to be reduced. Experience from the German market shows that the cost of maintaining the power system will increase with the development of RES

### **5.1. Development scenarios for the German market**

One idea to solve the re-dispatch problem in Germany is to introduce new regulations. The German government is considering steps to allow more green electricity, the production of which is currently limited due to transmission bottlenecks in the national grid. Under the proposed reform of the country's Energy Industry Act (EnWG - Gesetz über die Elektrizitäts- und Gasversorgung. Energiewirtschaftsgesetz), the German government intends to improve conditions so that electrolysers or flexible consumers can use renewable electricity locally at lower prices during periods when it would otherwise be restricted due to a lack of grid capacity. The instrument would take effect on October 1, 2024, and oblige transmission system operators to auction renewable electricity that is currently unused due to grid congestion. This should make it much cheaper (Kyllmann, 2023). Germany's experience shows that it is necessary to continuously expand the grid and introduce incentives and programs to support the development of energy storage.

SolarPower Europe experts point out that a critical technology to keep curtailment levels low in Germany will also be easily deployable energy storage (SolarPower Europe, 2024). The rapid installation of energy storage facilities will avoid growing curtailments and enable renewables' rapid growth. Still, it will also help reduce expenses related to managing grid curtailments, which have risen significantly to €3.1 billion in 2023, 2.5 times more than four years earlier. Currently, during times of excess capacity, renewable energy producers are compensated for withholding electricity, while fossil fuel plants are rewarded for increasing production during periods of low renewable output. As renewable capacity increases and conventional sources are phased out, the number of hours with supply-demand imbalances will increase, leading to higher capacity curtailment costs and grid management costs unless energy storage facilities are successfully deployed. Currently, the German market is the largest market for energy storage, with an installed capacity of 5.9 GWh at the end of 2023, compared to 2.3 GWh of energy storage capacity in 2022. SolarPower experts forecast further dynamic

development of energy storage in Germany, maintaining first place by 2028 with a 20% share of the total European market of 78.1 GWh.

Another challenge facing the German market is the stabilisation of the power grid as a result of RES development. One solution to this problem is the use of so-called grid-forming services. These services are an extension of energy storage and inverters with additional functionality. Today, energy storage systems can replace conventional power plants thanks to new stability system services. Grid support systems for large energy storage solutions are being placed at strategic points in the transmission network. They increase the flexibility of existing transmission systems, reduce bottlenecks, and simultaneously reduce the need to implement costly redistribution measures.

The first country in Europe to widely deploy these technologies is the United Kingdom. In Germany, the first smaller-scale projects were carried out in 2019 in the Bordesholm region (SMA Solar AG, 2020). As part of a research project at the end of 2019, Bordesholm Public Works, in cooperation with TH Köln and SMA, simulated power failures over a large area. To do this, the Bordesholm plants were isolated by a synchronous power switch from the European power grid for one hour. About 8000 Bordesholm residents and all households, plants, and institutions were continuously supplied with electricity using renewable energy. The final technical verifications were completed in 2022 (German Energy Solutions Initiative, 2022). In Germany, the market for non-frequency-based ancillary services is expected to be launched in 2024, making Germany the first continental European market for grid stabilisation services (Intersolar, 2024).

## **5.2. Development scenario for Poland**

Against the backdrop of the current situation in Germany, Poland is only at the beginning of the search for solutions. As a first step, the right direction is to strengthen the role of renewable energy sources for stabilising grid parameters. Currently, this role is assigned to conventional power generation, which in the case of Poland involves using coal-fired power plants for this purpose. However, these power plants are characterised by low flexibility of operation with high failure rates. In addition, they are unsuitable for rapid power changes because of the real risk of damage.

On the other hand, it is estimated that Poland needs about 7-8 GW of power to stabilise the grid. Therefore, PSE must consider their requirements for the minimum power that conventional power plants provide. Thus, with low customer demand, only 6-7 GW of space remains for other sources to operate unless energy is exported to neighbouring countries or stored (e.g., in pumped storage plants). As a result, conventional power plants provide adequate inertia to determine the parameters of the grid, ensuring its stability.

However, as the share of RES in the Polish energy mix increases, the inertia of the power system decreases. The decrease in inertia leads to the rise in the amplitude and dynamics of frequency fluctuations following disturbances in power supply resulting from the variable

nature of renewable sources. Currently, however, power market participants are discovering the ability of RES to provide non-frequency system services, which, together with flexibility services, are complementary services that stabilise the power grid. These services are already standard in Western European countries under the name above of grid-forming.

Photovoltaic inverters commonly used in PV installations are current sources and do not change grid parameters; they only adapt to them. Grid forming and the functionality of the new inverters, which become a voltage source in this arrangement, will allow renewable energy, which is far more flexible than conventional power, to change grid parameters. This will free up capacity backed by conventional power generation, providing more significant opportunities to manage unstable energy sources. In Poland, these services are currently being designed and analysed by the Polish Power Grid. Thus, the development of grid forming and other services like DSR will contribute to increased grid flexibility. However, this requires significant investment in the expansion of energy infrastructure, and in particular in the development of large-scale energy storage facilities.

Flexibility services, of which DSR is one, allow the level distribution system operators to introduce solutions to ensure the involvement of consumers, storage and generators in managing network congestion. Complementary to flexibility and system services are power market services and balancing market services. However, since energy prices in the balancing market at times of oversupply remain high from the perspective of the European market, i.e., about PLN 300 MWh, from the perspective of Polish conventional power plants, it is below their production costs. This results in a situation in which conventional power plants exacerbate losses, and on the other hand, Poland cannot export surpluses outside the country.

One of the main directions for RES development is the spread of energy storage. This is a good solution in every market segment, i.e., for individual customers, businesses, and large-scale storage. The development of energy storage can be stimulated by subsidy programs like My Current or supported by the National Recovery Plan (NRP). However, it should be linked to arbitrage and dynamic tariffs.

The combination of opportunities brought by energy storage and smart energy management functions, such as recharging electric cars, heating domestic water in buffer tanks, or automatically running air conditioning from surplus PV energy, will become increasingly popular.

Equally, technologies available in modern inverters, like ZeroExport, a power guard that prevents PV energy from entering the grid, or reactive power management in the form of the Q(U) function, are now helping to stabilise the power system.

## 6. Conclusion

In the period under review, Europe, including Poland, is experiencing a very intensive development of RES, particularly photovoltaics, which requires an extensive and adapted transmission infrastructure. At the same time, the dependence of solar power plants on atmospheric conditions and the increasing frequency of extreme weather events pose more and more challenges to the transmission grid operator. Due to the significant challenges posed by the rapid development of distributed power, it is essential to continuously modernize the power grid toward smart grids by conducting support programs to develop the national grid infrastructure. It is essential to increase the flexibility of the power system, which is becoming a critical factor in maintaining the stability of its operation and reducing the loss of energy not generated from RES due to the necessary shutdown.

Non-market reduction in the generation of photovoltaic sources will become increasingly common in Poland, Germany, and other European countries.

Equally, the share of energy storage in the power system is growing slower than it is based on actual demand, and the cost of implementation is still high. This results in a situation where photovoltaic power generation reductions remain the cheapest and most effective form of power system management. Suppose the number of reduced hours per year is a critical mass. In that case, it will not be a significant stimulant for developing energy storage, flexibility services, and system services. Therefore, even in a mature power system with much greater energy storage capacity, such measures will continue to be an instrument readily used by power market regulators.

## Author Contributions

Conceptualisation, A.M-F., K.N and A.B.; methodology, A.M-F. and K.N.; data curation, A.M-F., K.N and A.B.; writing-original draft, A.M-F., K.N and A.B. All authors have read and agreed to the published version of the manuscript.

## Data Availability Statement

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.



## Data Availability Statement

Data are contained within the article.

## Conflicts of Interest

The authors declare no conflict of interest.

## References

1. Adewumi, O.B., Fotis, G., Vita, V., Nankoo, D., Ekonomou, L. (2022). The Impact of Distributed Energy Storage on Distribution and Transmission Networks' Power Quality. *Applied Sciences*, 12(13), 6466. <https://doi.org/10.3390/app12136466>
2. Ahmed, I., Rehan, M., Hong, K.-S., Basit, A. (2022). A Consensus-based Approach for Economic Dispatch considering Multiple Fueling Strategy of Electricity Production Sector over a Smart Grid. *2022 13th Asian Control Conference (ASCC)*, 1196-1201. <https://doi.org/10.23919/ASCC56756.2022.9828267>
3. Ahmed, I., Rehan, M., Iqbal, N., Ahn, C.K. (2023). A Novel Event-Triggered Consensus Approach for Generic Linear Multi-Agents Under Heterogeneous Sector-Restricted Input Nonlinearities. *IEEE Transactions on Network Science and Engineering*, 10(3), 1648-1658. <https://doi.org/10.1109/TNSE.2022.3232779>
4. Alhammad, H.I., Khan, K.A., Alismail, F., Khalid, M. (2021). Capacity Optimization and Optimal Placement of Battery Energy Storage System for Solar PV Integrated Power Network. *2021 IEEE Energy Conversion Congress and Exposition (ECCE)*, 847-852. <https://doi.org/10.1109/ECCE47101.2021.9595426>
5. Alvi, U.-E.-H., Ahmed, W., Rehan, M., Ahmed, S., Ahmad, R., Ahmed, I. (2022). A novel incremental cost consensus approach for distributed economic dispatch over directed communication topologies in a smart grid. *Soft Computing*, 26(14), 6685-6700. <https://doi.org/10.1007/s00500-022-07061-4>
6. Andreotti, A., Petrillo, A., Santini, S., Vaccaro, A., Villacci, D. (2019). A Decentralized Architecture Based on Cooperative Dynamic Agents for Online Voltage Regulation in Smart Grids. *Energies*, 12(7), 1386. <https://doi.org/10.3390/en12071386>

7. Anjana, K.R., Shaji, R.S. (2018). A review on the features and technologies for energy efficiency of smart grid. *International Journal of Energy Research*, 42(3), 936-952. <https://doi.org/10.1002/er.3852>
8. Appunn, K. (2016, January 16). *Re-dispatch costs in the German power grid*. <https://www.Cleanenergywire.Org/Factsheets/Re-Dispatch-Costs-German-Power-Grid>.
9. Cheng, Q., Yan, Y., Liu, S., Yang, C., Chaoui, H., Alzayed, M. (2020). Particle Filter-Based Electricity Load Prediction for Grid-Connected Microgrid Day-Ahead Scheduling. *Energies*, 13(24), 6489. <https://doi.org/10.3390/en13246489>
10. Cheung, K., Xing W., But-Chung C., Ying X., Rios-Zalapa, R. (2010). Generation dispatch in a smart grid environment. *2010 Innovative Smart Grid Technologies (ISGT)*, 1-6. <https://doi.org/10.1109/ISGT.2010.5434781>
11. Faheem, M., Shah, S.B.H., Butt, R.A., Raza, B., Anwar, M., Ashraf, M.W., Ngadi, M.A., Gungor, V.C. (2018). Smart grid communication and information technologies in the perspective of Industry 4.0: Opportunities and challenges. *Computer Science Review*, 30, 1-30. <https://doi.org/10.1016/j.cosrev.2018.08.001>
12. German Energy Solutions Initiative (2022, July 20). *Grid-forming power converters provide stability for the energy transition*. <https://www.German-Energy-Solutions.de/GES/Redaktion/EN/News/2022/20220720-Grid-Forming-Power-Converters.html>.
13. Hetzer, J., Yu, D.C., Bhattarai, K. (2008). An Economic Dispatch Model Incorporating Wind Power. *IEEE Transactions on Energy Conversion*, 23(2), 603-611. <https://doi.org/10.1109/TEC.2007.914171>
14. Hossain, M.S., Madlool, N.A., Rahim, N.A., Selvaraj, J., Pandey, A.K., Khan, A.F. (2016). Role of smart grid in renewable energy: An overview. *Renewable and Sustainable Energy Reviews*, 60, 1168-1184. <https://doi.org/10.1016/j.rser.2015.09.098>
15. Howlader, H.O.R., Matayoshi, H., Senjyu, T. (2016). Distributed generation integrated with thermal unit commitment considering demand response for energy storage optimization of smart grid. *Renewable Energy*, 99, 107-117. <https://doi.org/10.1016/j.renene.2016.06.050>
16. Intersolar (2024, May 28). *Grid-forming technology is an important part of the energy transition*. <https://www.Intersolar.de/News/Interview-Duckwitz-Prabhakaran-Grid-Forming-Technology-Important-Part-Energy-Transition>.
17. IRENA (2022). <https://www.irena.org/Energy-Transition/Technology/Solar-energy>
18. Jamroen, C., Dechanupapritta, S. (2019). *Coordinated Control of Battery EnergyStorage System and Plug-in Electric Vehicles for Frequency Regulation in Smart Grid*. 2019 IEEE PES GTD Grand International Conference and Exposition Asia (GTD Asia), 286-291. <https://doi.org/10.1109/GTDAsia.2019.8715962>
19. José de Castro Vieira, S., Tapia Carpio, L.G. (2020). The economic impact on residential fees associated with the expansion of grid-connected solar photovoltaic generators in Brazil. *Renewable Energy*, 159, 1084-1098. <https://doi.org/10.1016/j.renene.2020.06.016>

20. Kabalci, Y. (2016). A survey on smart metering and smart grid communication. *Renewable and Sustainable Energy Reviews*, 57, 302-318. <https://doi.org/10.1016/j.rser.2015.12.114>
21. Ketter, W., Collins, J., Saar-Tsechansky, M., Marom, O. (2018). Information Systems for a Smart Electricity Grid. *ACM Transactions on Management Information Systems*, 9(3), 1-22. <https://doi.org/10.1145/3230712>
22. Keyhani, A., Chatterjee, A. (2012). Automatic Generation Control Structure for Smart Power Grids. *IEEE Transactions on Smart Grid*, 3(3), 1310-1316. <https://doi.org/10.1109/TSG.2012.2194794>
23. Khalid, M. (2024a). Smart grids and renewable energy systems: Perspectives and grid integration challenges. *Energy Strategy Reviews*, 51, 101299. <https://doi.org/10.1016/j.esr.2024.101299>
24. Khalid, M. (2024b). Smart grids and renewable energy systems: Perspectives and grid integration challenges. *Energy Strategy Reviews*, 51, 101299. <https://doi.org/10.1016/j.esr.2024.101299>
25. Khan, K.A., Quamar, M.M., Al-Qahtani, F.H., Asif, M., Alqahtani, M., Khalid, M. (2023). Smart grid infrastructure and renewable energy deployment: A conceptual review of Saudi Arabia. *Energy Strategy Reviews*, 50, 101247. <https://doi.org/10.1016/j.esr.2023.101247>
26. Kyllmann, C. (2023, October 18). *Germany wants to ensure more green electricity is “used instead of curtailed”*. <https://www.Cleanenergywire.Org/News/Germany-Wants-Ensure-More-Green-Electricity-Used-Instead-Curtailed-Media>.
27. Lam, A.Y.S., Leung, K.-C., Li, V.O.K. (2016). Capacity Estimation for Vehicle-to-Grid Frequency Regulation Services with Smart Charging Mechanism. *IEEE Transactions on Smart Grid*, 7(1), 156-166. <https://doi.org/10.1109/TSG.2015.2436901>
28. Lee, H., Ban, J., Kim, S.W. (2022). Microgrid Optimal Scheduling Incorporating Remaining Useful Life and Performance Degradation of Distributed Generators. *IEEE Access*, 10, 39362-39375. <https://doi.org/10.1109/ACCESS.2022.3167037>
29. Lund, H., Østergaard, P.A., Connolly, D., Mathiesen, B.V. (2017). Smart energy and smart energy systems. *Energy*, 137, 556-565. <https://doi.org/10.1016/j.energy.2017.05.123>
30. Maddikunta, P.K.R., Pham, Q.-V.B.P., Deepa, N., Dev, K., Gadekallu, T.R., Ruby, R., Liyanage, M. (2022). Industry 5.0: A survey on enabling technologies and potential applications. *Journal of Industrial Information Integration*, 26, 100257. <https://doi.org/10.1016/j.jii.2021.100257>
31. Mahdad, B., Srairi, K. (2015). Blackout risk prevention in a smart grid based flexible optimal strategy using Grey Wolf-pattern search algorithms. *Energy Conversion and Management*, 98, 411-429. <https://doi.org/10.1016/j.enconman.2015.04.005>
32. Manditereza, P.T., Bansal, R. (2016). Renewable distributed generation: The hidden challenges – A review from the protection perspective. *Renewable and Sustainable Energy Reviews*, 58, 1457-1465. <https://doi.org/10.1016/j.rser.2015.12.276>
33. Ministerstwo Klimatu i Środowiska (2024). *Projekt\_aKPEiK\_2024-02-29*.

34. Money.pl (2024, April 29). <https://Zamieszanie-wokol-rekompensat-za-wylaczenia-fotowoltaiki-pse-interweniuje>. <https://Www.Money.Pl/Gospodarka/Zamieszanie-Wokol-Rekompensat-Za-Wylaczenia-Fotowoltaiki-Pse-Interweniuje-7020726411672480a.Html>.
35. Moslehi, K., Kumar, R. (2010). A Reliability Perspective of the Smart Grid. *IEEE Transactions on Smart Grid*, 1(1), 57-64. <https://doi.org/10.1109/TSG.2010.2046346>
36. Naz, A., Javaid, N., Rasheed, M.B., Haseeb, A., Alhussein, M., Aurangzeb, K. (2019). Game Theoretical Energy Management with Storage Capacity Optimization and Photo-Voltaic Cell Generated Power Forecasting in Micro Grid. *Sustainability*, 11(10), 2763. <https://doi.org/10.3390/su11102763>
37. Phuangpornpitak, N., Tia, S. (2013). Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System. *Energy Procedia*, 34, 282-290. <https://doi.org/10.1016/j.egypro.2013.06.756>
38. Salman, U., Khan, K., Alismail, F., Khalid, M. (2021). Techno-Economic Assessment and Operational Planning of Wind-Battery Distributed Renewable Generation System. *Sustainability*, 13(12), 6776. <https://doi.org/10.3390/su13126776>
39. Sarshar, J., Moosapour, S.S., Joorabian, M. (2017). Multi-objective energy management of a micro-grid considering uncertainty in wind power forecasting. *Energy*, 139, 680-693. <https://doi.org/10.1016/j.energy.2017.07.138>
40. Sgouridis, S., Abdullah, A., Griffiths, S., Saygin, D., Wagner, N., Gielen, D., Reinisch, H., McQueen, D. (2016). RE-mapping the UAE's energy transition: An economy-wide assessment of renewable energy options and their policy implications. *Renewable and Sustainable Energy Reviews*, 55, 1166-1180. <https://doi.org/10.1016/j.rser.2015.05.039>
41. SMA Solar AG (2020). *Sieć autonomiczna dla regionu Bordesholm: zasilanie elektryczne także w razie awarii sieci*. <https://Www.Sma-Solar.Pl/Large-Scale-Energy-Solution/Siec-Autonomiczna-Regionu-Bordesholm>.
42. Solar Power Europe (2023). *EU Market Outlook for Solar Power*.
43. SolarPower Europe (2024). European Market Outlook for Battery Storage. *SolarPower Europe*. [www.solarpowereurope.org](http://www.solarpowereurope.org)
44. Vaccaro, A., Velotto, G., Zobaa, A.F. (2011). A Decentralized and Cooperative Architecture for Optimal Voltage Regulation in Smart Grids. *IEEE Transactions on Industrial Electronics*, 58(10), 4593-4602. <https://doi.org/10.1109/TIE.2011.2143374>
45. Vita, V., Ekonomou, L., Christodoulou, C.A. (2016). The impact of distributed generation to the lightning protection of modern distribution lines. *Energy Systems*, 7(2), 357-364. <https://doi.org/10.1007/s12667-015-0175-3>
46. Wehrmann, B. (2024, April 9). *Curtailling of renewable power increases in Germany in 2023 as re-dispatch costs recede*. <https://Www.Cleanenergywire.Org/News/Curtailling-Renewable-Power-Increases-Germany-2023-Re-Dispatch-Costs-Recede>.

47. Wysokienapiecie.pl (2023, April 23). *PSE-oglosily-zagrozenie-bezpieczenstwa-przez-nadmiar-mocy-co-to-oznacza/*. [https://Wysokienapiece.Pl/86062-Pse-Oglosily-Zagrozenie-Bezpieczenstwa-Przez-Nadmiar-Mocy-Co-to-Oznacza/](https://Wysokienapiecie.Pl/86062-Pse-Oglosily-Zagrozenie-Bezpieczenstwa-Przez-Nadmiar-Mocy-Co-to-Oznacza/).
48. Zafeiropoulou, M., Mentis, I., Sijakovic, N., Terzic, A., Fotis, G., Maris, T.I., Vita, V., Zoulias, E., Ristic, V., Ekonomou, L. (2022). Forecasting Transmission and Distribution System Flexibility Needs for Severe Weather Condition Resilience and Outage Management. *Applied Sciences*, 12(14), 7334. <https://doi.org/10.3390/app12147334>



## INCREASING THE LEVEL OF MUNICIPAL WASTE RECYCLING IN POLAND, ON THE EXAMPLE OF THE KRAKOW METROPOLIS

Justyna OSTROWSKA<sup>1\*</sup>, Marta SZYBA<sup>2</sup>

<sup>1</sup> AGH University of Krakow; jmuweis@agh.edu.pl, ORCID: 0000-0001-6882-2690

<sup>2</sup> AGH University of Krakow; mszyba@agh.edu.pl, ORCID: 0000-0002-6340-3232

\*Correspondence author

**Purpose:** The aim of the article is to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to identify the factors that influence these results. In order to increase recycling rates in municipalities, a calculation method has been proposed that can help estimate the amount of biodegradable waste composted in households.

**Design/methodology/approach:** To achieve the goal of analyzing recycling levels in municipalities, data from the Local Data Bank of the Central Statistical Office and the Małopolska Marshal's Office were used. The proposed method for calculating the mass of composted biodegradable waste was based on exemplary declarations on composting of biodegradable waste posted on municipal websites and indicators such as the amount of kitchen waste generated/person/year and the amount of green waste generated in kg/m<sup>2</sup> of green areas.

**Findings:** The analysis of recycling levels shows the problems that municipalities may have in achieving the limits set by the European Commission. Actions must be taken to increase recycling rates in municipalities, and one of them may be a proposed method for calculating the amount of composted biodegradable waste in households. Failure to achieve recycling levels will result in administrative penalties imposed by the Provincial Inspectorates of Environmental Protection (WIOŚ) and failure to meet sustainable development goals.

**Research limitations/implications:** Municipalities have household declarations regarding composting of biodegradable waste. The continuation of the research concerned checking the correctness of data in municipalities on the size of plots and the area of green areas using satellite maps, e.g. [geoportal.gov.pl](http://geoportal.gov.pl)

**Practical implications:** The work uses an original calculation method, helpful in estimating the amount of biodegradable waste subjected to composting. Municipalities could use this method, which would help estimate the neglected amounts of this type of waste in households. By using the proposed method, the management of the biodegradable waste fraction would be more transparent and reliable, which would help increase the achieved recycling levels.

**Social implications:** The implementation of the proposed solution could change the approach of waste producers to the segregation of municipal waste and influence greater attention during segregating biodegradable waste. Consequently, this would also improve waste management and improve the results in achieving sustainable development goals in municipalities.

**Originality/value:** The article is an attempt of response to the need to achieve higher and higher levels of recycling. The proposed solution has implementation value and is addressed to organizations managing waste management in local government units.

**Keywords:** recycled materials, waste management, sustainability, circular economy, recycling rate.

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

## 1. Introduction

The transformation towards a circular economy is one of the goals of the European Green Deal, alongside others leading to the ecological transformation of Europe (European Green Deal, 2024). Waste is a function of consumption, but can be reincorporated into productive activities through recycling (Bongers, Casas, 2022). Hence, it is so important to increase the level of recycling to meet the requirements of the circular economy legislative package, which requires a significant increase in waste recycling goals in the coming years. The transformation of the economy towards an economy that efficiently uses resources, including natural raw materials, is part of national smart specialization and affects both the Polish economy and the natural and social environment (Closing the loop, 2015). Acting in accordance with the circular economy concept involves the maximum use of waste and its reduction based on the 6R concept: refuse, reduce, reuse, recover, give back for recycling (recycle), think about what you can do better (rethink) (Krajowa inteligentna specjalizacja, 2024). Therefore, from an ecological and economic point of view, the most effective method is to segregate waste at the place of its creation (so-called at the source), which is beneficial for increasing recycling levels.

The problem of the constantly growing amount of waste collected in landfills has forced the European Commission to introduce broad changes in waste management in member states. Particularly significant changes affected countries that joined the EU structures after 2004. An example is Poland, where the waste revolution began with the entry of the Waste Act on 1 July, 2013 (Ustawa z dn. 14 grudnia 2012). It imposed on communes the obligation to manage municipal waste generated by commune residents and other waste producers. Fees for municipal waste management were transferred to waste producers. This change resulted from the Act of 1 July, 2011 amending the Act on maintaining cleanliness and order in municipalities and certain other acts (Ustawa z dn. 17 grudnia 2020).

Due to the specificity and complexity of waste management problems, many municipalities in Poland have problems with achieving the required recycling levels. The problem clearly requires appropriate action by municipalities to meet the necessary requirements to achieve the established recycling levels in the EU. Failure of administrative units to meet the required levels of waste recycling will result in the imposition of administrative penalties by the Provincial Inspectorates of Environmental Protection (WIOŚ), which will be covered from municipal budgets. The consequence of these penalties may be higher fees for the collection of municipal waste from households and companies, set by municipal councils (Różowicz, 2023).



The aim of the article is to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to try to identify the factors that influence these results. To achieve this goal, data from the Central Statistical Office (GUS) and the Małopolska Marshal's Office were used. In the following, a calculation method is being proposed that could help in estimating the amount of biodegradable waste composted in households. Currently, this waste is difficult to verify in terms of its quantity by the authorities responsible for recording it. An appropriate approach and application of the solution proposed in this article could significantly increase the achieved recycling levels in municipalities.

## 2. Waste Management in Poland

Waste management in Poland is carried out in accordance with legal guidelines, systematically amended and harmonized with European Union regulations. One of the most important regulations regarding waste management in the EU is Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Dyrektywa 2008/98/EC). In Poland, regulations regarding waste management are included in the Act of December 14, 2012 on waste (Ustawa z dn. 14 grudnia 2012). Moreover, under this Act, national and provincial Waste Management Plans are applied and updated - the latest regulation covers activities until 2028 (Uchwała nr 96). Waste management plans also include activities to prevent waste generation, which are implemented in particular based on the National Waste Prevention Program. (Ustawa z dn. 14 grudnia 2012, Lisowska, 2017). Additionally, environmental impact forecasts and strategic environmental impact assessments are formulated (Ministerstwo Klimatu i Środowiska). The second important regulation for waste management in Poland is the Act of September 13, 1996 on maintaining cleanliness and order in municipalities (Ustawa z dn. 13 września 1996), which transfers responsibility for municipal waste management in Poland to municipalities. The scope of this responsibility includes: selective collection, cleaning of the commune, storage and disposal of waste (Ustawa z dn. 13 września 1996). Waste producers should also comply with the above-mentioned requirements act and guidelines of the Unified Waste Segregation System (JSSO), which has been in force in Poland since July 1, 2017. Segregation takes into account the following waste fractions and container colors: paper (blue), metals and plastics (yellow), glass (green or white for transparent glass, if separation occurs), BIO (brown), mixed waste (black) (Nasze śmieci JSSO). The commune settles accounts with individual households, cooperatives and communities that are responsible for organizing collections in their area (Ustawa z dn. 13 września 1996). Waste producers in the commune also use the so-called PSZOK, i.e. Selective Municipal Waste Collection Points, where someone can leave, among others,

bulky waste, construction waste, green waste, used tires, e-waste and chemicals (Nasze śmieci PSZOK).

The proper management of waste management is controlled by the Provincial Inspectorates of Environmental Protection (WIOŚ) and the commune head, mayor or president of the city (Ustawa z dn. 27 kwietnia 2001). Penalties for non-compliance with the requirements are imposed on enterprises by the Provincial Inspectorate of Environmental Protection. However, if waste producers fail to segregate waste, the act does not provide for a penalty, but rather an increased fee imposed by municipalities. According to the law, it may be at least twice and at most four times higher than the fee for segregators (Ustawa z dn. 13 września 1996). Leaving waste in unauthorized places is also prosecuted by the Police and is punishable by a fine under Art. 75 of the Code of Petty Offenses up to PLN 500 (Ustawa z dn. 20 maja 1971).

### 3. Recycling Levels in Poland

Fulfilling recycling requirements is difficult due to the multitude of problems encountered by Member States and the different initial situations when introducing changes in this area. The recycling rate of municipal waste in the EU shows a long-term relationship between macroeconomic variables and recycling performance at national and regional levels. Therefore, sociodemographic, economic and institutional factors are important for the levels achieved in different member states (Hondroyiannis et al., 2024). Significant improvements are still needed at company, product design, collection system and market level (Antonopoulos et al., 2021). Attention is also paid to the qualitative aspects of recycling and it is proposed to establish a supplementary recycling index that would combine the quantitative and qualitative aspects of recycling in one measure. (Roithner, Rechberger, 2020). Another challenge is still waste producers' environmental education (Pawul, Sobczyk, 2011).

Recycling rates for municipal waste are set out in Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Dyrektywa 2008/98/EC). In Poland, changes were introduced regarding the recycling levels of municipal waste by the Act of 17 December, 2020 amending the Act on maintaining cleanliness and order in municipalities and certain other acts (Ustawa z dn. 17 grudzień 2020). The levels mentioned are included in the National Waste Management Plan 2028 (KWPGO) (Uchwała nr 96). From 2021, the recycling level is determined for total municipal waste as the ratio of the amount of municipal waste recycled to the amount of municipal waste generated. The act indicates new values for municipal waste recycling levels that municipalities will be obliged to achieve in the years 2021-2035. The increase in the recycling rate is set as follows: 20% for 2021, 25% for 2022, 35% for 2023, 45% for 2024 and 55% in 2025. In the following

years, these amounts will increase by 1 percentage point, up to 60% in 2030. In 2035, the recycling rate will reach 65% and will also apply in subsequent years (Ustawa z dn. 17 grudnia 2020). Municipalities that will not fulfill the provisions of the Act, will be subject to a fine calculated separately for the required level: preparation for reuse and recycling of municipal waste; reducing the mass of biodegradable municipal waste sent to landfill (Ustawa z dn. 17 grudnia 2020).

In order to meet the set targets for municipal waste recycling rates, Poland will need to carry out the following actions: (Kopeć et al., 2023).

- implement the Waste Prevention Program (ZPO) and reduce the amount of waste generated,
- increase public awareness and knowledge about ZPO, also in the field of food ZPO,
- increase organic recycling by promoting composting of bio-waste by residents,
- ensure selective collection of bio-waste from residents and catering establishments.

One of the mentioned waste fractions, which poses many problems and has great potential for a higher level of recycling, is biodegradable waste (Kłopotliwa frakcja). This is a group of waste in which it is difficult to verify their quantity by the authorities responsible for recording them. It should be noted that the waste producers themselves do not pay enough attention to appropriate segregation and thus the separation of this fraction from mixed waste. There is often a lack of motivation, specific patterns and appropriate encouragement to deal appropriately with biodegradable waste (Szyba, Muweis, 2022).

One of the regulations specifying the method of calculating the levels of preparation for re-use and recycling and the conditions for including the mass of municipal waste in the mass of municipal waste prepared for re-use and recycled is the Regulation of the Minister of Climate and Environment of 3 August, 2021 on the method of calculating the levels of preparation for re-use and recycling reuse and recycling of municipal waste (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021). It also specifies the treatment of bio-waste until December 31, 2026. Bio-waste constituting municipal waste that has not been separately collected, but has been subjected to aerobic or anaerobic treatment, is classified as recycled waste, provided that it meets the conditions for including the mass of municipal waste in recycled waste. In the document you can find out how to calculate the levels of preparation for re-use and recycling of municipal waste for waste codes: 20 01 08 (biodegradable kitchen waste), 20 02 01 (biodegradable waste), 19 05 03 (non-compliant compost – unusable) (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021).

The Regulation presents formula (1) and information how to calculate the level of preparation for reuse and recycling of municipal waste:

$$P = \frac{M_r}{M_w} \quad (1)$$

where:

$P$  - level of preparation for reuse and recycling of municipal waste.

$M_r$  - total weight of municipal waste prepared for reuse and recycled.

$M_w$  - total weight of municipal waste generated (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021).

The biggest problem is still education and encouragement to segregate this fraction of waste in multi-family homes, where there is little space for segregation of this fraction of waste, and their collection is carried out in common garbage shelters. A solution could be to encourage people to collect biodegradable waste in special paper bags and throw them into waste containers. This solution operates in Sweden, where the achieved recycling levels are very high (Domżał, 2017).

According to waste data from marshal reports for 2020, in 831 municipalities from 11 Polish voivodeships the required levels of preparation for reuse and recycling were not achieved in 2020 (Szczepański, 2020).

## 4. Methodology and Results

### 4.1. Object of Research

The subject of the analysis of municipal waste recycling levels was Kraków and the communes belonging to the Krakow Metropolis. Krakow is a dynamically developing city, as evidenced by the increase in the number of inhabitants from 761,000 in 2015, to over 803 thousand in 2022. The Krakow Metropolis includes 14 communes (see Fig. 1). Four of them are urban-rural communes (Świątniki Górne, Skawina, Niepołomice and Wieliczka) and the remaining ones are rural communes (Zielonki, Michałowice, Kocmyrzów-Luborzyca, Igołomia-Wawrzeńczyce, Biskupice, Mogilany, Czernichów, Liszki, Zabierzów, Wielka Wieś). The average population density in these communes is 317 people/km<sup>2</sup> (the lowest in the Igołomia-Wawrzeńczyce commune - 123 people/km<sup>2</sup>, the highest in the Wieliczka commune - 614 people/km<sup>2</sup>). The mentioned communes were inhabited by approximately 330,000 people in 2022. A total of 1,133,000 people lived in the Krakow Metropolis in 2022. (GUS).



**Figure 1.** Communes belonging to the Krakow Metropolis.

Source: (Metropolia Krakowska)

#### 4.2. Municipal waste collected from households \*in Krakow and communes of the Krakow Metropolis

Households are obliged to collect five fractions of municipal waste, i.e. glass, paper and cardboard, plastics and metals, biodegradable waste and mixed waste. Biodegradable waste is divided into two types i.e. biodegradable kitchen waste and biodegradable waste. A detailed list of collected municipal waste along with their codes and container colors is provided in Table 1.

**Table 1.**

*Type and code of municipal waste generated in households*

Type of waste	Waste code	Color of the waste container (bag).
Plastics	20 01 39	Yellow
Metals	20 01 40	Yellow
Glass	20 01 02	Green
Paper and cardboard	20 01 01	Blue
Biodegradable kitchen waste(kitchen)*	20 01 08	Brown
Biodegradable waste (green)*	20 02 01	Brown
Mixed waste	20 03 01	Black

\* in the text, instead of the full name of the waste, the names written in brackets will also be used.

Source: Rozporządzenie Ministra Klimatu z dn. 2 stycznia 2020

The above mentioned waste fractions are collected by their producers into bags or containers marked with appropriate colors (see Table 1) and collected by companies that collect segregated waste (glass, paper and cardboard, plastics and metals) and mixed waste and both types of biodegradable waste (MPO Kraków).

Collected municipal waste from households should be recycled or reused, in accordance with the concept of circular economy (Circular Economy). The level of preparation for reuse and recycling of municipal waste in 2022 was required to be at least 25%. The adopted goal in 2022 was achieved in all analyzed municipalities (see table 2). In 2024, the required levels should reach 45%. As the data in Table 2 show, in some communes (including Kraków) this may be difficult to achieve. One of the reasons is biodegradable waste due to its quantity and difficulties in collecting related to the nuisance caused by odors and the presence of insects and rodents.

**Table 2.**

*Levels of preparation for use and use in Krakow and the municipalities of the Krakow Metropolis in 2022*

Community	% in years	
	2021	2022
Kraków	28	27
Biskupice	49	46
Czernichów	32	32
Igołomia-Wawrzeńczyce	14	27
Kocmyrzów-Luborzyca	47	42
Liszki	b.d.	29
Michałowice	45	29
Mogilany	27	32
Niepołomice	41	36
Skawina	38	38
Świątniki Górne	34	38
Wieliczka	20	26
Wielka Wieś	32	43
Zabierzów	20	34
Zielonki	21	39

Source: Dane z Urzędu Marszałkowskiego Województwa Małopolskiego.

Data on the amounts of municipal waste collected in Krakow and the Krakow Metropolis are presented in Table 3. In 2022, over 340,000 tons of waste were collected, including almost 260,000 tons in Krakow. Almost 257 thousand tons of mixed waste (code 20 03 01) was collected. The largest number of them is approximately 197,000 tons were collected in Krakow, and among the communes of the Krakow Metropolis. The most of them were collected in Wieliczka (over 12.5 thousand tons). The smallest amount of mixed waste was collected in the Igołomia-Wawrzeńczyce Commune (over 1.2 thousand tons).

Among the recycled fractions, the most biodegradable waste (approximately 62.5 thousand tons) was collected (20/02/01). Among the communes, the largest amount was collected in the Krakow Commune (approximately 52 thousand tons). Among the communes belonging to the Krakow Metropolis, most of them were collected in the Niepołomice Commune (approximately 3.7 thousand tons). The second largest amount of biodegradable waste collected was the Zabierzów Commune, where almost 1.7 thousand tons of waste was collected in 2022.

**Table 3.**

*Number of tons of municipal waste collected separately in households in Krakow and municipalities of the Krakow Metropolis in 2022*

Community	Plastics and metals <sup>1</sup>	Glass <sup>1</sup>	Paper and cardboard <sup>1</sup>	Biodegradable waste	Biodegradable kitchen waste	Mixed waste	Sum of waste fractions
	in tons						
Świątniki Górne	333.18	248.21	160.22	521.08	0	1 828.16	3090.85
Mogilany	277.21	449.38	334.46	32.88	1 170.93	2 945.76	5210.62
Skawina	1 224.62	633.82	402.30	589.12	709.76	8 899.50	12 459.12
Czernichów	516.06	343.12	110.54	567.15	0	3 539.74	5076.61
Liszki	339.66	532.42	405.18	126.46	595.84	2 208.49	4208.05
Zabierzów	726.78	830.94	483.02	1696.87	542.24	4 756.94	9036.79
Wielka Wieś	0.00	425.14	243.74	1090,7	0	2 787.90	3456.78
Zielonki	1 170.87	1 038.14	812.96	41.98	1 497.54	5 588.42	10 149.91
Michałowice	269.13	311.94	318.70	536.2	0	2 341.10	3777.07
Kocmyrzów-Luborzyca	524.03	397.98	309.93	1 096.34	0	3 364.54	5692.82
Igołomia-Wawrzeńczyce	0.00	122.12	0.00	0	0	1 249.42	1371.54
Niepołomice	925.49	853.20	628.30	3 755.29	245.70	6 411.76	12819.74
Biskupice	173.22	314.46	217.18	402.12	0	1 777.70	2884.68
Wieliczka	1 437.55	791.36	802.89	369.69	331.14	12 508.68	16 241.31
<i>Total communes</i>	<i>7 914.38</i>	<i>7 292.23</i>	<i>5 229.42</i>	<i>10,843.02</i>	<i>5,093.15</i>	<i>60 208.11</i>	<i>80 644.14</i>
Kraków	24 515.65	18 796.77	20 062.88	51,659.07	22,116.72	196 537.11	259 912.41
<i>Total Krakow and communes</i>	<i>32 430.03</i>	<i>26 089.00</i>	<i>25 292.30</i>	<i>62,502.09</i>	<i>27,209.87</i>	<i>256 745.22</i>	<i>340 556.55</i>

<sup>1</sup>GUS

<sup>2</sup>Dane z Urzędu Marszałkowskiego Województwa Małopolskiego

Biodegradable waste also includes kitchen waste (code 20 01 08). A total of over 27.2 thousand tons of waste were collected. Most of them, almost 18 thousand tons were collected in Krakow. From the municipalities surrounding Krakow – the communes of Zielonki collected almost 1.5 thousand tons and Mogilany almost 1.2 thousand tons. In the communes of Świątniki Górne, Czernichów, Wielka Wieś, Michałowice, Kocmyrzów-Luborzyca and Igołomia-Wawrzeńczyce, no records were kept of the collected amounts of selectively collected kitchen waste. Table 3 shows that in 2022, almost 90,000 tons of both fractions of biodegradable waste were collected.

Households also generate waste from glass, paper and cardboard, as well as biodegradable kitchen waste. In 2022, were collected over 26,000 tons of glass (code 20 01 02), almost 25.3 thousand tons of paper and cardboard (code 20 01 01) and over 32 thousand tons of plastics (code 20 01 39) and metals (code 20 01 40).

#### **4.3. Analysis of recycling rates of biodegradable waste collected from Krakow and the Municipalities of the Krakow Metropolis**

As previously written, two types of biodegradable waste are generated in households, i.e. biodegradable kitchen waste (code 20 01 08) and biodegradable waste (code 20 02 01). Kitchen bio-waste is organic waste generated at home from fruit and vegetable remains (peelings, spoiled fruit and vegetables, etc.), food remains (without meat and bones), coffee and tea grounds, egg shells, groats, pasta, rice. The second type of bio-waste is green waste from home gardens, i.e. grass, leaves, flowers and their stems, branches, etc. Both types of waste (except branches) are collected by their producers in brown bags or containers of the same color and taken away by waste collection companies that also collects mixed municipal waste.

Unfortunately, some biodegradable waste is thrown into mixed waste. This most often happens in multi-family houses with chutes. Some of it is composted by producers living in single-family homes. This form of development should be used more widely because it reduces the costs of collection and development incurred by municipalities.

The amount of biodegradable waste generated in households is difficult to estimate because it is related to the place of residence of the producers of this waste.

Favoino and Giavini estimate that these quantities are as follows: (Favoino, Giavinim, 2020).

- in cities – 40 kg/inhabitant/year,
- in the suburbs – 160 kg/inhabitant/year,
- in rural areas – 200 kg/inhabitant/year.

In order to determine the amount of biodegradable waste collected in the municipalities of the Krakow Metropolis, the average weight of biodegradable waste per inhabitant was calculated. The calculations used the data from Table 2 on the amount of biodegradable waste collected from households in Krakow and the municipalities of the Krakow Metropolis in 2022 and the data on the number of inhabitants is in Table 4. The calculation results are in Table 4.



**Table 4.**

*Amount of biodegradable waste and biodegradable kitchen waste per capita in Krakow and the municipalities of the Krakow Metropolis in 2022*

Commune	Number of inhabitants		Waste in kg/capita	
	total	people/km <sup>2</sup>	biodegradable (20 02 01)	kitchen (20 01 08)
Kraków	803 280	2 457,6	64.3	27.5
Świątniki Górne	11 100	545,3	46.9	0.0
Mogilany	16 200	370,4	2.0	72.3
Skawina	44 000	441,0	13.4	16.1
Czernichów	15 300	182,5	37.1	0.0
Liszki	18 400	255,5	6.9	32.4
Zabierzów	29 300	294,4	57.9	18.5
Wielka Wieś	16 500	340,7	66.1	0.0
Zielonki	27 200	559,0	1.5	55.1
Michałowice	13 200	257,6	40.6	0.0
Kocmyrzów-Luborzyca	18 000	216,6	60.9	0.0
Igołomia-Wawrzeńczyce	7 900	125,4	0.0	0.0
Niepołomice	32 800	340,4	114.5	7.5
Biskupice	11600	281,0	34.7	0.0
Wieliczka	68 000	682,5	5.4	4.9

Source: (Dane z Urzędu Marszałkowskiego Województwa Małopolskiego, 2023, GUS).

The data in Table 4 shows that the amounts of collected biodegradable waste per inhabitant vary significantly, also in municipalities of a similar nature. An example is the urban-rural communes of Niepołomice and Wieliczka. In the first one, 122 kg/person of both types of waste was collected, and in the second one, 10.3 kg/person. It was similar in the agricultural communes of Czernichów and Igołomia-Wawrzeńczyce. In the first one, 37.1 kg/person (including 0 kg of kitchen waste) was collected, and in the second one, 0 kg of both types of waste.

Continuing the analysis of the amount of waste generated per capita in individual communes, it was found that in 2022 the most biodegradable waste was generated by a resident of Niepołomice - 114.5 kg/person/year. In second place was Kraków, 64.3 kg/person, and in third place was the Kocmyrzów-Luborzyca Commune, 60.9 kg/person. In the case of the mentioned communes, only in Kraków the value given by Favoino and Giavini was exceeded. However, in urban and rural communes, which can be compared with the suburbs of cities, they were much lower. The situation was similar in rural communes.

It seems that assuming the amount of waste generated per capita is not very precise, because we have two types of biodegradable waste. The amount of kitchen waste certainly depends on the number of inhabitants, while the amount of biodegradable waste with code 20 02 01 depends on the size of the plot and the method of its development.

#### **4.4. Increasing levels of reuse and recycling of municipal waste**

The amendment to the Act on maintaining cleanliness and order in municipalities allows for reducing waste collection fees for residents who declare home composting of bio-waste. (Ustawa z dn. 13 września 1996). The municipalities of the Krakow Metropolis apply different

criteria when calculating reliefs. The Igołomia-Wawrzeńczyce commune applies a discount of PLN 5/person. In the case of one or two-person households with large plots, it may not be a sufficient incentive to set up home composters. The Niepołomice commune applies a lump sum of PLN 20 per farm (Miasto gmina Niepołomice). In this case, single-person households with small plots of land receive excessive relief. Establishing home composters is not conducive to the need to submit declarations, the completion of which is complicated and may contain imprecise data. In the Wieliczka Commune, information should be provided on the number of inhabitants of the property, the estimated capacity of the composter in  $m^3$ , the estimated annual amount of kitchen bio-waste and green bio-waste from gardens and green areas that will be managed in this composter (Ekowieliczka).

Composting waste by households allows municipalities to reduce the costs associated with the disposal of municipal biodegradable waste. However, there is a problem with determining the mass of this waste intended for composting in home gardens. Due to the obligation of municipalities to achieve the designated recycling levels, they should consider the possibility of including composted waste in the mass of biodegradable waste collected. This would allow for increasing indicators of the level of preparation for reuse and recycling of municipal waste. For this purpose, the authors of the publication proposed a method for calculating the mass of composted waste in households. The first step should be a declaration from the owners or users of the property, which should include the area of the plot -  $S_d$  and the green area -  $S_z$  in  $m^2$ . The plot area is known to the owner and the commune because it is used to calculate land tax. The area of the green area can be measured by the owner and the given size can be checked. The mass of biodegradable waste -  $M_b$  can be calculated from the equation (2):

$$M_b = M_z + M_k \text{ [kg/year]} \quad (2)$$

where:

$M_z$  - mass of green waste from the backyard plot (grass, leaves, plant remains vegetables, branches of ornamental and fruit bushes and trees),

$M_k$  - mass of kitchen waste.

The mass of green waste and the mass of kitchen waste can be calculated using the dependencies: (3) and (4):

$$M_z = S_z * m_z \text{ [kg/year]} \quad (3)$$

$$M_k = m_k * N \text{ [kg/year]} \quad (4)$$

where:

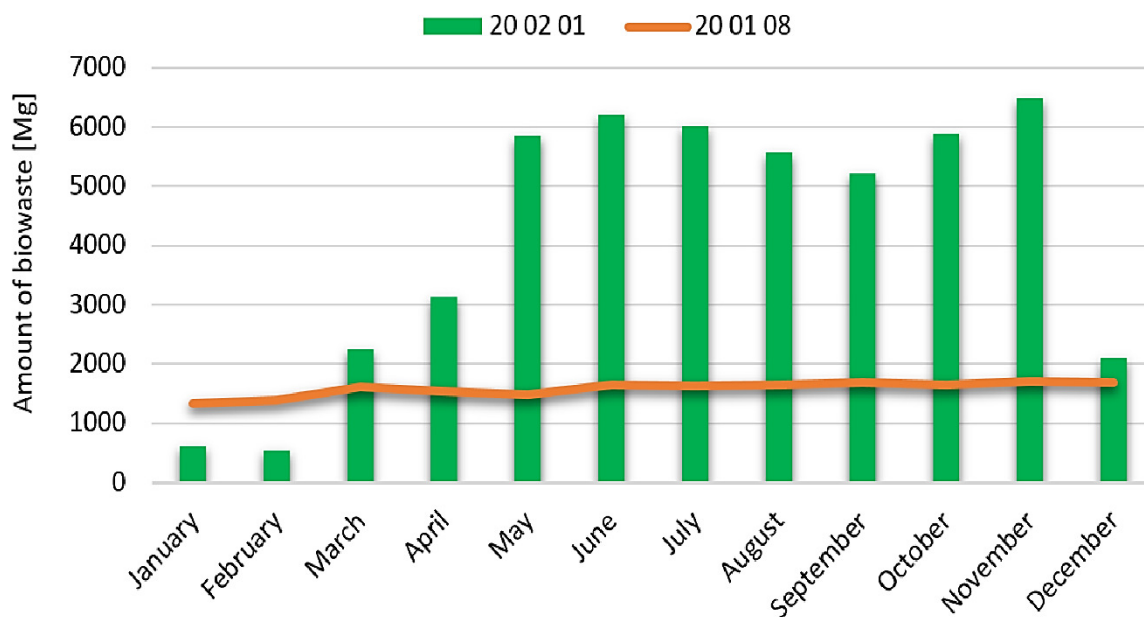
$m_z = 1,5-2,0$  [kg/ $m^2$  and year],

$m_k = 60-80$  [kg/person and year].

Coefficient values  $m_z$  i  $m_k$  were adopted according to: (Oszacowanie poziomu kompostowania bioodpadów).

A family of four, living in a house with an area of approximately 120 m<sup>2</sup>, built on a plot of 300 m<sup>2</sup>, with 150 m<sup>2</sup> of green area produces annually  $M_z = (1,5-2,0)*150,0 = 225,0$  to 300,0 kg of green waste and  $M_k = (60-80)*4 = 240$  to 320 kg of kitchen waste.

The estimated total weight of biodegradable municipal waste collected per year from a sample household is approximately 465 to 620 kg. The amount of biodegradable household waste collected will vary from month to month. As shown in Figure 2, kitchen waste is produced at an almost constant rate throughout the year. Green waste, on the other hand, is produced in greatest quantity from May to November. This is related to the growing season of plants and cleaning work in home gardens.



**Figure 2.** Amount of municipal biowaste collected Krakow in 2022.

Source: Szyba, Mikulik, 2023.

## 5. Summary

Recycling rates set by the European Commission are increased every year and are expected to reach 65% by 2035. In Poland, in 2023, the recycling rate was only 28% (Ecoekologia.pl). Biodegradable waste, which is one of the municipal waste fractions, plays an important role in achieving the recycling levels set for municipalities in Poland. Unfortunately, this fraction of waste is still neglected and is reluctantly segregated by waste producers, and its stream ends up in mixed waste. Households that separate biodegradable waste (green and kitchen) can do it in two ways. One of them is collecting waste into brown bags or containers or composting it in home composters. The information contained in the article shows that a significant part of biodegradable waste is disposed of in composters, especially in households located in rural

communes of the Krakow Metropolis where agricultural production is carried out. The compost produced is used as a natural fertilizer. In rural and urban-rural communes, financial discounts are introduced for running a home composter. On farms where large amounts of biodegradable green and kitchen waste are generated, collecting waste into bags is impossible due to their limit. The valuable mass of waste that can be included in recycling rates is incalculable. For these reasons, the aim of the article was to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to identify the factors that influence these results. To improve the current indicators, a calculation method was proposed that could help estimate the amount of biodegradable waste composted in households. A tool that could help collect data to estimate the mass of waste would be a survey for households declaring composting of biodegradable waste. Property owners and managers should provide the plot area, green areas and the number of people in the household in the application form. Based on this information, the amount of waste composted per year in a given household would be estimated.

## References

1. *Ankieta dotycząca zagospodarowania bioodpadów w kompostowniku*. Retrieved from: <https://wieliczka.konsultacjejst.pl/konsultacje/018e13b1-47ef-44ff-9ea6-ddebf79e6bc7>, 16.04.2024.
2. Antonopoulos, I., Faraca, G. et al. (2021). Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers. *Waste Management, Vol. 126*, pp. 694-705.
3. *Baza danych o produktach i opakowaniach oraz o gospodarce odpadami [Database on products and packaging and waste management]*. Retrieved from: <https://bdo.mos.gov.pl>, 16.04.2024.
4. Bongers, A., Casas, P. (2022) The circular economy and the optimal recycling rate: A macroeconomic approach. *Ecological Economics, Vol. 199*, p. 107504.
5. Closing the loop - EU action plan for a circular economy, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 2/12/2015, COM (2015) 614 final. Retrieved from: [https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC\\_1&format=PDF](https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF), 9.04.2024.
6. *Dane z Urzędu Marszałkowskiego Województwa Małopolskiego [Data from Marshal's Office of the Małopolska Voivodeship]* (2023).

7. Domżał, R. (2017) W Szwecji z resztek żywności pozyskują energię. *Biomasa na świecie, Magazyn Biomasa [In Sweden, they obtain energy from food leftovers, Biomass in the world, Biomass Magazine]*, no. 7(36), p. 34.
8. Dyrektywa Parlamentu Europejskiego i Rady 2008/98/WE z dnia 19 listopada 2008 r. w sprawie odpadów oraz uchylająca niektóre dyrektywy, Dz.U. L 312 z 22.11.2008, pp. 3-30 [*Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives*] Journal of Laws OJ L312, 22.11.2008 (2008).
9. Ecoekonomia.pl. Retrieved from: <https://ecoekonomia.pl/2024/03/05/jak-segregowalismy-odpady-w-2023-roku/>, 14.05.2024.
10. *Ekowieliczka*. Retrieved from: <https://eko.wieliczka.eu/pl>, 15.05.2024.
11. *European Green Deal*. Retrieved from: [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal\\_pl](https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_pl), 9.04.2024.
12. Favoino, E., Giavini, M. (2020). *Bio-waste generation in the EU: Current capture levels and future potential*. This report was commissioned by the Bio-based Industries Consortium (Bio-based Industries Consortium), p. 50.
13. *GUS Bank Danych lokalnych [GUS Local Data Bank]*. Retrieved from: <https://bdl.stat.gov.pl/bdl/dane/podgrup/temat>, 15.04.2024.
14. Hondroyiannis, G., Sardianou, E. et al. (2024). Recycling rate performance and socioeconomic determinants: Evidence from aggregate and regional data across European Union countries. *Journal of Cleaner Production*, Vol. 434, p. 139877.
15. *Kłopotliwa frakcja [A troublesome fraction]*, PAP Local Government Service. Retrieved from: <https://samorzad.pap.pl/kategoria/srodowisko/kłopotliwa-frakcja-branza-smieciowa-apeluje-o-rozwiazania-dla-bioodpadow>, 29.03.2024.
16. Kopeć, M., Szewczyk, W., et al. (2023) Szacowanie potencjału bioodpadów w przykładowej gminie [Estimating the potential of bio-waste in an example community]. *Polish Journal for Sustainable Development*, T. 27, cz. 2. Polskie Towarzystwo Inżynierii Ekologicznej w Rzeszowie, Oddział Południowo-Wschodni, Polskie Towarzystwo Gleboznawcze Oddział w Rzeszowie, pp. 35-42.
17. *Krajowa inteligentna specjalizacja [National smart specialization]*. Retrieved from: <https://smart.gov.pl/pl/gospodarka-o-obiegu-zamknietym/opis-specjalizacji>, 10.04.2024.
18. Lisowska, A. (2017). Cechy polityki ochrony środowiska na poziomie gminy [Features of environmental protection policy at the commune level]. *Samorząd Terytorialny [Local Government]*, 4, pp. 49-55.
19. *Metropolia krakowska [Krakow Metropolis]*. Retrieved from: [https://businessinmalopolska.pl/images/publikacje/MK\\_wersja\\_do\\_internetu\\_pl.pdf](https://businessinmalopolska.pl/images/publikacje/MK_wersja_do_internetu_pl.pdf), 14.04.2024.

20. *Miasto i gmina Niepołomice - gospodarka odpadami* [Niepołomice-waste management]. Retrieved from: <https://www.niepolomice.eu/informator-categories/gospodarka-odpadami-1/>, 16.04.2024.
21. *Ministerstwo Klimatu i Środowiska* [Ministry of Climate and Environment] Retrieved from: [bip.mos.gov.pl](http://bip.mos.gov.pl), 16.02.2024.
22. *MPO Krakow*. Retrieved from: <https://mpo.krakow.pl/pl/mieszkancy/selekcja/zasady>, 14.04.2024.
23. *Nasze śmieci. JSSO* [Our Garbage. JSSO]. Retrieved from: <https://naszesmieci.mos.gov.pl/materialy/artykuly/130-jednolity-system-segregacji-odpadow>, 12.04.2024.
24. *Nasze śmieci. PSZOK* [Our Garbage. PSZOK]. Retrieved from: <https://naszesmieci.mos.gov.pl/materialy/artykuly/148-pszok-legalny-i-wygodny-sposob-na-klopotliwe-odpady>, 9.05.2024.
25. *Oszacowanie poziomu kompostowania bioodpadów*. Retrieved from: <https://odpady.net.pl/wp-content/uploads/2021/05/Zalacznik-3-18.5-1.pdf>, 19.05.2024.
26. Pawul, M., Sobczyk, W. (2011). Edukacja ekologiczna w zakresie gospodarki odpadami jako narzędzie realizacji zrównoważonego rozwoju [Ecological education in the field of waste management as a tool for implementing sustainable development]. *Problemy Ekorozwoju* [Problems of Sustainable Development], vol. 6, no. 1, pp. 147-156.
27. Roithner, C., Rechberger, H. (2020). Implementing the dimension of quality into the conventional quantitative definition of recycling rates. *Waste Management*, Vol. 105, pp. 586-593.
28. Rozporządzenie Ministra Klimatu i Środowiska z dnia 3 sierpnia 2021 r. w sprawie sposobu obliczania poziomów przygotowania do ponownego użycia i recyklingu odpadów komunalnych. Dz.U. z dnia 20 sierpnia 2021 r., poz. 1530, par. 10. [Regulation of the Minister of Climate and Environment of 3 August 2021 on the method of calculating the levels of preparation for reuse and recycling of municipal waste]. *Journal of Laws*, August 20, 2021, item 1530, par. 10 (2021).
29. Rozporządzenie Ministra Klimatu z dnia 2 stycznia 2020 w sprawie katalogu odpadów, Warszawa dnia 3 stycznia 2020 r. poz 10 [Regulation of the Minister of Climate of 2 January, 2020 on the waste catalog, Warsaw January 3, 2020, item 10].
30. Różowicz K. (2023). Krajowa Izba Odwoławcza o karach za poziomy recyklingu. *Przegląd Komunalny*, 3(378). Retrieved from: <https://portalkomunalny.pl/plus/artykul/krajowa-izba-odwolawcza-o-karach-za-poziomym-recyklingu/>, 27.03.2024.
31. Szczepański, K. (ed.) (2020). *Sprawozdania marszałków województw z realizacji zadań z zakresu gospodarowania odpadami komunalnymi w 2020 r.* Instytut Ochrony Środowiska – Państwowy Instytut Badawczy (IOŚ-PIB). Retrieved from: <https://ios.edu.pl/wp-content/uploads/2022/08/raport-gospodarowanie-odpadami-komunalnymi-w-2020-r-sprawozdania-marszalkow-wojewodztw.pdf>, 14.05.2024.

32. Szyba, M., Muweis, J., (2022). The Importance of Biodegradable Waste in Transforming the Economy into a Circular Model in Poland. *Pol. J. Environ. Stud.*, Vol. 31, No. 3, pp. 2245-2253.
33. Szyba, M., Mikulik, J. (2023). Analysis of Feasibility of Producing and Using Biogas in Large Cities, Based on the Example of Krakow and Its Surrounding Municipalities. *Energies*, 16(22), 7588.
34. *Uchwała nr 96 Rady Ministrów z dnia 12 czerwca 2023 r. w sprawie Krajowego planu gospodarki odpadami 2028, M.P. 2023, poz. 702 [Resolution No. 96 of the Council of Ministers of 12 June, 2023 on the National Waste Management Plan 2028], M.P. 2023, item 702 (2023).*
35. *Ustawa z dnia 13 września 1996 r. o utrzymaniu czystości i porządku w gminach, Dz.U. z 2024 r. poz. 399. [Act of 13 September, 1996 on maintaining cleanliness and order in municipalities] Journal of Laws Laws of 2024, item 399 (2024).*
36. *Ustawa z dnia 14 grudnia 2012 r. o odpadach, Dz.U. z 2022 r., poz. 699, z póź.zm [Act of 14 December 2012 on waste], Journal of Laws of 2022, item 699, as amended (2022).*
37. *Ustawa z dnia 17 grudnia 2020 r. o zmianie ustawy o utrzymaniu czystości i porządku w gminach oraz niektórych innych ustaw, art. 1, Dz.U. z 2020 r. poz. 1439 i 2320 [Act of December 17, 2020 amending the Act on maintaining cleanliness and order in municipalities and certain other acts], Article 1, Journal of Laws of 2020, item 1439 and 2320 (2020).*
38. *Ustawa z dnia 20 maja 1971 r. Kodeks wykroczeń, art.75, Dz.U. z 2023 r. poz. 2119 [Act of 20 May, 1971, Code of Petty Offenses], Article 75, Journal of Laws of 2023, item 2119 (2023).*
39. *Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska art. 379, Dz.U. z 2024 r. poz. 54 [Act of 27 April, 2001 Environmental Protection Law] Art. 379, Journal Laws of 2024, item 54 (2024).*





## EVALUATING RISK IN THE OPERATION OF AGRICULTURAL MACHINERY BASED ON FARM SIZE

Maria PILARCZYK<sup>1\*</sup>, Robert ULEWICZ<sup>2</sup>

<sup>1</sup>Czestochowa University of Technology; mariapilarczyk5@gmail.com, ORCID: 0000-0001-7401-8885

<sup>2</sup>Czestochowa University of Technology; robert.ulewicz@pcz.pl, ORCID: 0000-0002-5694-4284

\* Correspondence author

**Purpose:** The aim of the study was to identify practical challenges, best practices, and solutions used during the deployment of agricultural machinery depending on the size of the farm

**Design/methodology/approach:** The method of observation and risk analysis was utilized in the operation of agricultural machinery using the FMEA method to identify potential threats and develop strategies for their mitigation.

**Findings:** Research conducted on farms has revealed significant issues such as improper maintenance, lack of safety guards, and outdated equipment. To enhance farm safety, it is recommended to adhere to maintenance schedules, replace old machinery with newer models, and use Failure Mode and Effects Analysis (FMEA) to identify and mitigate potential hazards.

**Research limitations/implications:** Further large-scale research is needed to develop effective strategies for improving farm safety. Implementing structured safety management systems like FMEA is recommended to systematically assess and minimize risks in both individual and large-scale farms.

**Practical implications:** Implementing recommended measures such as regular inspections and maintenance, replacing or modernizing outdated machinery, using appropriate safety guards, and participating in training sessions will help reduce the risk of machinery failures and the number of accidents.

**Originality/value:** This article presents new research findings on agricultural machinery safety in individual and large-scale farms, identifying significant issues and proposing specific improvement measures for farmers and agricultural safety experts. These insights help farmers understand risks better and implement safety enhancements when operating machinery.

**Keywords:** farm safety, agricultural efficiency, agricultural technology.

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

## 1. Introduction

Managing the safety of operating agricultural machinery is a cyclical process that begins with identifying sources of hazards. It involves determining all potential dangers associated with the use of agricultural machinery. Risk assessment is then carried out, which involves identifying how significant the potential hazards are when working with agricultural machinery and the likelihood of their occurrence. Risk assessment helps determine which hazards are most significant and require immediate preventive action. Based on hazard identification and risk assessment, preventive measures are taken to minimize the risk of accidents (Klimkiewicz, 2002).

Currently, there is growing pressure to ensure sustainable development, which also includes the agricultural sector. Sustainable agriculture combines aspects of work safety, production efficiency, and environmental protection (Carvalho et al., 2023; Kuzior et al., 2022). In the European Union, the safety and health of agricultural workers are becoming a priority. In Poland, as in other European countries, agriculture is one of the most dangerous sectors of the economy, and workplace accidents have serious consequences for people's health and lives. These hazards result not only from operating agricultural machinery but also from working with animals and using plant protection products.

The most differentiating factor in equipping farms with mechanization means is undoubtedly their size, measured by the area. The area is the main determinant of production scale (Muzalewski, 2007). Managing the deployment of agricultural machinery and work safety on farms requires considering technical, human, legal, and organizational aspects.

In Poland, small family farms dominate, often with limited financial and technological resources. This makes it difficult to invest in modern machinery and technologies that improve work safety and minimize negative environmental impact. An additional factor increasing the risk is the employment of a larger number of temporary workers, often without proper training. The lack of clear division of duties and supervision, especially in the case of family members' cooperation, can lead to dangerous situations (Rondelli et al., 2018; Moradhaseli et al., 2017).

Compared to family farms, large agricultural enterprises have greater financial and technological resources. Therefore, they can better manage work safety and implement more advanced sustainable development practices. These enterprises often employ trained workers in occupational safety and health and regularly conduct training for employees. The hierarchical organizational structure in large companies allows for better supervision of employees and division of responsibilities, reducing the risk of errors and accidents. Large enterprises use modern precision farming technologies, which allow for production optimization and reduced raw material consumption, positively impacting the environment (Caffaro et al., 2017). An effective agricultural policy should consider the specific needs of smaller farms to

encourage them to implement safer practices and technologies that promote sustainable development.

Among farmers and agricultural entrepreneurs, awareness of the negative effects of workplace accidents is increasing. There is a growing demand for solutions that will improve work safety in agriculture (Zambon et al., 2018). An effective agricultural policy should consider the specific needs of smaller farms to encourage them to implement safer practices and technologies that promote sustainable development. A joint effort by the government, scientific institutions, and representatives of the agricultural industry can contribute to creating better working conditions for farmers and protecting the natural environment.

The aim of the study was to identify practical challenges, best practices, and solutions used during the deployment of agricultural machinery depending on the size of the farm.

## **2. Management of agricultural machinery operation processes**

In the machinery operation process, distinct activities include utilization, servicing, power supply, and management. In individual farmsteads, the primary emphasis is on machinery operation, encompassing maintenance to keep them in operational condition and restoring required functionalities through inspections, repairs, and maintenance (Hu et al., 2019; Sims, Heney, 2017). Main servicing tasks involve periodic technical inspections, serving a preventive purpose and extending the period of trouble-free machinery operation. In large-scale farms, the focus is on machinery management and maintenance to ensure their optimal performance and long-term trouble-free operation (Wolak, 2018).

In individual farms, access to qualified services and specialized equipment is often lacking. The working environment of agricultural machinery is exceptionally demanding and diverse, requiring consideration of many factors during their operation and ensuring work safety (Arana et al., 2010; Lipiński et al., 2021; Ulewicz et al., 2023). These machines are exposed to extreme temperatures, moisture, dust, mud, and chemicals, which can accelerate wear and corrosion of structural elements and adversely affect their reliability. Additionally, these machines operate under high mechanical loads, causing wear of components and increasing the risk of failures. Strong vibrations generated during operation can lead to loosening of connections, cracking of machine parts, and damage to delicate electronic devices.

Tight schedules for field work, high costs of spare parts, and service fees often prompt farmers to attempt repairs themselves, which can lead to errors and deterioration of machinery condition. Servicing agricultural machinery increasingly requires specialized knowledge and skills due to advanced electronic, hydraulic, and mechanical systems (Kim et al., 2016).

Choi et al. (2024) identified insufficient machinery maintenance/management, inappropriate working environment, human factors, and inadequate education/training and lack of regulations or guidelines as the main causes of accidents in agriculture. Machinery degradation during operation poses a safety hazard in agriculture, especially in Polish individual farms, where the average age of machinery is high. The main factors influencing machinery degradation include intensive use, lack of regular maintenance, unfavorable weather conditions, and improper use of machinery. Hazards include breakdowns, fires, accidents, operator injuries, environmental pollution, work stoppages, and financial losses (Lundqvist, Gustafsson, 1992; Turgut et al., 2018).

Research shows that half of the accidents in agriculture occur during machinery operation, and two-thirds of them result from haste, fatigue, and stress. Improper machinery operation is associated with serious consequences stemming from their faulty technical condition. Assessing the technical condition of machinery is a crucial element of managing their operation (Khodabakhshian, 2013).

Active management of the machinery operation process aims to prevent unforeseen breakdowns and ensure their reliable performance. The reliability of agricultural machinery is one of the most critical factors determining the profitability of running a farm, as efficient machines enable timely field work, influencing yields and production quality. Proper management of machinery operation and workplace safety on a farm requires the implementation of several best practices, such as adhering to operating instructions, conducting regular technical inspections and maintenance, using appropriate personal protective equipment, maintaining cleanliness and order in the workplace, and adhering to safety protocols (Irwin, Poots, 2015). Training for farmers in machinery operation and maintenance also impacts machinery operation and workplace safety (Sorensen et al., 2017).

### **3. Risk analysis in the operation of agricultural machinery using the FMEA method**

Risk analysis is a crucial step in the operation of agricultural machinery, aiming to identify, assess, and eliminate potential hazards. Detecting and addressing these hazards can significantly reduce the risk of accidents and injuries on farms.

The Failure Mode and Effects Analysis (FMEA) method enables the identification and analysis of potential defects in agricultural machinery, as well as determining their possible consequences. Additionally, it allows for the identification of actions that can eliminate or minimize the risk of these defects and documenting the entire analysis process (Wolniak, 2018; Wolniak, 2019). The FMEA document requires regular reviews and updates even after the production process begins (Wolniak, Skotnicka, 2011; Wolniak, Skotnicka-Zasadzień, 2014).

Production processes in agriculture are subject to continuous changes due to factors such as seasonality, new technologies, and regulatory changes. Regular FMEA reviews enable the identification and assessment of new potential errors and hazards resulting from these changes.

Risk analysis using FMEA significantly reduces the risk of accidents and injuries in challenging and changing work conditions on farms. An important stage of FMEA is assessing the probability of occurrence, impact, and detectability of each potential failure. These three aspects are assessed using numerical scales, allowing for the calculation of the Risk Priority Number (RPN) for each of them. The RPN is the product of three factors: the probability of failure (P), which determines how often a particular failure may occur; the impact of the failure (S), which determines the consequences for the system; and the detectability of the failure (D), which determines the likelihood of detecting the failure before its consequences occur. After calculating the RPN for all potential failures, the FMEA team can easily identify those requiring immediate intervention. Corrective actions are typically prioritized based on the failures with the highest RPN, as they are the most likely and have the most severe consequences. The final stage of FMEA is monitoring and review. After implementing corrective actions, it is crucial to monitor their effectiveness and regularly review the entire FMEA analysis.

The probability of failure (P) is a scale used to assess the likelihood of machine failure risk.

**Criteria for assessing the probability of failure:**

1. Very low: The probability of failure under normal operating conditions is highly unlikely. The machine operates steadily and with high reliability.
2. Low: Very little chance of failure. The machine operates correctly, but minor failures may occur due to unforeseen events.
3. Moderately low: There is some probability of problems occurring, but they are sporadic and minor. They may occur due to improper use or unfavorable conditions.
4. Occasional possibility: The risk of failure is moderately high. Possible events several times a year even with proper operation, but they do not affect machine operation.
5. Fairly likely: There is a high probability of a problem occurring that could disrupt machine operations.
6. Likely occurrence several times a year: The risk of failure is very high. Problems may occur frequently and cause serious disruptions in machine operation.
7. Very high probability: Failures may occur frequently, regularly, and may cause significant problems.
8. Very high chance of occurrence: Failures are practically certain to occur frequently under normal conditions. They may cause significant disruptions in machine operation.
9. Almost certain to occur: The event is practically guaranteed to occur under certain conditions.
10. Certain occurrence: Encompasses failures that will definitely occur under normal machine operating conditions.

Potential impact (S) is used to assess the severity of the consequences of a failure.

**Criteria for assessing the potential impact:**

1. Insignificant: The failure does not cause any damage, injuries, or disruptions to the machine's operation.
2. Minimal: The failure may cause minor damage or injuries that do not require repair or interruption of work.
3. Small: The failure may cause minor damage or injuries, requiring minor repairs and a short interruption of work.
4. Minor: The failure may cause moderate damage or injuries, requiring repairs and a short interruption of work.
5. Moderate: The failure may cause significant disruptions in machine operations or injuries requiring immediate attention and intervention.
6. Significant: The failure may cause serious damage or injuries, requiring repairs and a longer interruption of work.
7. Large: The failure may cause serious damage or injuries, requiring major repairs and a longer interruption of work.
8. Very Large: The failure may cause very serious damage or injuries, requiring immediate shutdown of the machine and extensive repairs, and may have a significant impact on production or the environment.
9. Critical: The failure may cause extremely serious harm to human health and safety, as well as very large environmental pollution. Machines require immediate shutdown.
10. Catastrophic: The failure may cause catastrophic damage or injuries, as well as permanent environmental pollution. Machines require immediate shutdown and serious repairs. Catastrophic impact on production and the environment.

Detection difficulty (D) is used to assess the ease of detecting a potential failure before it occurs.

**Criteria for assessing the detection difficulty:**

1. Immediate detection ease: Failure is quick to locate and very easy to detect for anyone.
2. Very high detection ease: Detecting issues is possible but may require some effort. Failure is easily detectable by individuals with basic machine operation training.
3. High detection ease: Failure is detectable by experienced individuals familiar with the machine.
4. Moderate detection difficulty: Failure requires some effort or the use of specialized tools for detection.
5. Moderately challenging to detect: Failure requires more specialized knowledge or tools, which may be less common.
6. Difficult to detect: Failure is challenging to detect and requires significant technical knowledge and specialized diagnostic tools.

7. Very difficult to detect: Failure is very difficult to detect and requires advanced diagnostics, advanced skills, and specialized tools.
8. Extremely difficult to detect before failure: Failure is practically impossible to detect before it occurs and can only be detected through monitoring or data analysis.
9. Practically impossible to detect before failure: Failure is practically impossible to detect before it occurs and may be detected under highly unlikely circumstances.
10. Certain to be overlooked before failure: Failure is certain to occur, with no warning signs or possibility of detection before it occurs.

#### **4. Results and discussion**

Comparison of managing the process of safe operation of agricultural machinery in individual and industrial farms reveals some similarities and significant differences. Training, regular inspections, maintenance, adapting machinery to work conditions, compliance with regulations and safety standards, and risk management are elements of managing the process of safe operation of machinery on farms. These elements form a comprehensive management system aimed at ensuring maximum safety and efficiency in working with agricultural machinery.

The hazard analysis revealed that technical, organizational, and economic factors have a significant impact on the safety of working with agricultural machinery and tractors. A study conducted on individual and multi-area farms identified several important practices related to managing safety and the workflow of agricultural machinery operations. A common problem identified in individual farms was inadequate maintenance of machinery, which often led to increased risk of breakdowns and accidents. Additionally, in many cases, machines lacked necessary safety guards, which are important for protecting workers from potential injuries. The absence of these safeguards posed a serious threat to the health and lives of workers. In contrast to individual farms, such situations were sporadic in multi-area farms, mainly due to better work organization and higher investments in machinery maintenance. Multi-area farms have a more coordinated maintenance system, which includes regular inspections and servicing of machines. Additionally, employees in multi-area farms are usually more aware of safety and hygiene regulations, leading to strict compliance. This also includes the use of appropriate guards and safety features on machines, which are crucial for protecting the health and lives of workers. Multi-area farms more effectively minimize the risk of breakdowns and accidents associated with the operation of agricultural machinery due to a more professional infrastructure and higher safety standards.

Training and education for agricultural machinery operators vary depending on the scale of operations. In individual farms, the approach to training was typically less formal. Experienced workers or farm owners would instruct new operators on-site, demonstrating basic machine operation principles, safety regulations, and associated hazards. In contrast, multi-area farms had more formal training programs. These programs were conducted by qualified personnel with relevant knowledge and experience. They typically covered machine operation and maintenance principles, workplace safety and hygiene, first aid, and environmental protection issues. According to Kapela and Jabłonki (2008), a significant portion of individual farmers are willing to participate in training on agricultural machinery operation. Up to 42.5% of individual farmers are willing to dedicate up to 10 hours to training. The high willingness of farmers to participate in training indicates the existing demand for such services.

In agricultural farms, the approach to machinery inspection and maintenance varied depending on the scale of operations. In individual farms, farmers often conducted inspections and maintenance of agricultural machinery themselves or used the services of local mechanics. In contrast, on multi-area farms, there were formalized inspection and maintenance procedures in place. Qualified mechanics regularly checked the condition of the machines and replaced worn-out parts. They had access to specialized diagnostic equipment, allowing for more precise examination and diagnosis of faults. Regardless of the scale of operations, all farmers are required to carry out periodic technical inspections of sprayers. These inspections, conducted by authorized entities, confirm the efficiency of devices for applying plant protection products. It is also worth mentioning that some insurance policies may require combine harvesters to be inspected by an external company before insurance is granted. Improper maintenance of agricultural machinery, delaying necessary servicing activities, and replacing original consumables with cheaper alternatives are the main causes of unexpected breakdowns that can endanger workers (Jóska, Kołodziejcki, 2008).

In individual farms, older agricultural machinery was often used, which did not always meet current safety standards. This was due to financial constraints. As a result, the risk of breakdowns and accidents was higher. However, in multi-area farms, this problem was rare because owners invested in newer agricultural machinery, which was more reliable and met current safety standards. Additionally, they conducted regular maintenance of the machinery, which allowed them to keep it in good working condition and minimize the risk of breakdowns and accidents. Moreover, modern machinery was covered by manufacturer warranties, guaranteeing access to service and repairs if needed. The farm also had a schedule for regular maintenance and inspections of agricultural machinery. This allows for the detection and repair of faults at an early stage, preventing breakdowns and extending the lifespan of the machinery.

The process of adapting agricultural machinery to the specific needs of a farm varied depending on its size. In individual farms, the adjustment of machinery often occurred intuitively. Farmers relied on their own experience or the experience of their neighbors, adjusting the parameters of the machinery to current needs. In contrast, in multi-area farms,



a detailed analysis of the farm's specifics and the type of work to be performed was conducted before purchasing machinery. Based on this analysis, equipment with appropriate parameters and functionalities was selected. Additionally, in multi-area farms, there was the possibility of ordering machinery with special configurations or additional safety systems.

While multi-area farms typically adhere to more formal and comprehensive safety management systems for agricultural machinery, regulations regarding safety and hygiene during the operation of agricultural machinery apply to all farms, including individual ones (Regulation of the Minister of Agriculture and Rural Development of February 14, 2024), on safety and hygiene at work in the operation of tractors, machinery, tools, and technical devices used in agriculture (Official Gazette 2024, item 228). In individual farms, where farmers usually work alone or with family members, there is no obligation to conduct external safety inspections. However, this does not mean that these farmers are exempt from complying with regulations. The responsibility for safety lies solely with the farmer.

The greatest differences between individual farms and industrial-scale ones lie in risk management. In individual farms, farmers rely on their experience and intuition to identify hazards, and preventive actions are taken ad hoc, without a formal process. In contrast, industrial-scale farms employ formalized procedures, precisely identifying and managing risks by implementing accident and malfunction prevention systems. Marks-Bielska et al. (2018) demonstrated that the vast majority of individuals working on farms (80%) were unaware of the types of risks they are exposed to.

The findings suggest that improving workplace safety with agricultural machinery on individual farms requires the implementation of formal training programs, easy access to safety information, and financial support for the purchase of modern machinery. Encouraging farmers to collaborate and exchange experiences can increase awareness and improve safety practices.

In large-scale farms, it's essential to maintain and update training programs, invest in modern machinery and technologies, and implement monitoring and diagnostic systems. Regular inspections and maintenance should be conducted by qualified mechanics. Risk management systems need to be regularly reviewed and updated to ensure effective protection for workers.

In addition to the above-mentioned actions, implementing a structured safety management system, such as Failure Modes and Effects Analysis (FMEA), could significantly enhance safety when working with agricultural machinery in both individual and large-scale farms.

The application of the Failure Mode and Effects Analysis (FMEA) method in assessing risks associated with the safety of agricultural machinery on farms has yielded critical insights into potential hazards and necessary corrective actions. The results summarized in tables 1 and 2 of the FMEA illustrate various threats, their calculated Risk Priority Number (RPN), and suggested interventions. A threshold RPN of 120 was established to prioritize issues requiring immediate attention.

**Table 1.**

*Determining the level of risk of hazards in the safe operation of agricultural machinery in individual farms using the FMEA method*

Hazard ID	Description of hazard	Probability of failure (1-10)	Potential impact (1-10)	Detection difficulty (1-10)	RPN
Z1	Unshielded moving parts	8	9	4	288
Z2	Use of outdated tractors	6	7	6	252
Z3	High machine workload	6	6	6	216
Z4	Lack of regular maintenance	8	9	4	288
Z5	Operation in harsh conditions	4	8	8	256
Z6	Ignoring safety protocols	10	8	4	320
Z7	Inadequate operator training	6	6	6	216
Z8	Use of non-standard parts	6	8	8	384
Z9	Poor electrical insulation	8	10	4	320
Z10	Overloading of machines	8	6	6	288

Source: Own research.

**Table 2.**

*Determining the level of risk of hazards in the safe operation of agricultural machinery in large-scale farms using the FMEA method*

Hazard ID	Description of hazard	Probability of failure (1-10)	Potential impact (1-10)	Detection difficulty (1-10)	RPN
Z1	Unshielded moving parts	4	9	3	108
Z2	Use of outdated tractors	3	7	4	84
Z3	High machine workload	6	6	5	180
Z4	Lack of regular maintenance	3	9	4	108
Z5	Operation in harsh conditions	4	8	8	256
Z6	Ignoring safety protocols	4	8	3	96
Z7	Inadequate operator training	2	6	6	72
Z8	Use of non-standard parts	4	8	6	192
Z9	Poor electrical insulation	4	10	4	160
Z10	Overloading of machines	6	6	4	144

Source: Own research.

In this analysis, a permissible threshold value of the Risk Priority Number (RPN) was set at 160. This means that any threats with a resulting score exceeding this value are classified as highly risky and require immediate as well as strategic corrective actions to effectively mitigate potential hazards. The analysis of individual threats is as follows:

High-Risk Threats (RPN > 160):

**Z1: Unshielded moving parts (RPN = 288)**

In individual farms, this threat poses significant risks due to the potential for serious injuries such as cuts, amputations, or even fatal accidents. The immediate installation of protective guards on all machines with moving parts is absolutely necessary. Additionally, regular safety checks to verify the integrity and functionality of these guards are crucial for maintaining a safe work environment.

**Z2: Use of outdated tractors (RPN = 252)**

In individual farms, the operation of outdated tractors can lead to increased failure rates, posing risks of mechanical failures resulting in operator injuries due to sudden stops or

component malfunctions. Strategies to minimize this risk include upgrading to newer models compliant with current safety standards, increasing the frequency of maintenance inspections, and implementing a rigorous training program to educate operators about potential hazards associated with operating older equipment.

### **Z3 to Z10 (RPN from 216 to 384)**

In individual farms, a significant level of threats is observed, such as excessive machine loading or poor electrical insulation, which exceed the permissible RPN level. This situation indicates systemic issues with machine maintenance, operational standards, and compliance with safety regulations. The implementation of a comprehensive set of corrective actions is necessary to improve this situation.

In multi-area farms, the only threat in this group is working conditions that may lead to excessive machine wear, increased risk of failures, and hazardous situations for operators. This suggests the existence of a more rigorous approach to safety, characterized by better risk control and more coordinated efforts to ensure safety.

### **Z3 (RPN 180) and Z4 (RPN 192)**

Threat Z3 pertains to high machine loading, which can lead to excessive wear and increased risk of failures. Meanwhile, threat Z8 is related to the use of non-compliant parts, which may cause machine malfunctions and increase the risk of accidents. In individual farms, all threats were in higher risk groups, suggesting greater risks associated with machine operation and potentially lower safety and maintenance standards. Jóska and Kołodziejcki (2008) also highlighted this issue, emphasizing that the condition of agricultural vehicles and machinery during their operation depends primarily on the proper selection of operational materials, the conditions of use, and the correct execution of maintenance activities. Failure to adhere to maintenance schedules properly leads to excessive wear of components, increased likelihood of failures, and consequently, accidents.

In multi-area farms, the remaining threats fall into the minimal risk group (Z1, Z2, Z4, Z6, Z7), which requires monitoring, and the significant risk group, which requires assessment and corrective actions (Z10).

Research conducted in individual farms reveals widespread issues with inadequate machine maintenance and a lack of necessary safety guards. These neglects lead to increased risks of equipment failures and accidents. The analysis by Pompeii et al. (2015) and our research indicate that improper use of equipment and the use of devices without appropriate safeguards are common in agriculture. Pompeii et al. (2015) found that 64.8% of tractors in agricultural holdings were defective. Similarly, Juliszewski (2007) identified that faulty machinery and poor technical condition (e.g., lack of shields on moving parts, defective telescopic PTO shafts) are among the main causes of agricultural accidents. Pawlak and Nowakowicz-Dębek (2015) demonstrated that one of the causes of agricultural accidents is a lack of knowledge about occupational health and safety (OHS) principles and reluctance to familiarize oneself with safety instructions for machine and equipment operation. Kogler et al. (2015) found that the

majority of agricultural accidents in Austria resulted from contact with machinery (55%) and loss of control over machinery (73%) during its operation (60%) and during harvest-related activities (63%). According to the research by Ichihara et al. (2019), machinery-related injuries (12.2%) were also the most common type of agricultural accidents in Japan. Another significant risk in individual farms is the improper use of machinery and equipment. Additionally, there is a clear correlation between the use of older machines and the frequency of equipment breakdowns, highlighting the risks associated with outdated agricultural tools. These results are consistent with the research of other authors, who also emphasize the higher risk of accidents in individual farms compared to multi-area farms. As Kuta and Cież (2013) point out, individual farms often have fewer opportunities to invest in new equipment and technology. Modern agricultural machinery can significantly improve the level of work safety.

In multi-area farms, only one threat in this category was identified, namely, working conditions that may lead to excessive machine wear, increased risk of failures, and hazardous situations for operators.

Compared to individual farms, multi-area farms stand out with characteristics such as fewer hazards and a more rigorous approach to safety. There is a lower number of risks related to machine maintenance, operational standards, and compliance with safety regulations, likely stemming from a stricter safety approach, which entails better risk control and more coordinated actions to ensure worker safety. As McNamara et al. (2021) report, in large agricultural farms, training in occupational safety and health increases employee awareness and contributes to reducing the number of accidents. However, it's essential to note that even in multi-area farms, it's not possible to completely eliminate the risk associated with working in unsuitable conditions. Therefore, despite generally better safety control in these farms, ongoing monitoring and risk management are still necessary to ensure full worker safety.

Ensuring safe working conditions in workshops and fields is essential for protecting the health and lives of farmers. This includes proper workshop equipment, adapting repair areas to safety requirements, and providing farmers with appropriate personal protective equipment.

To improve safety in agriculture, structured safety management systems such as FMEA should be implemented, allowing for systematic assessment and minimization of risks associated with machinery operation.

## 5. Conclusion

Technical, organizational, and economic factors have a significant impact on the safety of working with machinery on individual farms. In the surveyed individual farms, the most common irregularities included the lack of appropriate guards and protections, poor technical condition of machinery, and errors in operation. The aging of machinery and limited access to

servicing made it difficult for farmers to maintain them in proper technical condition. Machinery repairs often took place in unfavorable conditions, increasing the risk of accidents. Irregular inspections and maintenance led to breakdowns and damage.

In the multi-area farm, there is observed a lower number of hazards due to a rigorous approach to safety. Effective risk control methods are implemented, and safety procedures are regularly updated. Training programs for employees are also conducted. Support programs are utilized, and modern technologies are promoted. However, monitoring and risk management are still necessary to ensure full safety for the workers.

It is also crucial to raise awareness about the hazards associated with using old agricultural machinery and actively promote their replacement with new ones that meet current safety standards. The technical condition of agricultural machinery plays a vital role in work safety. Regular inspections and maintenance according to the manufacturer's recommendations are necessary to keep the machines in good technical condition. During repairs and maintenance of agricultural machinery, it is important to use only original spare parts. This ensures not only the durability of the machines but, above all, guarantees their safety during operation. Used agricultural equipment should have a visible CE marking and a declaration of conformity with the currently applicable regulations.

To improve workplace safety in both individual farms and large-scale farms, implementing structured safety management systems such as FMEA is recommended. These systems enable systematic assessment and minimization of risks associated with machinery operation.

## References

1. Arana, I., Mangado, J., Arnal, P., Arazuri, S., Alfaro, J.R., Jarén, C. (2010). Evaluation of risk factors in fatal accidents in agriculture. *Spanish Journal of Agricultural Research*, 8, pp. 592-595, doi:10.5424/sjar/2010083-1254.
2. Caffaro, F., Micheletti, M., Roccato, M., Cavallo, E. (2017). It does not occur by chance: A mediation model of the influence of workers' characteristics, work environment factors, and near misses on agricultural machinery-related accidents. *International Journal of Occupational and Environmental Health*, 7(23), pp. 52-59, doi:10.1080/10773525.2017.1404220.
3. Carvalho, A., José Sá, C., Correia, F., McDermott, O., Dinis-Carvalho, J., Fonseca, L. (2023). The Sustainable Impact of the Use of Science Based Targets in Organisations. *System Safety: Human - Technical Facility - Environment*, 5(1), pp. 231-239, doi:10.2478/czoto-2023-0025.

4. Choi, W., Kim, K., Jung, W. (2024). Mini Review (PRISMA) on Causes of Incidents and Injuries Occurring in Agricultural Workplaces. *Agriculture*, 14, 514, doi:10.3390/agriculture14040514.
5. Hu, Y., Xiao, S., Wen, J., Li, J. (2019). An ANP-multi-criteria-based methodology to construct maintenance networks for agricultural machinery cluster in a balanced scorecard context. *Computers and Electronics in Agriculture*, 158, pp. 1-10, doi:10.1016/j.compag.2019.01.031.
6. Ichihara, G., Matsukawa, T., Kitamura, F., Yokoyama, K. (2019). Risk factors for occupational accidents in agricultural enterprises in Japan. *Industrial Health*, 57(5), pp. 627-636, doi:10.2486/indhealth.2017-0218.
7. Irwin, A., Poots, J. (2015). The human factor in agriculture: An interview study to identify farmers' non-technical skills. *Safety Science*, 74, pp. 114-121, doi:10.1016/j.ssci.2014.12.008.
8. Jóska, M., Kołodziejcki, D. (2008). Wybrane problemy eksploatacyjne pojazdów i maszyn rolniczych w zakresie ich serwisowania. *Journal of Research and Applications in Agricultural Engineering*, 53(2), pp. 5-7.
9. Juliszewski, T. (2007). Postęp techniczny w rolnictwie a bezpieczeństwo pracy. *Atest*, 11, pp. 21-23.
10. Kapela, K., Jabłonka, R. (2008). Preferencje dotyczące szkoleń rolników z zakresu zespołowego użytkowania maszyn. *Inżynieria Rolnicza* 4(102), pp. 361-366.
11. Khodabakhshian, R. (2013). A review of maintenance management of tractors and agricultural machinery: preventive maintenance systems. *Agricultural Engineering International: CIGR Journal*, 15(4), pp. 147-159.
12. Kim, H., Lee, K., Räsänen, K. (2016). Agricultural injuries in Korea and errors in systems of safety. *Annals of Agricultural and Environmental Medicine*, 23, pp. 432-436, doi:10.5604/12321966.1219182.
13. Klimkiewicz, M. (2002). Bezpieczeństwo a obsługa techniczna maszyn w gospodarstwach rodzinnych. *Zeszyty Problemowe Postępów Nauk Rolniczych*, 486, pp. 569-575.
14. Kogler, R., Quendler, E., Boxberger, J. (2015). Occupational accidents with mowing machines in Austrian agriculture. *Annals of Agricultural and Environmental Medicine*, 5(22), pp. 137-141, doi:10.5604/12321966.1141383
15. Kuta, Ł., Cież, J. (2013). Ocena poziomu bezpieczeństwa pracy w rodzinnym gospodarstwie rolnym. *Journal of Research and Applications in Agricultural Engineering*, 58(2), pp. 92-97.
16. Kuzior, A., Pidorycheva, I., Liashenko, V., Shevtsova, H., Shvets, N. (2022). Assessment of National Innovation Ecosystems of the EU Countries and Ukraine in the Interests of Their Sustainable Development. *Sustainability*, 14, 8487, doi:10.3390/su14148487.

17. Lipiński, T., Ulewicz, R. (2021). The effect of the impurities spaces on the quality of structural steel working at variable loads. *Open Engineering*, 11(1), pp. 233-238. doi:10.1515/eng-2021-0024
18. Lundqvist, P., Gustafsson, B. 1992. Accidents and accident prevention in agriculture a review of selected studies. *International Journal of Industrial Ergonomics*, 10, pp. 311-319, doi:10.1016/0169-8141(92)90098-K.
19. Marks-Bielska, R., Babuchowska, K., Kucińska, O. (2018). Uwarunkowania zarządzania ryzykiem na przykładzie wybranych gospodarstw rolnych. *Zagadnienia Doradztwa Rolniczego*, 2, pp. 115-130.
20. McNamara, J., Fox, M., Kinsella, J., O'Connor, D. (2021). Promoting Farmer occupational safety and health (OSH) services through Extension. *Agronomy Research* 19(S2), pp. 1060-1074, doi:10.15159/AR.21.059.
21. Moradhaseli, S., Farhadian, H., Abbasi, E., Ghofranipour, F. (2017). Factors affecting the incidence of occupational accidents among farmers. *Health Education and Health Promotion*, 5, pp. 39-56.
22. Muzalewski, A. 2007. Koszty eksploatacji maszyn. *Instytut Budownictwa Mechanizacji i Elektryfikacji Rolnictwa*. Warszawa.
23. Pawlak, H., Nowakowicz-Dębek, B. (2015). Agriculture: accident-prone working environment. *Agriculture and Agricultural Science Procedia*, 7, pp. 209-214, doi:10.1016/j.aaspro.2015.12.019.
24. Pompei, D., Rossi, R., Vecchiola, R., Angelone, A.M., Fabiani, L. (2015). Accident prevention in agriculture in the ASL1 Abruzzo Local Health Service: protection facilities for tractors. *Medicina del Lavoro*, 106(4), pp. 261-70.
25. Rondelli, V., Casazza, C., Martelli, R. (2018). Tractor rollover fatalities, analyzing accident scenario. *Journal of Safety Research*, 67, pp. 99-106, doi:10.1016/j.jsr.2018.09.015.
26. Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 14 lutego 2024 r. w sprawie bezpieczeństwa i higieny pracy przy obsłudze ciągników, maszyn, narzędzi i urządzeń technicznych stosowanych w rolnictwie (Dz.U. 2024, poz. 228).
27. Sims, B., Heney, J. (2017). Promoting Smallholder Adoption of Conservation Agriculture through Mechanization Services. *Agriculture*, 7, 64, doi:10.3390/agriculture7080064.
28. Sorensen, J.A., Tinc, P.J., Weil, R., Drouillard, D. (2017). Symbolic Interactionism: A Framework for Understanding Risk-Taking Behaviors in Farm Communities. *Journal Agromedicine*, 22, pp. 26-35, doi:10.1080/1059924X.2016.1248306.
29. Turgut, K., Gurbuz, S., Oguzturk, H., Bican, S., Kama, A.K. (2018). An unknown cause of agricultural accidents: Hoeing machine. *Eurasian Journal of Emergency Medicine*, 17, pp. 28-32, doi: 10.5152/eajem.2018.22931.
30. Ulewicz, M., Walkowiak, W., Brandt, K., Porwolik-Czomperlik, I. (2023). Ion flotation of zinc(II) and cadmium(II) in the presence of side-armed diphosphaza-16-crown-6 ethers. *Separation Science and Technology*, 38(3), pp. 633-645, doi:10.1081/SS-120016655.

31. Wolak, A. (2018). TBN performance study on a test fleet in real-world driving conditions using present-day engine oils. *Measurement*, 114, pp. 322-331, doi: 10.1016/j.measurement.2017.09.044.
32. Wolniak, R. (2018). *Basic concepts of operation management and its control*. Gliwice: Wydawnictwo Politechniki Śląskiej.
33. Wolniak, R. (2019). Problems of use of FMEA method in industrial enterprise. *Production Engineering Archives*, 23, pp. 12-17. doi:10.30657/pea.2019.23.02
34. Wolniak, R. (2019). Problems of use of FMEA method in industrial enterprise. *Production Engineering Archives* 23, pp. 12-17, doi: 10.30657/pea.2019.23.02.
35. Wolniak, R., Skotnicka, B. (2011). Metody i narzędzie zarządzania jakością. *Teoria i Praktyka*. Gliwice: Politechnika Śląska.
36. Wolniak, R., Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija*, 53(4), pp. 709-712.
37. Zambon, I., Piergentili, A., Salvati, L., Monarca, D., Matyjas-Łysakowska, P., Colantoni, A. (2018). Applied Research for a Safer Future: Exploring Recent Job Accidents in Agriculture, Italy (2012-2017). *Processes*, 6, 87, doi:10.3390/pr6070087.



## LIFESTYLE AS DETERMINANT OF EDIBLE INSECT FOOD CONSUMPTION AMONG SELECTED MEMBERS OF GENERATION Z

Anna PLATTA<sup>1\*</sup>, Anna MIKULEC<sup>2\*</sup>, Monika RADZYMIŃSKA<sup>3</sup>

<sup>1</sup> Faculty of Management and Quality Science, Gdynia Maritime University; a.platta@wznj.umg.edu.pl, ORCID: 0000-0002-7963-1889

<sup>2</sup> Faculty of Engineering Sciences, University of Applied Science in Nowy Sącz; amikulec@ans-ns.edu.pl, ORCID: 0000-0002-2737-5967

<sup>3</sup> Faculty of Economic Sciences, Institute of Management Science and Quality, University of Warmia and Mazury in Olsztyn; mradz@uwm.edu.pl, ORCID: 0000-0003-0531-268X

\* Correspondence author

**Purpose:** This study aimed to determine whether the lifestyles of young consumers (students) in Poland can influence their attitudes towards foods containing edible insects.

**Design/methodology/approach:** The empirical survey was conducted via an online platform (CAWI) among 749 students in Poland in 2023.

**Findings:** The younger consumers, namely students, were characterised by positive attitudes towards food with edible insects. These consumers demonstrated an attentiveness to the consumption of foods with high nutritional value, a tendency towards physical activity, and a lack of attachment to the culinary traditions of their region of origin.

**Research limitations/implications:** The research has certain limitations. Despite the large size of the study group, the results obtained are not representative and cannot be generalised to the population of students in Poland.

**Practical implications:** The results of this study may be of use in the development of new edible insect-based food products.

**Social implications:** The research adds to the knowledge of the dietary behaviour of young adults (Generation Z) by taking into account lifestyle variables.

**Originality/value:** The study of young consumers' preferences, acceptance, and willingness to try, eat and/or buy insect-based foods plays a key role in the prospects of entomophagy in Poland.

**Keywords:** insect-based foods, edible insects, food sustainability, acceptance of novel foods, young consumers.

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

## 1. Introduction

Insect-based foods are rarely accepted by young consumers in Poland despite their nutritional and environmental potential. There is a discrepancy between consumers' understanding of the need to reduce meat consumption, due to issues such as climate change and insufficient agricultural land (Turan, Berber, Sesal, 2024), and their personal preference for foods containing edible insects in their composition (Modlinska et al., 2021; Piwowar et al., 2023). Over the past decade, numerous consumer studies have been conducted to understand the attitudes of consumers living in Western Europe towards edible insects (Onwezen et al., 2021; Puteri, Jahnke, Zander, 2023). These surveys have demonstrated a high level of neophobia, or reluctance to try new foods, among consumers in this region (Onwezen et al., 2021; Wassmann, Siegrist, Hartmann, 2021). In some studies, aversion to eating insects has been shown to correlate positively with a tendency to prefer familiar foods, lack of insect visibility and fear of new food production technologies (Schlup, Brunner, 2018). Consumer research has shown that the emerging insect-based food industry faces significant challenges, particularly in overcoming consumer aversion to eating insects (Barton, Richardson, McSweeney, 2020; Dupont, Fiebelkorn, 2020; La Barbera et al., 2018; Lammers, Ullmann, Fiebelkorn, 2019; Modlinska et al., 2020; Orsi, Voegelé, Stranieri, 2019; Petrescu-Mag, Rastegari Kopaei, Petrescu, 2022; Piwowar et al., 2023; Schäufele, Barrera Albores, Hamm, 2019).

It seems reasonable to look for factors influencing the attitudes of the younger generation towards new foods, including foods containing edible insects in their composition. It is estimated that Generation Z already accounts for around 26% (2.47 billion) of today's population ([www.earthweb.com/gen-z-statistics/](http://www.earthweb.com/gen-z-statistics/)), so its purchasing power is enormous and will continue to grow. Therefore, as the needs and expectations of new, young consumers change, strategies for reaching this group need to be developed. The traditional marketing approach, the 4Ps (product, price, place, promotion), is not working anymore. It is being replaced by a new way of working known as the 4Cs (consumer, cost, convenience, communication) (Al Laheebi, 2020). Generation Z tries to make conscious purchases, gather product information, analyse and compare - the most important thing is not the features and advantages of the product presented by the manufacturer, but the benefits and opportunities to satisfy specific needs that come with the purchase. They often choose products that are more expensive, but which represent the majority of value to them. They are often motivated by ecological reasons or are opposed to waste. Convenience of purchase and convenient access to information about the product and service is particularly important to them. To reach this audience, it is necessary to be able to select the most appropriate channel and form of communication. Above all, the message should be authentic, sincere, concrete, engaging, and, where possible and necessary, entertaining. It is therefore important to adopt an appropriate brand and product philosophy.

Consequently, identifying potential target consumers is of particular importance in the context of insect-based food products, as a clear divide has been discovered between consumers who are opposed to and those who are in favour of trying them (Sogari, Menozzi, Mora, 2017; Mikulec et al., 2024). Orsi, Voegelé and Stranieri (2019) and Verbeke (2015) proposed that the marketing of insect-based food products should focus on young people and children. This is not only because they represent future generations of consumers, but also because they exert a significant influence on the attitudes of those around them.

The aim of this study was to determine whether the lifestyles of young consumers (students) in Poland can influence their attitudes towards foods containing edible insects in their composition.

A research hypothesis was formulated: Lifestyle variables determine the attitudes of a selected group of Generation Z consumers towards food containing edible insects.

## 2. Research methodology

An empirical study was conducted among 749 students at three Polish universities: Gdynia Maritime University, the Academy of Applied Sciences in Nowy Sącz and the University of Warmia and Mazury in Olsztyn. The survey was conducted using a specially designed questionnaire, via a web-based platform (CAWI, Computer Assisted Web Interview) in 2023. All respondents gave their free, informed consent to participate in the survey and were assured of anonymity. Participants in the study were those declaring to eat all foods and not to limit their consumption of meat or animal products.

The survey questionnaire included statements relating to:

- Attitudes towards insect foods (4 items): I think buying new insect food is a good idea (1); I think buying new insect food is a wise choice (2); I like the idea of buying new, innovative insect food (3); Buying new, innovative insect food would be enjoyable (4) (Wang et al., 2013).
- Lifestyle (8 items): I am a person committed to work (1); I am a person committed to studying (2); I am a person pleasure oriented (3); I am a person who values convenience and speed of food preparation (4); I am a person who pays attention to the consumption of food with high nutritional value (5); I am a person who values the culinary traditions of the origin region (6); I am a person with high health consciousness (7); I am a person with high physical activity (8). The first, fifth, sixth, and seventh items were adapted from Arvola et al. (2007) and the others (2, 3, 4, 8) were additional.

During the survey, the respondent expressed his or her level of approval or disapproval of all the posted items using a 5-point Likert scale, where the values 1, 2, means: definitely not, rather not; the value 3 denoted an answer: I do not know, I have no opinion; and values 4, 5, corresponded to answers: rather yes, definitely yes (Likert, 1932).

The empirical material was presented in the form of a percentage distribution of the answers given regarding attitudes and lifestyle determinants. The answers were aggregated and presented for three groups: “no” (the number of “definitely no” and “rather no” responses were aggregated), “don't know/don't have an opinion” and “yes” (the number of “definitely yes” and “rather yes” responses were aggregated). A Chi-square test with Yates correction was conducted to determine the relationship between attitudes towards foods containing edible insects and lifestyle determinants. Spearman's rank correlation analysis was used to determine the relationship between attitudes towards insect food and lifestyle.

A multinomial ordered logit model was constructed with the dependent variable exploring attitudes towards foods containing edible insects. The explanatory variable was calculated based on the variables determining attitudes towards edible insect foods (i.e.: I think buying new foods containing insects is a good idea (1); I think buying new foods containing insects is a wise choice (2); I like the idea of buying new, innovative foods containing insects (3); Buying new, innovative foods containing insects would be enjoyable (4). Based on the responses, 3 attitudes were distinguished: negative, ambivalent and positive. The independent variables are lifestyle determinants. The objective variable is ordinal (categories: negative, ambivalent, positive).

A *p*-value of less than 0.05 was assumed for all statistical analyses. The calculations were performed using Microsoft Excel 2000 and Statistica 13.3 (Tibco Software, Palo Alto, USA).

### **3. Results and discussion**

The group of respondents comprised 749 individuals, of whom 412 were women and 337 were men. In terms of the lifestyle variables analysed, 59.68% of the respondents declared a commitment to work, while 86.85% indicated a commitment to study. This indicates that many students combine study with work. Among those surveyed, 81.02% declared themselves to be pleasure-oriented, 86.52% valued convenience and speed of food preparation, and only 64.36% paid attention to the high nutritional value of the food they consumed. Interestingly, less than half, 48.73%, indicated a valuing of the culinary traditions of the region they come from. In addition, 63.82% considered themselves to be health-conscious, and 51.26% considered themselves to be physically active (Table 1).

**Table 1.**  
*Study sample characteristics addressing lifestyle determinants*

Features	Number of people	% of indications
<b>Commitment to work</b>		
Definitely not	84	11.21
Rather not	118	15.76
I do not know/I have no opinion	100	13.35
Rather yes	255	34.05
Definitely yes	192	25.63
<b>Commitment to learning</b>		
Definitely not	11	1.47
Rather not	46	6.14
I do not know/I have no opinion	40	5.34
Rather yes	426	56.88
Definitely yes	226	30.17
<b>Pleasure-oriented</b>		
Definitely not	14	1.90
Rather not	36	4.80
I do not know/I have no opinion	92	12.28
Rather yes	407	54.32
Definitely yes	200	26.70
<b>Valuing the convenience and speed of food preparation</b>		
Definitely not	15	2.00
Rather not	35	4.67
I do not know/I have no opinion	51	6.81
Rather yes	353	47.13
Definitely yes	295	39.39
<b>Paying attention to the consumption of foods with high nutritional value</b>		
Definitely not	24	3.20
Rather not	112	14.95
I do not know/I have no opinion	131	17.49
Rather yes	294	39.26
Definitely yes	188	25.10
<b>Valuing the culinary traditions of the origin region</b>		
Definitely not	69	9.21
Rather not	167	22.30
I do not know/I have no opinion	148	19.76
Rather yes	228	30.44
Definitely yes	137	18.29
<b>High health consciousness</b>		
Definitely not	20	2.67
Rather not	102	13.62
I do not know/I have no opinion	149	19.89
Rather yes	313	41.79
Definitely yes	165	22.03
<b>High physical activity</b>		
Definitely not	52	6.94
Rather not	191	25.51
I do not know/I have no opinion	122	16.29
Rather yes	249	33.24
Definitely yes	135	18.02

Source: own elaboration based on survey results.

Only some lifestyle variables were found to influence the statements related to young consumers' attitudes towards food containing edible insects (Table 2-9).

The level of commitment to work or study did not significantly influence attitudes towards food containing edible insects, nor was there any correlation between the variables analysed. All groups were dominated by “no” and “I have no opinion” respondents. The most negative

responses were declared by respondents for statements such as “I like the idea of buying new, innovative foods containing insects” and “Buying new, innovative foods containing insects would be enjoyable” (Table 2-3).

**Table 2.**

*Attitudes towards food containing insects about work commitment*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	38.12	39.11	22.77	40.00	39.00	21.00	44.52	35.12	20.36	Chi2 = 2.6; df = 4; p = 0.62	-0.04
I think buying new insect food is a wise choice	37.13	42.57	20.30	38.00	44.00	18.00	43.18	38.26	18.56	Chi2 = 2.81; df = 4; p = 0.58	-0.04
I like the idea of buying new, innovative insect food	49.01	31.68	19.3	47.00	31.00	22.00	53.24	26.62	20.13	Chi2 = 2.61; df = 4; p = 0.62	-0.02
Buying new, innovative insect food would be enjoyable	52.97	36.63	10.40	54.00	34.00	12.00	57.49	33.33	9.18	Chi2 = 1.73; df = 4; p = 0.78	-0.04

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

**Table 3.**

*Attitudes towards food containing insects about commitment to learning*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	47,37	31,58	21,05	40,00	45,00	15,00	41,87	36,66	21,47	Chi2 = 2,37; df = 4; p = 0.69	0.03
I think buying new insect food is a wise choice	40,35	42,11	17,54	40,00	50,00	10,00	40,95	39,42	19,63	Chi2 = 3,31; df = 4; p = 0.51	0.04
I like the idea of buying new, innovative insect food	47,37	29,82	22,81	47,50	42,50	10,00	51,84	27,61	20,55	Chi2 = 5,69; df = 4; p = 0.22	-0.02
Buying new, innovative insect food would be enjoyable	54,39	33,33	12,28	57,50	40,00	2,50	55,83	34,05	10,12	Chi2 = 3.93; df = 4; p = 0.42	-0.01

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

The level of pleasure orientation and attention to convenience and speed of food preparation also did not significantly differentiate respondents in terms of their declared attitudes towards

food containing edible insects. And no correlation was observed between the variables analysed (Tables 4 and 5). The majority of respondents gave “no” and “I have no opinion” answers to questions related to attitudes towards products containing edible insects. The highest number of negative responses, over 50%, was observed for the statements: “I like the idea of buying new, innovative foods containing insects” and “Buying new, innovative foods containing insects would be enjoyable” (Table 4).

**Table 4.**

*Attitudes towards foods containing insects about pleasure orientation*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	46.00	40.00	14.00	42.39	38.04	19.57	41.85	36.24	21.91	Chi2 = 2.06; df = 4; p = 0.73	0.00
I think buying new insect food is a wise choice	48.00	42.00	10.00	43.48	42.39	14.13	39.87	39.70	20.43	Chi2 = 5.51; df = 4; p = 0.23	0.05
I like the idea of buying new, innovative insect food	56.00	32.00	12.00	55.43	29.35	15.22	50.25	28.17	21.58	Chi2 = 4.64; df = 4; p = 0.33	0.07
Buying new, innovative insect food would be enjoyable	60.00	32.00	8.00	59.78	32.61	7.61	59.78	32.61	7.61	Chi2 = 1.56; df = 4; p = 0.82	0.04

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

**Table 5.**

*Attitudes towards foods containing insects about convenience and speed of food preparation*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	58.00	28.00	14.00	47.06	41.18	11.76	40.59	37.04	22.38	Chi2 = 9.10; df = 4; p = 0.06	0.06
I think buying new insect food is a wise choice	54.00	28.00	18.00	41.18	49.02	9.80	39.81	40.43	19.76	Chi2 = 8.087; df = 4; p = 0.09	0.07
I like the idea of buying new, innovative insect food	60.00	26.00	14.00	58.82	27.45	13.73	50.00	28.86	21.14	Chi2 = 4.15; df = 4; p = 0.39	0.07
Buying new, innovative insect food would be enjoyable	64.00	32.00	4.00	64.71	27.45	7.84	54.48	35.03	10.49	Chi2 = 5.13; df = 4; p = 0.27	0.07

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

The surveyed group of students declared that they pay attention to the consumption of foods with high nutritional value. This was found to be a significant differentiating factor between respondents in terms of their answers to the two statements on the scale for assessing attitudes towards food containing edible insects. The majority of people, whether they paid attention to the high nutritional value of the food or not, were significantly more likely to answer that they did not like the idea of buying new, innovative foods containing edible insects ( $p = 0.03$ ) (49.59-56.49%). In contrast, students who could not specify whether they paid attention to the nutritional value of the food they consumed were significantly more likely to give answers that were ambivalent to the idea of buying new, innovative foods containing insects (32.82%). The distribution of responses was similar for the statement: “Buying new, innovative foods containing insects would be enjoyable” ( $p = 0.02$ ). Where a negative answer was given by 58.82% of students not paying attention to the high nutritional value of the food, 61.07% of those with no opinion on whether buying food containing edible insects would be pleasant and 53.53% of those paying attention to the nutritional value of the food consumed (Table 6).

**Table 6.**

*Attitudes towards foods containing insects about paying attention to the consumption of foods with high nutritional value*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	39.71	40.44	19.85	46.56	37.40	16.04	41.70	35.48	22.82	Chi2 = 4.03; df = 4; p = 0.40	0.03
I think buying new insect food is a wise choice	42.65	40.44	16.91	44.27	40.46	15.27	39.42	40.04	20.54	Chi2 = 2.66; df = 4; p = 0.62	0.04
I like the idea of buying new, innovative insect food	52.21	27.21	20.58	56.49	32.82	10.69	49.59	27.80	22.61	Chi2 = 10.39; df = 4; <b>p = 0.03</b>	0.03
Buying new, innovative insect food would be enjoyable	58.82	32.35	8.83	61.07	35.88	3.05	53.53	34.44	12.03	Chi2 = 12.32; df = 4; <b>p = 0.02</b>	0.03

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

The analysis of the collected material allowed the identification of the lifestyle variable that most influences respondents' attitudes towards foods containing edible insects in their composition. This variable is: “valuing the culinary traditions of the region of origin”. Significant negative correlations were observed between individual statements related to attitudes towards new foods and the level of valuing regional culinary traditions (Table 7). Whereby, the less the students valued culinary traditions the more positive attitudes towards foods containing edible insects in their composition were manifested. For the statement:



“I think buying new foods containing insects is a wise choice”, significant differences were observed between groups ( $p = 0.04$ ). Those who do not value the traditions of the region of origin and those with an ambivalent attitude to this lifestyle variable were significantly more likely to answer “I have no opinion”. In contrast, those who value the culinary traditions of the region of origin were significantly more likely to answer: “I don't think buying new foods with edible insects is a wise choice” (Table 7). The literature indicates that the tourist experience is an important factor in food awareness, a source of knowledge about the positive attributes of new foods, and a demand factor that determines the willingness to accept these innovations (Piwowar et al., 2023). Consumers who are looking for new food experiences tend to have a higher acceptance of insects as food (Ribeiro et al., 2022). Foreign travel was found to be an important factor influencing Polish consumers' perceptions of food innovation among 20-44 year-olds (Piwowar et al., 2023). According to the literature, the highest likelihood of consuming insect-based foods was observed in individuals with low levels of food neophobia and low disgust sensitivity, but with high levels of variety-seeking tendencies (Lammers, Ullmann, Fiebelkorn, 2019; Modlińska et al., 2021; Ribeiro et al., 2022; Rovai et al., 2021). It should be expected that tourist gastronomy will contribute to the popularisation of insects as food among young consumers in Poland.

**Table 7.**

*Attitudes towards foods containing insects about valuing the culinary traditions of the origin region*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R**
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	36.02	39.83	24.15	39.19	38.51	22.30	47.40	33.97	18.63	Chi2 = 8.52; df = 4; p = 0.07	<b>-0.13</b>
I think buying new insect food is a wise choice	33.46	45.76	20.76	39.19	41.22	19.59	46.30	36.16	17.54	Chi2 = 10.136; df = 4; <b>p = 0.04</b>	<b>-0.12</b>
I like the idea of buying new, innovative insect food	47.46	30.08	22.46	49.32	33.11	17.57	54.52	25.75	19.73	Chi2 = 4.93; df = 4; p = 0.29	<b>-0.10</b>
Buying new, innovative insect food would be enjoyable	54.24	37.29	8.47	55.41	33.78	10.81	56.99	32.60	10.41	Chi2 = 1.84; df = 4; p = 0.76	<b>-0.08</b>

Explanatory notes: \* N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude; \*\* bold values are statistically significant.

Source: own elaboration based on survey results.

Understanding which factors may influence consumer perceptions of edible insects plays a key role in the prospects of entomophagy consequently the production and consumption of new food proteins. According to Mancini et al. (2019), to achieve this goal, communication

with potential young consumers becomes crucial. Food choice motivations, such as convenience, health and ecological well-being, have minimal impact on the acceptance of insects as food and feed, among the Norwegian and Portuguese population (Ribeiro et al., 2022). In a study conducted among Polish students, we found similar relationships, as the level of pleasure orientation of the students surveyed and attention to convenience and speed of food preparation did not significantly affect their attitudes towards insect food (Table 4). In addition, health consciousness ( $p = 0.05$ ) and physical activity ( $p = 0.03$ ) of the respondents significantly influenced only one statement included on the scale for assessing attitudes toward new foods with edible insects: “I think buying new foods containing insects is a wise choice” (Table 8 and 9). In contrast, no correlation was observed between the variables analysed. It was found that, for the other lifestyle items, the predominant responses were “no” and “don't know/don't have an opinion” to individual statements describing attitudes towards new foods. Only those with high health consciousness were significantly more likely (21.34% of people), compared to the other groups (17.21% for those who did not declare high health consciousness and 12.75% for those with no opinion on whether they were characterised by high health consciousness) to give a “yes” answer to the statement: “I think buying new foods containing insects is a wise choice” (Table 8).

**Table 8.**

*Attitudes towards foods containing insects about health consciousness*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	47.54	35.25	17.21	40.27	43.62	16.11	41.42	34.94	23.64	Chi2 = 7.57; df = 4; p = 0.11	0.06
I think buying new insect food is a wise choice	47.54	35.25	17.21	39.60	47.65	12.75	39.54	39.12	21.34	Chi2 = 9.39; df = 4; <b>p = 0.05</b>	0.07
I like the idea of buying new, innovative insect food	58.20	27.05	14.75	51.68	31.54	16.78	49.37	28.03	22.60	Chi2 = 6.23; df = 4; p = 0.18	0.06
Buying new, innovative insect food would be enjoyable	59.84	33.60	6.56	59.73	33.56	6.71	53.56	34.73	11.71	Chi2 = 6.05; df = 4; p = 0.20	0.05

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

In contrast, they were significantly more likely to answer “yes” to the statement: “I believe that buying new foods containing insects is a wise choice”, which was given by those with low physical activity (22.64%, compared to only 9.84% of those with no opinion on whether they were a person with high physical activity and 19.53% of those with high physical activity)

(Table 9). According to the literature, young adults in Poland (generation Z) express a willingness to take several actions related to changing eating habits to improve the nutritional status of the body (Platta et al., 2023a, 2023b). The predominant ambivalent attitude among students in Poland towards health or environmental concerns in terms of willingness to consume edible insects (Mikulec et al., 2024) may lead to greater resistance or increased susceptibility to persuasion and influence. Ambivalent attitudes are assumed to be flexible and, depending on the context, can either help individuals to better adapt or prevent them from reaching satisfactory conclusions (Rothman et al., 2017; van Harreveld, Nohlen, Schneider, 2015). Therefore, opportunities should be created for young consumers to acquire positive experiences in the consumption of edible insect dishes, thus increasing the target group accepting edible insects as a food source.

**Table 9.**

*Attitudes towards insect food about physical activity*

Statements	No			I have no opinion			Yes			Chi2	Spearman's R
	[%]										
	N*	A	P	N	A	P	N	A	P		
I think buying new insect food is a good idea	42.39	34.98	22.63	44.26	41.80	13.94	41.40	36.20	22.40	Chi2 = 518; df = 4; p = 0.27	0.00
I think buying new insect food is a wise choice	38.68	38.68	22.64	42.62	47.54	9.84	41.67	38.80	19.53	Chi2 = 10.52; df = 4; <b>p = 0.03</b>	-0.01
I like the idea of buying new, innovative insect food	52.26	27.98	19.76	50.82	33.61	15.57	50.78	27.34	21.88	Chi2 = 3.28; df = 4; p = 0.51	0.01
Buying new, innovative insect food would be enjoyable	58.44	34.16	7.40	58.20	34.43	7.37	53.39	34.38	12.23	Chi2 = 5.34; df = 4; p = 0.25	0.06

Explanatory notes: \*N – negative attitude. A – ambivalent attitude. P – positive attitude – attitude.

Source: own elaboration based on survey results.

Table 10 presents a model showing the variables influencing attitudes towards insect food. Assuming a significance level of 5%, the statistically significant variables are: I am a person who values convenience and speed of food preparation (category: no) and I am a person who values the culinary traditions of my region of origin (category: no). In interpreting the individual variables, the odds ratio was used, from which it can be concluded that:

- people who do not value convenience and speed of food preparation are about 60% more likely to have a positive attitude towards food containing edible insects than people who value convenience and speed of food preparation, *ceteris paribus*;

- those who do not value the culinary traditions of their region of origin are about 24% more likely to have a positive attitude towards foods containing edible insects than those who value the culinary traditions of their region of origin, *ceteris paribus* (Table 10).

The literature highlights that people's motivations for consuming edible insects are based on the geographical location of the countries in which they live. Therefore, market segmentation and consumer characteristics must be taken into account when designing strategies to encourage the consumption of edible insects as part of a global strategy for sustainable food systems (Florença et al., 2022). It may be that consumers are already aware that raising and consuming insects can be a solution to environmental and health problems (Guiné et al., 2023; Kornher, Schellhorn, Vetter, 2019), but educating the European population about the sustainable properties of insect-based foods and targeting marketing strategies to this trait is not sufficient to convince consumers to buy and eat insects (Modlinska et al., 2021).

**Table 10.**  
*Models indicating variables affecting attitudes towards insect food*

Variable name	Category	Coef.	Std. Err.	Walda	95% confidence		p-value*	OR
Free expression 1	-	-0.512	0.190	7.232	-0.885	0.139	<b>0.007</b>	0.599
Free expression 2	-	1.737	0.201	74.702	1.343	2.131	<b>0.000</b>	5.679
I am a person committed to work	No	-0.080	0.115	0.478	-0.306	0.146	0.489	0.923
I am a person committed to work	I do not know/I have no opinion	0.042	0.141	0.090	-0.234	0.319	0.764	1.043
I am a person committed to learning	No	-0.073	0.208	0.124	-0.481	0.335	0.725	0.929
I am a person committed to learning	I do not know/I have no opinion	0.104	0.224	0.214	-0.335	0.542	0.644	1.109
I am a pleasure-oriented person	No	0.189	0.206	0.841	-0.215	0.593	0.359	1.208
I am a pleasure-oriented person	I do not know/I have no opinion	-0.013	0.166	0.006	-0.338	0.313	0.939	0.987
I am a person who values the convenience and speed of food preparation	No	0.469	0.217	4.673	0.044	0.894	<b>0.031</b>	1.598
I am a person who values the convenience and speed of food preparation	I do not know/I have no opinion	-0.139	0.205	0.461	-0.540	0.262	0.497	0.870
I am a person who pays attention to foods with high nutritional value	No	-0.067	0.143	0.218	-0.348	0.214	0.640	0.935
I am a person who pays attention to foods with high nutritional value	I do not know/I have no opinion	0.204	0.132	2.386	-0.055	0.463	0.122	1.227
I am a person who values the culinary traditions of my origin region	No	-0.272	0.109	6.280	-0.485	0.059	<b>0.012</b>	0.762
I am a person who values the culinary traditions of my origin region	I do not know/I have no opinion	-0.047	0.119	0.157	-0.280	0.186	0.692	0.954
I am a person with a high health consciousness	No	0.241	0.147	2.695	-0.047	0.529	0.101	1.273

Cont. table 10.

Consciousness	I do not know/ I have no opinion	-0.079	0.129	0.376	-0.331	0.173	0.540	0.924
I am a person of high physical activity	No	-0.122	0.110	1.219	-0.338	0.094	0.269	0.885
I am a person of high physical activity	I do not know/ I have no opinion	0.101	0.129	0.614	-0.151	0.353	0.433	1.106

Explanatory notes: \* bold values are statistically significant.

Source: own elaboration based on survey results.

#### 4. Conclusions and future perspectives

Insect consumption is not historically documented in Poland. The lack of experience with the consumption of insects and insect-containing foods means that the acceptance of insects as food among Poles is still unclear. The study aimed was to determine whether the lifestyle of young consumers in Poland (Generation Z), using students as an example, can influence their attitudes towards foods containing edible insects. Thanks to the research conducted, we can better understand the attitudes and needs of young food consumers in Poland and, as a result, provide them with such information about food products containing insects or the products themselves that they expect. The results of our research partially confirmed the hypothesis. A lifestyle determinant influencing students' attitudes towards food containing edible insects was an appreciation of the culinary traditions of the region of origin. Students who did not value the culinary traditions of their origin region demonstrated positive attitudes towards foods with edible insects in them. This factor may have influenced the attempt to purchase and consume new foods containing edible insects by representatives of Generation Z in Poland. The promotion of food containing edible insects to young consumers in Poland should be based on presenting its nutritional value and highlighting the role of nutrients in ensuring the health of the population. Reaching out to relevant target groups and creating opportunities for them to have new experiences in consuming food containing edible insects is the most effective way to encourage young consumers to purchase and consume food with insects. The results obtained may contribute to efforts to promote the viability of producing new foods containing edible insects. Future research should take into account several other factors, including gender, age, ethnicity and religious background, which may influence the acceptance of insects as novel foods by consumers in Poland.

## Acknowledgements

The publication was co-financed from a subsidy granted to the Maritime University of Gdynia - Project number: WZNI/2024/PZ/1.

## References

1. Al Laheebi, G. (2020) Application of the 4Cs marketing mix in the digital environment. *International Journal of Psychosocial Rehabilitation*, No. 24(10), pp. 2113-2122, doi: 10.37200/V24I10/23795.
2. Arvola, A., Lähteenmäki, L., Dean, M., Vassallo, M., Winkelmann, M., Claupein, E., Saba, A., Shepherd, R. (2007). Consumers' beliefs about whole and refined grain products in the UK, Italy and Finland. *Journal of Cereal Science*, Vol. 46, No. 3, pp. 197-206. Retrieved from: <https://doi.org/10.1016/j.jcs.2007.06.001>.
3. Barton, A., Richardson, C.D., McSweeney, M.B. (2020). Consumer attitudes toward entomophagy before and after evaluating cricket (*Acheta domesticus*)-based protein powders. *Journal of Food Science*, Vol. 85, No. 3, pp. 781-788. Retrieved from: <https://doi.org/10.1111/1750-3841.15043>.
4. Dupont, J., Fiebelkorn, F. (2020). Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. *Food Quality and Preference*, No. 85, Article No. 103983. Retrieved from: <https://doi.org/10.1016/j.foodqual.2020.103983>.
5. Florença, S.G., Guiné, R.P.F., Gonçalves, F.J.A., Barroca, M.J., Ferreira, M., Costa C.A., Correia, P.M.R., Cardoso, A.P., Campos, S., Anjos, O., Cunha, L.M. (2022). The Motivations for Consumption of Edible Insects: A Systematic Review. *Foods*, No. 11, Article No. 3643. Retrieved from: <https://doi.org/10.3390/foods11223643>.
6. Guiné, R.P.F., Duarte, J., Chuck-Hernández, C., Boustani, N.M., Djekic, I., Bartkiene, E., Sarić, M.M., Papageorgiou, M., Korzeniowska, M., Combarros-Fuertes, P. et al. (2023). Validation of the scale knowledge and perceptions about edible insects through structural equation modelling. *Sustainability*, Vol. 15, No. 4, Article No. 2992. Retrieved from: <https://doi.org/10.3390/su15042992>.
7. Kornher, L., Schellhorn, M., Vetter, S. (2019). Disgusting or innovative-consumer willingness to pay for insect based burger patties in Germany. *Sustainability*, No. 11, Article No. 1878. Retrieved from: <https://doi.org/10.3390/su11071878>.
8. La Barbera, F., Verneau, F., Amato, M., Grunert, K. (2018). Understanding Westerners' disgust for the eating of insects: The role of food neophobia and implicit associations. *Food*

- Quality and Preference*, No. 64, pp. 120-125. Retrieved from: <https://doi.org/10.1016/j.foodqual.2017.10.002>.
9. Lammers, P., Ullmann, L.M., Fiebelkorn, F. (2019). Acceptance of insects as food in Germany: Is it about sensation seeking, sustainability consciousness, or food disgust? *Food Quality and Preference*, No. 77, pp. 78-88. Retrieved from: <https://doi.org/10.1016/j.foodqual.2019.05.010>.
  10. Lee, J.S., Hsu, L.T., Han, H., Kim, Y. (2010). Understanding how consumers view green hotels: how a hotel's green image can influence behavioral intentions. *Journal of Sustainable Tourism*, Vol. 18, No. 7, pp. 901-914. Retrieved from: <https://doi.org/10.1080/09669581003777747>.
  11. Likert, R.A. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, Vol. 22, No. 140, pp. 5-55.
  12. Mancini, S., Fratini, F., Turchi, B., Mattioli, S., Dal Bosco, A., Tuccinardi, T., Nozic, S., Paci, G. (2019). Former foodstuff products in *Tenebrio Molitor* rearing: Effects on growth, chemical composition, microbiological load, and antioxidant status. *Animals*, Vol. 9, No. 9, Article No. 484, doi: 10.3390/ani9080484.
  13. Mikulec, A., Platta, A., Radzymińska, M., Ruszkowska, M., Mikulec, K., Suwała, G., Kowalski, St., Kowalczewski, P.Ł., Nowicki, M. (2024). Attitudes and purchase intentions of Polish university students towards food made from insects - a modelling approach. *PLoS ONE*, Vol. 19, No. 3, Article No. e0300871. Retrieved from: <https://doi.org/10.1371/journal.pone.0300871>.
  14. Modlinska, K., Adamczyk, D., Maison, D., Goncikowska, K., Pisula, W. (2021). Relationship between acceptance of insects as an alternative to meat and willingness to consume insect-based food - A study on a representative sample of the Polish population. *Foods*, No. 10, Article No. 2420. Retrieved from: <https://doi.org/10.3390/foods10102420>.
  15. Onwezen, M.C., Bouwman, E.P., Reinders, M.J., Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plantbased meat alternatives, and cultured meat. *Appetite*, No. 159, Article No. 105058. Retrieved from: <https://doi.org/10.1016/j.appet.2020.105058>.
  16. Orsi, L., Voegelé, L.L., Stranieri, S. (2019). Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany. *Food Research International*, No. 125, Article No. 108573. Retrieved from: <https://doi.org/10.1016/j.foodres.2019.108573>.
  17. Petrescu-Mag, R.M., Rastegari Kopaei, H., Petrescu, D.C. (2022). Consumers' acceptance of the first novel insect food approved in the European Union: Predictors of yellow mealworm chips consumption. *Food Science and Nutrition*, Vol. 10, No. 3, pp. 846-862. Retrieved from: <https://doi.org/10.1002/fsn3.2716>.
  18. Piwowar, A., Wolańska, W., Orkusz, A., Kapelko, M., Harasym, J. (2023). Modelling the Factors Influencing Polish Consumers' Approach towards New Food Products on the

- Market. *Sustainability*, No. 15, Article No. 2818. Retrieved from: <https://doi.org/10.3390/su15032818>.
19. Platta, A., Mikulec, A., Radzyńska, M., Ruszkowska, M., Suwała, G., Zborowski, M., Kowalczewski, P.L., Nowicki, M. (2023a). Body image and willingness to change it-A study of university students in Poland. *PLoS ONE*, Vol. 18, No. 11, Article No. e0293617, pp. 1-20. Retrieved from: <https://doi.org/10.1371/journal.pone.0293617>.
  20. Platta, A., Mikulec, A., Radzyńska, M., Ruszkowska, M., Suwała, G. (2023b). Eating-related health behaviors and body perception: a study of young adults in Poland. *Food Science. Technology. Quality*, Vol. 135, No. 2, pp. 122-143, doi: 10.15193/zntj/2023/135/451.
  21. Puteri, B., Jahnke, B., Zander, K. (2023). Booming the bugs: How can marketing help increase consumer acceptance of insect-based food in Western countries? *Appetite*, No. 187, Article 106594. Retrieved from: <https://doi.org/10.1016/j.appet.2023.106594>.
  22. Ribeiro, J.C., Sposito Gonçalves, A.T., Moura, A.P., Varela, P., Cunha, L.M. (2022). Insects as food and feed in Portugal and Norway - Cross-cultural comparison of determinants of acceptance. *Food Quality and Preference*, No. 102, Article No. 104650. Retrieved from: <https://doi.org/10.1016/j.foodqual.2022.104650>.
  23. Rothman, N.B., Pratt, M.G, Rees, L., Vogus, T.J. (2017). Understanding the dual nature of ambivalence: Why and when ambivalence leads to good and bad outcomes. *Academy of Management Annals*, Vol. 11, No. 1, pp. 33-72. Retrieved from: <https://doi.org/10.5465/annals.2014.0066>.
  24. Rovai, D., Michniuk, E., Roseman, E., Amin, S., Lesniasukas, R., Wilke, K., Garza, J., Lammert, A. (2021). Insects as a sustainable food ingredient: Identifying and classifying early adopters of edible insects based on eating behavior, familiarity, and hesitation. *Journal of Sensory Studies*, Vol. 36, No. 5, pp. 3-17. Retrieved from: <https://doi.org/10.1111/joss.12681>.
  25. Schäufele, I., Barrera Albores, E., Hamm, U. (2019). The role of species for the acceptance of edible insects: Evidence from a consumer survey. *British Food Journal*, Vol. 121, No. 9, pp. 2190-2204. Retrieved from: <https://doi.org/10.1108/BFJ-01-2019-0017>.
  26. Schlup, Y., Brunner, T. (2018). Prospects for insects as food in Switzerland: A tobit regression. *Food Quality and Preference*, No. 64, pp. 37-46. Retrieved from: <https://doi.org/10.1016/j.foodqual.2017.10.010>.
  27. Sogari, G., Menozzi, D., Mora, C. (2017). Exploring young foodies' knowledge and attitude regarding entomophagy: A qualitative study in Italy. *International Journal of Gastronomy and Food Science*, No. 7, pp. 16-19. Retrieved from: <https://doi.org/10.1016/j.ijgfs.2016.12.002>.
  28. Turan, Y., Berber, D., Sesal N.C. (2024). Could insects be an alternative food source? A comprehensive review. *Nutrition Reviews*, nuae019. Retrieved from: <https://doi.org/10.1093/nutrit/nuae019>.



29. van Harreveld, F., Nohlen, H.U., Schneider, I.K. (2015). The ABC of ambivalence: Affective, behavioral, and cognitive consequences of attitudinal conflict. *Advances in Experimental Social Psychology*, No. 52, pp. 285-324, doi:10.1016/bs.aesp.2015.01.002
30. Verbeke, W. (2015). Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. *Food Quality and Preference*, No. 39, pp. 147-155. Retrieved from: <https://doi.org/10.1016/j.foodqual.2014.07.008>.
31. Wang, Y., Wiegerinck, V., Krikke, H., Zhang, H. (2013). Understanding the purchase intention towards remanufactured product in closed-loop supply chains: An empirical study in China. *International Journal of Physical Distribution*, Vol. 43, No. 1, pp. 866-888. Retrieved from: <https://doi.org/10.1108/IJPDLM-01-2013-0011>.
32. Wassmann, B., Siegrist, M., Hartmann, C. (2021). Correlates of the willingness to consume insects: A meta-analysis. *Journal of Insects as Food and Feed*, Vol. 7, No. 5, pp. 909-922. Retrieved from: <https://doi.org/10.3920/JIFF2020.0130>.



## ANALYSIS OF LEAN MANUFACTURING KNOWLEDGE CORRELATION MODELS FOR INDIA AND THE USA

Iwo PODLOCH<sup>1\*</sup>, Jakub KOCJAN<sup>2</sup>, Krzysztof NOWACKI<sup>3</sup>

<sup>1</sup> Silesian University of Technology; iwo.podloch@polsl.pl, ORCID: 0009-0008-2259-3069;  
Magna International

<sup>2</sup> Silesian University of Technology; jakub.kocjan@polsl.pl, ORCID: 0009-0003-3972-2879;  
Lean System Sp. z o.o.

<sup>3</sup> Silesian University of Technology; krzysztof.nowacki@polsl.pl, ORCID: 0000-0003-2925-084X

\* Correspondence author

**Purpose:** This article presents the findings of a statistical study that used surveys to collect data from English-speaking countries and India, where English is widely used as a common language. The surveys aimed to understand the knowledge, attitudes, and awareness of production management systems among employees at selected plants of a multinational automotive corporation. Statistical analysis was used to identify relationships within the "knowledge" subgroup of the data, and a detailed expert study was conducted based on the results. The study not only describes the identified correlations but also provides recommendations on how to enhance the performance of areas with low knowledge scores by leveraging these correlation.

**Design/methodology/approach:** Based on responses collected in a survey based on the Likert scale in research groups. Using scale reliability analysis with the  $\alpha$ -Cronbach test and the Nunnally criterion reliability, statistically significant pairs of correlations were defined and subjected to further expert analysis.

**Findings:** Based on the correlation analysis, a higher level of understanding of Lean Manufacturing issues was noticed in India than in the USA, and in both study groups there was a relationship proving that the use of Lean tools was perceived not as work improvement but as additional work.

**Keywords:** management systems, Lean Manufacturing, statistical analysis.

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

### 1. Introduction

The benefits of implementing the Lean Manufacturing system include reducing losses in the process: The Lean methodology aims to eliminate stages of the production process that do not create added value. Lean Manufacturing leads to increased productivity. By streamlining processes, the repeatability and quality of products improves. The implementation of Lean

Manufacturing focuses on improving the awareness and thus the involvement of employees, enabling them to use the full potential of their ideas for improvements. Reducing the amount of losses and waste and improving productivity lead to significant savings over time, and improving quality and efficiency clearly translates into increased customer satisfaction and reduced complaint levels. Lean Manufacturing can make a company more agile and able to change quickly in response to market demands or disruptions (Emiliani, 2006; Hafey, 2010; Hill, 2011; Jasińska, 2015; Koch, 2011; Liker, 1998; Netland, 2016; Prońko et al., 2008; Radeka 2013; Snee 2010; Tice, 2005; Womack et al., 2007).

However, implementing Lean Manufacturing is a transformational endeavor that comes with challenges, many of which involve changing deeply ingrained habits. One of the main obstacles is resistance to change. Employees, and sometimes management, may become comfortable with established processes and wary of new systems that change their routines or appear to threaten job security. Overcoming this resistance requires careful change management and clear communication about the benefits of the new approach (Bednarek, 2007; Dudek, 2016; Graupp, Wrona, 2010; Holweg, 2007; Koch, 2011; Netland, 2016; Nogalski et al., 2010; Nowacki, 2019; Shook, Rother, 2017).

Adopting Lean Manufacturing is not just about changing processes; it's about changing the workplace culture to one that values continuous improvement and efficiency and is able to implement improvement ideas from every crew member, regardless of their level in the organization. Creating this culture change requires ongoing commitment and can be difficult to sustain, especially with the daily pressures of running a business. Another significant difficulty is the need for extensive training and education. Both employees and managers must be trained in Lean principles and methodologies, which can require a significant investment of time and resources. After the initial, energizing period of implementing Lean principles, one of the challenges is maintaining momentum and focus. It is easy for organizations to fall back into old habits, especially if the ongoing benefits of a lean approach are not immediately apparent or if the company lacks strong leadership in lean principles. Production management is based on just-in-time (JIT) production, which reduces inventory costs (Deif, 2019; Duhigg, 2013; Garvin, 1986; Hofstede, 2000; Khaba, Bhar, 2016; Kull et al., 2014; Minkov, Hofstede, 2011; Netland, 2016; Pereira et al., 2017; Plum, 2008; Podloch, 2023, 2022; Wangwacharakul et al., 2014; Wiengarten et al., 2011; Wong, 2007).

In summary, moving to lean manufacturing requires significant effort and a shift in mindset, but the long-term benefits in terms of productivity, employee engagement, quality and cost savings can be significant. The dynamics of implementing and maintaining Lean principles in a company depends on many factors. One of them is employee attitudes resulting from cultural conditions. As the aim of the research, the development and comparative analysis of the knowledge models of the Lean area in the US and India as two countries with diametrically opposed cultural conditions was adopted (Bhasin, Burcher, 2006; Hill, 2011; Holweg 2007; Lewis, 2020; Murman, 2002; Nicholas, 2010; Prońko et al., 2008; Ward, Zhou, 2006).

## 2. Research methodology

The research was conducted using a proprietary questionnaire containing 18 questions on knowledge in the area of Lean Manufacturing, which is presented in Table 1. The set of questions was developed in cooperation with the Lean department of the company (a global automotive concern) where the research was conducted. Questions were answered on a 5-point Likert scale, where 1 meant definitely no, and 5 meant definitely yes.

**Table 1.**  
*Questions included in the research questionnaire*

The content of the question	
How would you rate your knowledge of Lean principles? - my own	Q1
How would you rate your knowledge of Lean principles? - among the staff at your workplace	Q2
Do you think that the operator is responsible for the condition of the machine he works on?	Q3
Do you think that keeping records of machine parameters, activities, etc. on MAFACT boards is important?	Q4
Who do you think is responsible for safety in the area?	Q5
Who is responsible for ensuring product quality? (you can choose more than one answer)	Q6
Which problem do you think is more important? Scrap or Rework	Q7
Do you think that implementing and updating the Retooling Standardization can bring tangible benefits?	Q8
Should part of the responsibility for maintaining machines lie with the operator?	Q9
Is the role of the process engineer and/or setup person to speed up machine uptime at all costs?	Q10
Should a process engineer and/or production engineer analyze the layout of machines and stations and the number of operators in his area?	Q12
Is 100% Pull production possible regardless of the production type?	Q13
Should Maintenance be involved in detailed analysis of failures and the use of advanced systems for planning the replacement of parts?	Q14
Is Continuous Flow always possible?	Q15
According to Should your Finance departments be trained in Lean and MAFACT principles?	Q16
Should machines be grouped by? their uses? e.g. all CNC machines next to each other?	Q17
Do you think machines should be placed in neat rows facing the same direction?	Q18
Is it possible to achieve full replacement of operators? This means that all employees can be freely assigned to other positions?	Q19

The results were subjected to scale reliability analysis using the  $\alpha$ -Cronbach test. The Nunali criterion was used to verify the reliability of the scale. Using the stepwise method, questions were removed from the scale, after removing which the  $\alpha$ -Cronbach's value increased. After obtaining a satisfactory  $\alpha$ -Cronbach's value (min. 0.7), Pearson's r test was used to analyze the correlation between pairs of questions. In each case, a significance level of  $\alpha = 0.05$  was assumed. Based on the obtained correlation coefficients for pairs for which  $p < \alpha$ , LM knowledge models of India and the US were built.

The obtained results can be compared with the results of quality audits of the implementation of production management support systems, including, to a large extent, Lean Manufacturing. The audits evaluate individual issues on a point scale and are carried out by certified internal auditors. The auditors undergo regular calibrations so that their assessments can be comparable among themselves. The details of the auditing and calibration process are

part of the company's "Know How", but at its core it was built on the well-known WCM (World Class Manufacturing) system - one of the systems extracted over the years from the basic Toyota Production System and later Lean Manufacturing and developed by Fiat Automotive, among others. Also for reasons of data confidentiality, the exact numerical results of the audits cannot be given. They will be compared on a percentage basis for the entire groups of regions studied.

### 3. Research results

The survey included 200 employees at various organizational levels from Canada, the US, India and the UK. Due to problems related to legal restrictions on conducting surveys in the UK and the resulting low percentage of completed surveys relative to the number of employees in the production facility, the UK was finally excluded from the analysis. Also excluded finally was Canada where, despite the collection of 18 surveys in relation to the number of employees, the survey return rate was about 1%. In Canada, in contrast to the UK where legal and internal company regulations hindered any initiative to spread the survey, the low response in Canada seems to be the result of a lack of need to share an opinion or possibly a lack of pressure from management for an information company that could be more visible to the workforce. In the US, 199 completed questionnaires were collected which represents 2% of the crew. In India, 70 completed questionnaires were submitted which represents 6% of the crew. The results of the analysis for India are presented in Table 2.

**Table 2.**  
*Correlations between pairs of the India scale*

	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19
Q1	0,638	0,132	0,368	0,045	0,128	0,177	0,145	-0,136	0,32	0,449	0,017	0,34	0,317	-0,06	-0,107	-0,119	0,221
Q2	.	0,149	0,164	-0,005	0,061	-0,016	-0,027	-0,092	0,151	0,115	0,002	0,275	0,179	0,075	-0,215	-0,347	0,263
Q3	.	.	0,272	0,171	0,051	-0,06	0,267	0,446	0,489	0,334	0,468	0,449	0,469	0,193	0,019	-0,24	0,495
Q4	.	.	.	0,341	0,22	0,327	0,727	0,319	0,319	0,473	0,102	0,315	0,334	0,147	-0,046	0,018	0,200
Q5	.	.	.	.	0,369	0,286	0,289	0,227	0,091	0,192	0,204	0,074	0,015	0,194	-0,119	-0,164	0,233
Q6	.	.	.	.	.	0,455	0,223	0,07	0,136	0,225	0,025	0,205	0,067	-0,097	0,118	-0,152	0,25
Q7	.	.	.	.	.	.	0,136	0,064	0,022	0,308	0,108	0,227	0,085	0,069	-0,027	-0,012	0,054
Q8	.	.	.	.	.	.	.	0,385	0,396	0,479	0,22	0,392	0,43	0,158	-0,188	-0,079	0,211
Q9	.	.	.	.	.	.	.	.	0,322	0,313	0,397	0,282	0,322	0,616	0,079	0,207	0,319
Q10	.	.	.	.	.	.	.	.	.	0,547	0,475	0,494	0,749	0,009	-0,138	-0,1	0,434
Q12	.	.	.	.	.	.	.	.	.	.	0,23	0,417	0,555	0,168	-0,235	-0,138	0,265
Q13	.	.	.	.	.	.	.	.	.	.	.	0,333	0,546	0,321	-0,033	0,099	0,534
Q14	.	.	.	.	.	.	.	.	.	.	.	.	0,548	0,064	-0,069	-0,094	0,478
Q15	.	.	.	.	.	.	.	.	.	.	.	.	.	0,103	-0,201	-0,148	0,325
Q16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0,218	0,326
Q17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0,42	-0,051
Q18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0,124

Stepwise analysis of the scale's reliability, selected a homogeneous scale consisting of 18 questions for India with a  $\alpha$ -Cronbach's value for the scale of 0.740 and 15 for the US with

a  $\alpha$ -Cronbach's value for the scale of 0.701. In the case of the USA, questions Q2, Q17 and Q18 were removed as not fitting the scale. In addition, question Q11 was omitted in both cases. A pairwise correlation analysis was conducted for the scale. Based on the analysis, 30 statistically significant pairs were selected for the USA and 46 for India, which were used to build the LM knowledge model. The results of the analysis for USA are presented in Table 3. Statistical significance was determined based on the p-value of  $\alpha = 0.05$ .

**Table 3.**  
*Correlations between pairs of the USA scale*

	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q12	Q13	Q14	Q15	Q16	Q19
Q1	0,258	0,172	0,041	0,059	0,174	0,169	0,207	0,125	0,188	0,133	0,108	0,02	0,262	0,036
Q3	.	0,042	0,043	0,157	0,277	0,041	0,205	0,049	0,009	0,248	0,106	0,088	0,207	0,147
Q4	.	.	0,204	0,194	0,106	0,3	0,097	0,042	0,223	0,068	0,257	-0,008	0,038	0,192
Q5	.	.	.	0,491	0,285	0,08	0,025	-0,027	0,136	0,079	0,035	0,005	0,063	0,05
Q6	.	.	.	.	0,196	0,037	0,125	0,203	0,053	0,077	0,043	0	0,057	0,106
Q7	.	.	.	.	.	0,07	0,118	0,074	0,027	0,125	0,12	-0,026	0,139	-0,093
Q8	.	.	.	.	.	.	0,38	0,163	0,548	0,125	0,451	0,095	0,375	0,083
Q9	.	.	.	.	.	.	.	0,185	0,255	0,157	0,275	0,085	0,316	0,147
Q10	.	.	.	.	.	.	.	.	0,167	0,311	-0,078	0,253	0,067	0,111
Q12	.	.	.	.	.	.	.	.	.	-0,061	0,396	0,151	0,188	0,154
Q13	.	.	.	.	.	.	.	.	.	.	0,092	0,259	0,07	0,085
Q14	.	.	.	.	.	.	.	.	.	.	.	0,038	0,213	-0,01
Q15	.	.	.	.	.	.	.	.	.	.	.	.	0,045	0,191
Q16	.	.	.	.	.	.	.	.	.	.	.	.	.	-0,001

## 4. LM Knowledge Model

The graphical construction of the knowledge model, due to the significant number of correlations, was built primarily based on the ability to build a consistent and graphically clear model, the second determining factor was the value of correlations between questions. The result was the graphical versions of the models shown in fig. 1 and fig. 2.

### 4.1. LM knowledge model for the US

The developed LM knowledge model requires expert verification and the determination of the possibility of indirect influence on individual questions through the formation of knowledge in the range corresponding to the individual pairs, which are the components of the model. The content analysis of individual pairs between questions was developed with the values of individual correlations, starting with the largest. Of the pairs of questions that were selected to build the LM knowledge model for the US, each has a positive correlation  $r$ , meaning that by raising awareness in one area we can simultaneously positively influence another related area.



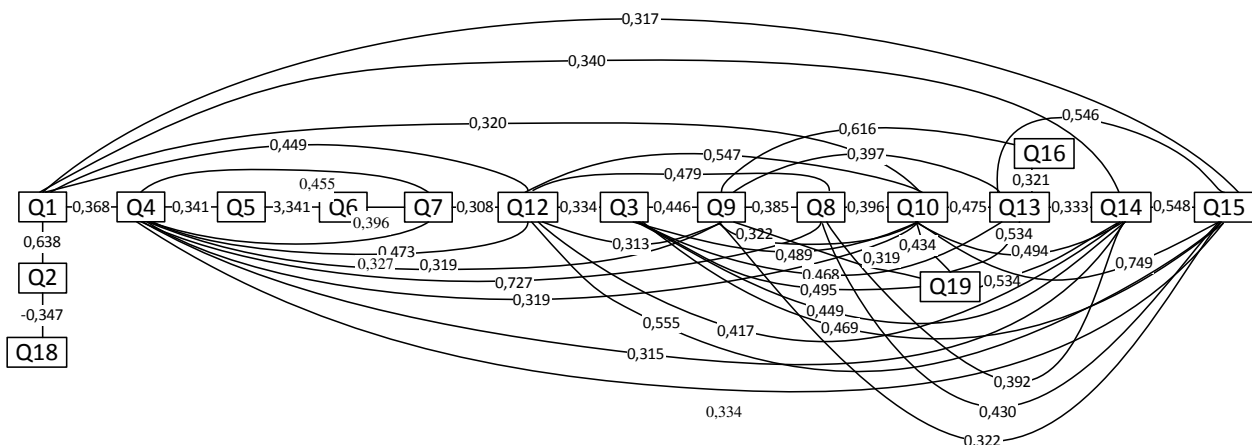


Other unambiguous correlations include links between the terms Continuous Flow, Pull System, cycle time work and LayOut analyses, questions that can be directly associated with optimizations conducted by the Lean Manufacturing team (Antosz, 2015; Wolniak, 2013; Żebrucki, Kruczek, 2011).

Another interesting group of links are questions related to accountability issues, Lean Manufacturing training for non-manufacturing departments and skill matrices. These linkages can be interpreted as associating Lean Manufacturing tools more with expanding responsibilities or additional work without necessarily ultimately improving the conditions of that work by optimizing it (Johansson et al., 2013; Koch, 2011).

#### 4.2. LM knowledge model for India

Of the pairs of questions that were selected to build the LM knowledge model for India, most of the pairs have a positive r-correlation, meaning that by raising awareness in one area we can simultaneously positively influence another related area. The only pair of correlations with a negative coefficient is the pair Q2 and Q18. Respondents rating the level of knowledge among the general workforce as high in their subjective assessment also gave the most inappropriate answer to the question about how machines should be set up.



**Figure 2.** LM India knowledge model.

In a study group containing Indian manufacturing plants, the correlations of the various Lean Manufacturing tools are characterized by the logical relationship of these tools to the issues these tools are designed to address by design. Correlations such as Continuous Flow and cycle time. Standardization and station record keeping, Continuous Flow and LayOut, improving cycle time and working on LayOut. Repeated correlations are also noticeable in maintenance issues (Table 5) (Wong, 2007; Antosz, 2015).

**Table 5.**  
*Correlations between pairs of the India description*

Q10 – Q15 (r = 0,749)	issues of Continuous Flow and working on cycle time
Q4 – Q8 (r = 0,727)	keeping records of setting parameters and standardizing work
Q1 – Q2 (r = 0,638)	both questions directly concern the subjective assessment of the level of knowledge
Q9 – Q16 (r = 0,616)	issues of responsibility and training of non-production workers
Q12 – Q15 (r = 0,555)	issues related to Continuous Flow and LayOuts
Q14 – Q15 (r = 0,548)	the issue of Continuous Flow and Lean tools in maintenance
Q12 – Q10 (r = 0,547)	working on cycle time and LayOut
Q13 – Q15 (r = 0,546)	Pull System and Continuous Flow issues
Q3 – Q19 (r = 0,495)	issues of operators' liability and their substitutability (skills matrix)
Q10 – Q14 (r = 0,494)	improving cycle time and analyzing failure causes
Q3 – Q10 (r = 0,489)	issues of responsibility and role of the process engineer
Q12 – Q8 (r = 0,479)	issues regarding work standardization and LayOut
Q10 – Q13 (r = 0,475)	work on cycle time and Pull System
Q4 – Q12 (r = 0,473)	issues related to tracking setting parameters and LayOuts
Q3 – Q15 (r = 0,469)	Continuous Flow issues and responsibility for the condition of machines
Q3 – Q13 (r = 0,468)	Pull System issues and responsibility for the condition of machines
Q3 – Q14 (r = 0,449)	issues of responsibility for the condition of machines and maintenance tasks
Q1 – Q12 (r = 0,449)	assessment of the level of knowledge and responsibility of process engineers for working on LayOut
Q3 – Q9 (r = 0,446)	both questions directly concern responsibility for the condition of machines;
Q6 – Q7 (r = 0,455)	both questions directly concern problems with the quality of details;
Q10 – Q19 (r = 0,434)	the issue of the role of the process engineer and skills matrix;
Q8 – Q15 (r = 0,430)	issues related to standardization of work and Continuous Flow;
Q12 – Q14 (r = 0,417)	issues related to conducting LayOut and post-failure analyzes and Lean tools in maintenance;
Q8 – Q10 (r = 0,396)	linking the issue of standardization of work and acceleration of cycle time
Q8 – Q14 (r = 0,392)	issues of work standardization and lean tools in maintenance;
Q9 – Q8 (r = 0,385)	issues related to responsibility for machine maintenance and standardization of work
Q1 – Q4 (r = 0,368)	issues of keeping records of parameters and assessing the level of knowledge
Q5 – Q6 (r = 0,367)	both questions directly raise issues of responsibility
Q2 – Q18 (r = -0,347)	issues related to working on LayOut and assessing the level of knowledge
Q4 – Q15 (r = 0,334)	issues of managing setting parameters and Continuous Flow
Q4 – Q7 (r = 0,327)	issues of maintaining parameter settings and assessing quality problems
Q9 – Q10 (r = 0,322)	issues of responsibility for maintaining machines and the role of the process engineer
Q9 – Q15 (r = 0,322)	issues of responsibility for maintaining machines and Continuous Flow
Q4 – Q5 (r = 0,341)	issues of maintaining setting parameters and liability
Q1 – Q14 (r = 0,340)	issues of using Lean tools by maintenance and assessing the level of knowledge
Q13 – Q14 (r = 0,333)	issues in the field of Pull System and Lean tools used by maintenance
Q12 – Q3 (r = 0,334)	issues of the operator's responsibility for machines and the role of the process engineer
Q16 – Q13 (r = 0,321)	the topic of employee training in the field of Lean for non-production employees and the Pull System
Q1 – Q10 (r = 0,320)	the issue of the engineer's role in working on cycle times and assessing the level of knowledge
Q9 – Q19 (r = 0,319)	issues of operators' liability and the possibility of replacing them (skills matrix)
Q12 – Q9 (r = 0,313)	issues of operator responsibility and the role of the process engineer regarding LayOuts
Q4 – Q9 (r = 0,319)	issues of maintaining setting parameters and responsibility for maintaining machines
Q4 – Q10 (r = 0,319)	issues of maintaining setting parameters and the role of the process engineer
Q1 – Q15 (r = 0,317)	issues of knowledge level and Continuous Flow
Q4 – Q14 (r = 0,315)	issues of maintaining setting parameters and maintenance responsibility for using Lean tools
Q7 – Q12 (r = 0,308)	issues of assessing quality problems and the role of the process engineer regarding LayOuts

In the knowledge model for Lean Manufacturing in the US, 30 statistically significant correlations were identified, when in the model for India, 46 were identified, which may lead to the belief that the smaller number of correlations are only those characterized by logical relationships. The complexity of the graphical representation of the knowledge model for India may lead to similar conclusions. However, analyzing the individual correlations separately, the correlations found in the Indian study group are more logical than those found in the US study group, in which correlations occur in issues when Lean Manufacturing analytical tools are linked to opinions on liability issues.

The groups of correlations found in the model for India are characterized by a higher awareness of the issues raised in the questionnaire by which one can infer an overall higher level of knowledge about production management systems in Indian plants than in plants from the US. The correlations in the India group occur in the linkage of specific Lean tools that are actually related to each other in a logical way.

## **5. Possible applications of the LM knowledge model**

The results of correlation studies confirm the connections between individual areas of knowledge and can therefore be used to identify individual areas of knowledge on which work in individual plants may result in increasing the overall level of understanding of the Lean Manufacturing system.

The results of correlation analyzes for the two groups presented suggest the lack of training presenting the practical use of Lean Manufacturing tools in the group of plants from the USA. It would be valuable to conduct workshops proving that Lean Manufacturing issues are not only training material that the company wants to provide to employees to improve their results, but that the working conditions after the workshops make the work more comfortable, we face fewer unexpected problems and at the same time we can be more efficient without extra effort.

Based on the identified correlations occurring in the US model of plants, it would be reasonable to conduct an extensive training program explaining the terminology of individual Lean Manufacturing tools so that employees would be able to identify the role of individual tools. The second stage would have to be conducting a series of workshops. Referring to the connections between issues related to responsibility and additional training, it would be reasonable to conduct not simulation workshops, but Kaizen workshops on selected production lines, involving mixed teams not only in production, so that the crew could see what effects the implementation of Lean tools can bring on a pilot line.

Training programs that could be carried out in Indian plants using the higher level of knowledge that was achieved there could be Value Stream Mapping analysis programs, which eliminated Work in Progress storage, Inventory Turns and the introduction of One Piece Flow

wherever possible, advanced SPC programs focused on analysis production results to anticipate potential quality problems. The potential identified among the staff of Indian plants is worth developing and attempting to introduce advanced optimizations for the benefit of the company (Walenty nowicz, 2015; Żebrucki, Kruczek, 2011).

## 6. Conclusion

According to the research, the created model can be used to study relationships and conduct additional statistical analyses. The article presents general models, however, by assessing the level of knowledge of individual people and previously defined groups using the model, it is possible to identify groups of employees that may require more attention. The results of the assessment of the study conducted on different groups of the study population were similar, although differences in the general and specific assessment of the area may appear in future studies.

The analysis clearly shows that increasing the level of knowledge in the field of Lean principles and improving production efficiency in the examined plant can be achieved through intensive training. This training should focus on simulating flow design, production planning, variances in planning systems, plant-wide part flow implementation methods, and planning and analyzing line-level optimization opportunities (such as LayOut and Line Balance) for specialists and operations engineers. This group is extremely important because it serves as a bridge between office and production employees, and their attitude significantly influences how leaders and operators perceive the Lean system tools. Moreover, transferring this positive attitude to the shop floor is crucial to raising the overall level of Lean knowledge throughout the plant.

A significant difference between the correlations indicated in the knowledge models in plants in India and the USA was verified by the results of corporate audits of the compliance of the plant's production management system with the expected level of implementation of Lean Manufacturing tools. The comparison of audit results confirms the observations made on the basis of correlation analyses, and the results of the plants from the Indian group are over 8.43% higher than the results of the US group.

## References

1. Antosz, K. (2015). *Lean Manufacturing doskonalenie produkcji*. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
2. Bednarek, M. (2007). *Doskonalenie Systemów Zarządzania, nowa droga do przedsiębiorstwa lean*. Warszawa: Difin.
3. Bhasin, S., Burcher, P. (2006). Lean viewed as a philosophy. *Journal of Manufacturing Technology Management*, 17.
4. Deif v. Beek, A. (2019). *National culture insights on manufacturing competitiveness and talent management relationship*. San Luis Obispo, California: California Polytechnic State University.
5. Dudek, M. (2016). *Szczupłe systemy wytwarzania*. Warszawa: Difin.
6. Duhigg, Ch. (2013). *Siła nawyku. Dlaczego robimy to, co robimy i jak można to zmienić w życiu i biznesie*. PWN.
7. Emiliani, B. (2006) Origins of lean management in America. *Journal of Management History*, 12.
8. Garvin, D.A. (1986). Quality Problems, Policies, and Attitudes in the United States and Japan: An Exploratory Study. *Academy of Management Journal*.
9. Graupp, P., Wrona, R. (2010). *Podręcznik TWI*. Lean Enterprise Institute.
10. Hafey, R.B. (2010). *Lean Safety. Transforming Your Safety Culture with Lean Management*. New York: CRC Press.
11. Hill, A.V. (2011). *The Encyclopedia of Operations Management*. FT Press.
12. Hofstede, G. (2000). *Kultury i organizacje. Zaprogramowanie umysłu*. Warszawa: PWE.
13. Holweg, M. (2007). The Genealogy of Lean Production. *Journal of Operations Management*.
14. Jasińska, S., Żurek, M., Wyrwicka, M.K. (2015). Analiza efektywności wdrożenia Lean Manufacturing. Studium przypadku. *Economics and Management*, 1. Politechnika Poznańska.
15. Johansson, P.E.C., Lezama, T., Malmsköld, L., Sjögren, B., Moestam, A.L. (2013). *Current State of Standardized Work in Automotive Industry in Sweden*. Forty Sixth CIRP Conference on Manufacturing Systems.
16. Khaba, S., Bhar, Ch. (2016). *Modeling the key barriers to lean construction using interpretive structural modeling*. Dhanbad, India: Department of Management Studies, Indian School of Mines.
17. Koch, T. (2011). Jak stosować metody Lean Manufacturing (Oszczędnego Wytwarzania) do wprowadzania innowacji. *E-narzędzia i technologie generatywne jako szybka ścieżka do innowacji, no. 1*. Warszawa: Politechnika Wroclawska.

18. Koch, T. (2011). *Minione 10 lat ruchu Lean w Polsce: wnioski i perspektywy*. X Międzynarodowa Konferencja Lean Manufacturing: materiały konferencyjne, Wrocław 2010. Lean Enterprise Institute Polska. za: Jak stosować metody Lean Manufacturing (Oszczędnego Wytwarzania) do wprowadzania innowacji, materiały, Warszawa.
19. Kull, T.J., Yan, T., Liu, Z., Wacker, J.G. (2014). The moderation of lean manufacturing effectiveness by dimensions of national culture: testing practice-culture congruence hypotheses. *International Journal of Production Economics*.
20. Lewis, M.A. (2020). Lean production and sustainable competitive advantage. *International Journal of Operations and Production Management*.
21. Liker, J.K. (1998). *Becoming Lean. Inside Stories of U.S. Manufacturers*. New York: Productivity Press.
22. Minkov, M., Hofstede, G. (2011). The Evolution of Hofstede's Doctrine. *Cross Cultural Management: An International Journal*.
23. Murman, E. et al. (2002). *Lean Enterprise Value. Insights from MIT's Lean Aerospace Initiative*. New York: Palgrave.
24. Murphy, M. (2002). Organisational Change and Firm Performance. *OECD Science, Technology, and Industry Working Papers, 14*. Paris: OECD.
25. Netland, T.H. (2016). Critical success factors for implementing lean production: the effect of contingencies. *International Journal of Production Research*.
26. Nicholas, J. (2010). *Lean Production for Competitive Advantage*. New York: CRC Press.
27. Nogalski, B., Czerska, J., Klimek, A. (2010). Wykorzystanie metod teorii masowej obsługi i lean management w usprawnianiu procesów w zarządzaniu organizacją publiczną. *Współczesne Zarządzanie, no. 1*.
28. Nowacki, K. (2019). *Modelowanie Bezpieczeństwa w Przemysle*. Gliwice: Wydawnictwo Politechniki Śląskiej.
29. Shook, J., Rother, M. (2017). *Naucz się widzieć*. Lean Enterprise Institute.
30. Pakdil, F., Leonard, K.M. (2017). Implementing and sustaining lean processes: the dilemma of societal culture effects. *International Journal of Production Research*.
31. Pereira, C.M., Anholon, R., Batocchio, A. (2017). Obstacles and Difficulties Implementing the Lean Philosophy in Brazilian Enterprises. *Brazilian Journal of Operations & Production Management*.
32. Plum, E. (2008). *Cultural Intelligence*. Middlesex University Press.
33. Podloch, I. (2023) Lean Manufacturing Knowledge Correlation Model, Advances in Production. *Intelligent Systems in Production Engineering and Maintenance, Lecture Notes in Networks and Systems, vol. 790*. Springer, p. 607, ISBN 978-3-031-45020-4.
34. Podloch, I. (2022). Zakres badań dotyczących świadomości zagadnień nt. systemów zarządzania i gotowości na ich wdrażanie. *Systemy Wspomagania w Inżynierii Produkcji, vol. 11, iss. 2, pp. 1-7*.

35. Prońko, J., Soboń, A., Zamiar, Z. (2008). *Zarządzania produkcją*. Kielce: Wydawnictwo Uniwersytetu Humanistyczno-Przyrodniczego w Kielcach.
36. Radeka, K. (2013). *The Mastery of Innovation. A Field Guide to Lean Product Development*. Boca Raton: CRC Press.
37. Shook, J., Rother, M. (2017). *Naucz się widzieć*. Lean Enterprise Institute.
38. Snee, R.D. (2010). Lean Six Sigma – getting better all the time. *International Journal of Lean Six Sigma*.
39. Tice, J. (2005). Lean Production and EMSs: Aligning Environmental Management with Business Priorities. *Environmental Quality Management, Winter*.
40. Walentynowicz, P. (2015). *Zakres zastosowania Lean Management w przedsiębiorstwach produkcyjnych*. Konferencje KZZ 2015, zebrane artykuły.
41. Wangwacharakul, P., Berglund, M., Harlin, U., Gullander, P. (2014). Cultural aspects when implementing lean production and lean product development experiences from a Swedish perspective. *Quality Innovation Prosperity*.
42. Ward, P., Zhou, H. (2006). Impact of Information Technology Integration and Lean/Just-In-Time Practices on Lead-Time Performance. *Decision Sciences, 37*.
43. Wiengarten, F., Fynes, B., Pagell, M., de Búrca, S. (2011). Exploring the impact of national culture on investments in manufacturing practices and performance. *International Journal of Operations & Production Management*.
44. Wong, M. (2007). *The Role of Culture in Implementing Lean Production System, Department of Industrial Engineering*. Taichung: Tunghai University.
45. Womack, J., Jones, D., Roos, D. (2007). *The Machine That Changed the World*.
46. Womack, J. (2001). *Odchudzanie Firm: Eliminacja marnotrawstwa - kluczem do sukcesu*. Warszawa: Centrum Informacji Menedżera.
47. Wolniak, R. (2013). *Metody i narzędzia Lean production i ich rola w kształtowaniu innowacji w przemyśle*. Konferencje KZZ 2013, zebrane artykuły.
48. Żebrucki, Z., Kruczek, M. (2011). *Doskonalenie struktury łańcucha dostaw z wykorzystaniem koncepcji Lean*.





## TEACHING QUALITY ASSESSED BEFORE, DURING AND AFTER COVID-19

Małgorzata RATAJ<sup>1\*</sup>, Iryna BEREZOVSKA<sup>2</sup>

<sup>1</sup> University of Information Technology and Management, Rzeszów; mrataj@wsiz.edu.pl,  
ORCID 0000-0002-0469-2687

<sup>2</sup> University of Information Technology and Management, Rzeszów; iberezovska@wsiz.edu.pl,  
ORCID 0009-0002-1095-0694

\* Correspondence author

**Purpose:** The Covid-19 pandemic has become a challenging time for education worldwide. Though different modes of distant learning have already become widely used at many of Higher Education Institutions (HEIs) long before the pandemic, the lockdowns involved total migration of teaching on various platforms of learning content management despite a level of available technological support and skills of teachers. These forced innovations have had a significant impact on the quality of teaching which has not yet been fully assessed in research. Student perception of the change learning environment and their assessment of the quality of the education they received are one of the little-studied problems. The paper presents the study results on how students are satisfied with the teaching quality ensured by different modes of instruction.

**Design/methodology/approach:** The University of Information Technology and Management has implemented the Course Experience Questionnaire which is a standard tool for semester assessing the quality of courses. For this research in total 40,734 surveys were collected. The study covers the 4 years 2019-2022.

**Findings:** The statistical analysis of research shows the instruction mode itself does not have a noticeable effect on the acquired knowledge and skills. The technological maturity of the teaching staff these days is a necessity.

**Practical implications:** What outcomes and implications for practice, applications and consequences are identified? How will the research impact upon the business or enterprise? What changes to practice should be made as a result of this research? What is the commercial or economic impact? Not all papers will have practical implications.

**Originality/value:** The results of the research and observations show that timely intervention of IT experts and high-performance infrastructure are the pre-requisites needed to teach with ease in traditional, hybrid and online forms.

**Keywords:** student satisfaction, teaching quality, online education, hybrid education.

**Category of the paper:** Case study.

## 1. Introduction

The Covid-18 pandemic has affected education system all over the world, however it also reveals the full extent of its evolving and adaptive nature. Educators at higher education institutions were challenged with many problems and are dealing with these problems effectively despite obstacles, for example insufficient time to react, lack of communication/computer facilities and software resources, insufficient PC skills of teachers etc.

The pandemic led to forced adaptation and promotion of e-learning methods. COVID-related issues continue to be addressed by researchers. Overall, extensive results provide valuable ideas for all professionals in education practice and management, who plan teaching activities during crises affecting public health.

The COVID-19 pandemic has been overcome, nevertheless the experience learned is still has a great value. The pandemic may simulate to a certain extent long-term public crises of other nature which have some common features with the COVID-19 situation, e.g. duration, disorganization of social life in many respects, disturbance in routine services, a threat to human health and life etc. Examples of this abound in today life. In order to establish this point, it is enough to mention the war in Ukraine.

The COVID-19 pandemic preceded the war and partly overlapped with it. Ukrainian colleagues reported in their research publications (Lavrysh et al., 2022; Tsekhmister, 2022) that lockdowns extended the scope of distance learning which became a critical salvation when the war began. Many of other instructional approaches which were implemented because of the pandemic have found a new use in the war time.

In-depth analysis, interpretation, conclusion delivering and decision- making based on wide data collected by researchers all over the world definitely requires a long time not only for data processing, but also to reach a more objective, distant in time point of view. Thus, COVID-related research is going on. No matter how rich available data are, there are and there always will be gaps characteristic of specific countries, learners, instructional modes, education systems etc.

The fast implementation of distance learning has had a significant impact on the quality of teaching which has not yet been fully assessed in research. Student perception of the change learning environment and their assessment of the quality of the education they received are one of the little-studied problems. To address this issue, the study focuses on the analysis of the challenges teachers face in different forms of teaching and create a support system for them.

## 2. Literature review

The Covid-18 pandemic has enormous consequences on education all over the world that is documented in many details in multiple publications. Earlier papers focused on the importance of migrating from traditional or blended teaching modes to the full-scale distance education, however the performance of students was found relatively low, e.g. in case of teaching medical informatics to international students (Berezovska, Semenets, Vakulenko, 2020). The issue of teaching quality and student satisfaction gradually moved to one of leading positions in literature. Various instructional technology and tools are considered. Web video conferencing ensured student satisfaction, and teaching quality, though a blended mode was found an optimal solution of future course delivery (Fatani, 2020). Modelling, e.g. structural equation modelling, was used to examine "student satisfaction with e-learning, the adaption of online learning channels, digital competency of students' involvement, and academic achievement during COVID-19" (Younas, Muhammad et al., 2022).

A large-scale study population (Bezerra et al., 2021) consist of 10,092 students. Online survey completed by these students in 10 countries on 4 continents during the first wave of the COVID-19 pandemic highlighted key factors "which have influenced how students perceive their academic performance during this emergency changeover to e-learning". According to the study results, administrative, technical and learning support delivered by tutors and librarians were key factors of the effectiveness of e-learning. Energetic position, responsiveness, and timely feedback from teachers, as well as overall quality of course delivery and IT infrastructure were among main factors, while IT-related skills of learners and "online interactions with colleagues and teachers were shown to be slightly less important factors, yet still statistically significant". Another research showed student satisfaction "with Google Hangouts the most for lecture delivery, followed by Google Classroom and LMS (Moodle) for course management and assessments" (Almusharraf, Khahro, 2020). Many platforms were used to continue education process. Statistical analysis and a combined sampling method was applied to explore the efficiency of Microsoft Teams implementation (Cruz-Pérez et al., 2020).

Relationship "between quality of learning experience, the second construct student satisfaction and the third construct perceived overall experience among undergraduate students" was explored, and the analysis outcome "reiterates the importance of course content, course structure, lecture-delivery quality, instructor mentoring and student-instructor interactions" (Al Tawil et al., 2022). Numerous papers examine student satisfaction and quality of teaching with specific context of different countries (Nikou, Maslov, 2023; Basuony et al., 2021; Surahman, Sulthoni, 2020; Ananda et al., 2021; Alipour-Anbarani et al., 2023). Hierarchical linear modelling was performed to explore "relationships among student, faculty (adaptations of faculty members to distance education) and institutional (distance learning capacities of the universities) variables that affected satisfaction of the students related to

distance education in higher education institutions in Turkey during COVID-19 pandemic" (Ergin-Kocaturk, Karadag, 2021). This study was carried out at 30 universities and covered almost 15,000 students and nearly 4,000 academics. It was found that "universities with higher distance education capacities got higher satisfaction scores".

Even this concise literature overview gives an idea of how many aspects have been posed by the research on teaching quality and student satisfaction during the COVID-19 pandemic. Elaborate analytical methods and statistics models have been offered to find out determinant factors and their interrelations. Nevertheless, it is important to gather more data on this important issue which continues to be problematic because post-pandemic return to traditional teaching mode is followed by appearing new facet in student attitude to studies.

According to what we were able to find, there are not many studies referring to comparison of data collected during and after COVID-19. Additionally there is lack of data on assessment of teaching quality after COVID-19. This gap of research data has become a focus of our study.

### **3. Methodology of research**

The UITM students were involved in the study conducted in the four years (2019-2022) of summer semesters before, during and after the pandemic. In 2019 and 2022, the summer semester was held entirely in the traditionally form. Online mode became inevitable due to the COVID-19 pandemic in the 2020 summer semester. Hybrid classes were held during the wane of the pandemic.

Total numbers of the UITM students reported by the Central Statistical Office are: 2019 – 5320; 2020 – 5424; 2021 – 5267 and in 2022 – 5236.

#### **Population of Research**

In the study, 315 staff members were engaged in the 2019 summer semester; 248 in the 2020 summer semester; 405 in the 2021 summer semester, and 434 in the 2022 summer semester.

In total, 40,734 surveys were collected:  $n = 8462$  - traditional teaching in 2019;  $n = 15,738$  online mode in 2020;  $n = 7182$  hybrid mode of course content delivery in 2021, and  $n = 16,734$  - resuming to the traditional teaching in 2022.

## General Background of Research

The UITM faculty are very international. They teach courses included in the four major programs offered at the University: Management, Computer Science, Medical Science, and Media Communication.

Distance learning and online collaboration tools have been implementing at the UITM for 20 years to provide online classes in addition to studies on campus. The MOODLE platform and Cisco Webex are tools that are in intensive use now. “Thanks to these two platforms, students can participate in online classes conducted by academic staff, work on projects, and collaborate with other students using advanced collaboration tools for text, voice, and video communication. Before the pandemic only selected academic staff were trained to create online content and deliver online synchronous and asynchronous classes. When the pandemic started the E-learning Department organised a number of training courses, assisted with online content, and provided a helpdesk to support the academic staff during such a dynamic shift from traditional to online mode of delivery” (Berniak, Plebańska, Rataj, 2021).

Each semester the course quality is analysed using the Course Experience Questionnaire disseminated to students through the UITM Quality System. This questionnaire includes 6 sections of standard questions regarding the teaching quality. The questions are designed to be mode-specific, that is, they bear the imprint of the course delivery mode: traditional – 2019, 2020; online – 2020, hybrid – 2021.

The data collected during the four years under consideration are presented in Table 1. In the following years, the Human Resources Department improved or changed the individual questions. Questions in brackets have been assigned to the year they were in the survey.

The UITM uses a five-point scale for assessing student knowledge, where 5 is the highest score and 2 is failing grade. Students rated teachers on the same scale.

**Table 1.**  
*The Course Experience Questionnaire results*

Summer semester	2019		2020		2021		2022	
Questions	Average	St.dev	Average	St.dev	Average	St.dev	Average	St.dev
Q1(2019). Do you think that the teacher is usually well prepared for classes? Q1(2020-2021). Do you think that the teacher is usually well prepared for online classes? Q1(2022). In your opinion, did the teacher create a friendly atmosphere in the classroom?	4.64	0.33	4.58	0.36	4.60	0.43	4.58	0.57
Q2. Does the teacher clearly explain the topic being discussed? Q2(2022) In your opinion, did the instructor convey the issues discussed in an understandable and interesting way?	4.56	0.39	4.52	0.40	4.56	0.43	4.54	0.58

Cont. table 1.

Q3. Is the teacher trying to generate interest in the course? Is How strong are the creativity and dedication of the teacher? Are different stimulation methods and teaching aids used? (Presentations, group work, dialogues, case studies, working with a text, etc.). Q3(2020-2021). Is the teacher trying to generate interest in the course? Is How strong are the creativity and dedication of the teacher? Are different stimulation methods and teaching aids used (multimedia presentations, group work in BB Collaborate, role-play, case studies, working with a text, uploading electronic materials, videos)? Q3(2022). Did the teacher provide additional teaching materials related to the subject?	4.52	0.41	4.5	0.40	4.62	0.41	4.56	0.57
Q4. Has the teacher determined the topics and the rules for obtaining credit for them? Does the teacher adhere to this rules? Q4(2022). Do you think that the topics and conditions for credits were clearly defined and were followed?	4.60	0.37	4.57	0.36	4.62	0.42	4.58	0.57
Q5. Does the teacher readily answer your questions and resolve your doubts during class? Q5(2020-2021). Does the teacher readily answer your questions and resolve your doubts during class? Does the teacher allow you to ask questions via the chat or microphone? Does the teacher answer students' questions and read personal messages? Q5(2022). Did your tutor enable you to have contact with him/her outside of the classroom, e.g. during consultations?	4.64	0.33	4.61	0.35	4.67	0.37	4.53	0.56
Q6. Do you believe that your knowledge and and/or skills have improved due to this activities? Does your the teacher use the learning time effectively? Is individual student work discussed and commented? Q6(2022). Would you recommend this teacher to other students?	4.48	0.39	4.48	0.38	4.60	0.42	4.53	0.59

Source: Own creation.

Data collected over the time period under consideration showed that quality assessment does not depend on the mode of course delivery.

A low standard deviation confirms that the data points are fairly close to the mean. This is an indicator of the unanimity of students in assessing teachers.

### Data analysis, results and discussion

When analysing the data, we took into account the gender of the teacher, the courses taught and the academic rank.

#### Gender

The gender breakdown of teachers during the period under consideration was as follows:

- 2019 - 49 percent female and 51 percent male;
- 2020 - 39 percent female, and 61 percent male;
- 2021 - 50 percent female, and 50 percent male;
- 2022 - 47 percent female, and 53 percent male.

During traditional classes in 2019 and hybrid instruction in 2021, female teachers performed slightly better from the students perspective (Table 2). This can be explained by the fact that female faculty members commonly teach theoretical, social, and humanities disciplines. Typically, students evaluated such classes favourably and tolerantly than courses in applied sciences, however research data shows that gender is not associated with a noticeable influence on the quality of teaching as perceived by students.

This analysis covers the whole spectrum of disciplines taught by all male and female faculty, without dividing between science, technology and humanities. However it seem that the nature of discipline matters and we are planning to conduct more detailed analysis in our future studies to compare the quality of teaching deliver by male and female faculty within disciplines of similar type.

**Table 2.**

*Final points scored by teachers*

Question number	Q1	Q2	Q3	Q4	Q5	Q6	average
Male 2019	4.58	4.47	4.44	4.53	4.57	4.38	4.50
Male 2020	4.58	4.50	4.45	4.53	4.55	4.44	4.51
Male 2021	4.57	4.52	4.61	4.62	4.65	4.57	4.59
Male 2022	4.55	4.58	4.59	4.54	4.56	4.54	4.56
Female 2019	4.70	4.64	4.60	4.67	4.70	4.57	4.65
Female 2020	4.55	4.45	4.44	4.53	4.57	4.43	4.50
Female 2021	4.66	4.62	4.66	4.66	4.72	4.66	4.66
Female 2022	4.55	4.60	4.58	4.54	4.57	4.54	4.56

Source: Own creation.

The analysis of the results for female teachers shows that according to 6 survey parameters students rate the work on this category of teachers worse in 2022, when classes resumed in the traditional format, than in 2019, when this format was still the norm. This situation definitely requires further interpreting. Currently we can only suggest that classroom teaching requires some specific skills which should be used and trained on the regular basis. Our next step will be to identify, what these skills are.

### Teaching Field

In terms of student satisfaction the mode of instruction is irrelevant to the field of teaching. Detailed results are presented in Table 3.

**Table 3.**

*Field of teaching vs quality of teaching*

Question number	Q1	Q2	Q3	Q4	Q5	Q6	average
Management 2019	4.65	4.51	4.45	4.59	4.58	4.44	<b>4.54</b>
Management 2020	4.61	4.51	4.47	4.55	4.56	4.46	<b>4.53</b>
Management 2021	4.58	4.54	4.61	4.63	4.68	4.60	<b>4.61</b>
Management 2022	4.65	4.71	4.67	4.62	4.64	4.64	<b>4.65</b>
Computer Science 2019	4.49	4.37	4.30	4.49	4.49	4.26	<b>4.40</b>
Computer Science 2020	4.46	4.33	4.33	4.46	4.51	4.35	<b>4.41</b>
Computer Science 2021	4.64	4.60	4.66	4.67	4.71	4.64	<b>4.65</b>
Computer Science 2022	4.62	4.58	4.65	4.67	4.72	4.64	<b>4.64</b>

Cont. table 3.

Medical Science 2019	4.68	4.57	4.53	4.56	4.61	4.49	<b>4.57</b>
Medical Science 2020	4.63	4.57	4.51	4.56	4.60	4.51	<b>4.56</b>
Medical Science 2021	4.63	4.58	4.64	4.62	4.68	4.61	<b>4.63</b>
Medical Science 2022	4.39	4.46	4.41	4.37	4.38	4.37	<b>4.40</b>
Media Communication 2019	4.57	4.49	4.45	4.54	4.60	4.41	<b>4.51</b>
Media Communication 2020	4.60	4.50	4.45	4.56	4.59	4.42	<b>4.52</b>
Media Communication 2021	4.35	4.30	4.51	4.15	4.36	4.14	<b>4.30</b>
Media Communication 2022	4.53	4.64	4.61	4.49	4.51	4.52	<b>4.55</b>

Source: Own creation.

The average grade in all fields of teaching ranges from 4,30 to 4,65. No field of teaching was rated particularly worse or better. Also, the individual years when the mode of teaching changed had no influence on the quality of teaching as assessed by students.

### Academic Title

The academic rank breakdown of the UITM faculty is as follows:

- 2019 - 8 percent professors, 35 percent PhDs, and 56 percent MAs and BAs;
- 2020 - 10 percent professors, 32 percent PhDs, and 58 percent MAs and BAs;
- 2021 - 12 percent professors, 32 percent PhDs, and 56 percent MAs and Bas;
- 2022 - 11 percent professors, 33 percent PhDs, and 56 percent MAs and BAs.

Analysing the relationship between the academic rank and teaching quality, we found that, from the students' point of view, teacher with lower academic rank teach better than the higher-ranking colleagues. To explain this relation it should be taken in account that lower ranked faculty are mostly involved in teaching applied courses while higher ranked once teach fundamental matters.

Over the analysed periods, teachers with doctoral, master's and bachelor's degrees remained at their level of teaching quality. The situation with professors is somewhat worse, which may be due to age and insufficient digital competencies. Professors mainly give lectures, the theoretical part of the subject, which is always underestimated by students. The applied nature of the classes taught by the MAs and Bas could be favourable for assessing the quality of their teaching.

**Table 4.**

*The academic title vs quality of teaching*

Question number	Q1	Q2	Q3	Q4	Q5	Q6	average
Professor 2019	4.55	4.36	4.29	4.49	4.52	4.28	<b>4.42</b>
Professor 2020	4.43	4.31	4.22	4.37	4.36	4.26	<b>4.33</b>
Professor 2021	4.32	4.25	4.34	4.37	4.43	4.34	4.34
Professor 2022	4.48	4.54	4.53	4.49	4.53	4.50	4.51
PhD 2019	4.59	4.49	4.45	4.52	4.57	4.41	<b>4.51</b>
PhD 2020	4.61	4.49	4.46	4.53	4.55	4.45	<b>4.52</b>
PhD 2021	4.61	4.58	4.64	4.64	4.72	4.62	4.63
PhD 2022	4.57	4.60	4.60	4.57	4.59	4.56	4.58



Cont. table 4.

Master and bachelor 2019	4.68	4.62	4.59	4.66	4.69	4.54	<b>4.63</b>
Master and bachelor 2020	4.58	4.52	4.5	4.57	4.61	4.48	<b>4.54</b>
Master and bachelor 2021	4.69	4.64	4.70	4.70	4.72	4.67	4.69
Master and bachelor 2022	4.55	4.60	4.59	4.54	4.56	4.54	4.56

Source: Original data.

## 4. Conclusion

The study was undertaken to figure out how the instruction mode influences the quality of teaching perceived by students. The results obtained indicate that the instruction mode itself (traditional, hybrid, online) does not have a noticeable impact on how students evaluate the quality of the education they received. This means that the teaching mode can be chosen accordingly to the prevailing circumstances. “Modern technology used in education enables educators to implement the educational process regardless of the form of communication. Lecturers who have substantive knowledge and are able to convey it in a traditional form do it effectively in an online form as well. Similarly, lecturers who are able to engage students, provide effective feedback, or engage in interactions with students, do it at a comparable level, regardless of the mode of education. With the support of the institution and good infrastructure, the teaching staff can implement the educational procedure both traditionally and online.” (Berniak, Plebańska, Rataj, 2021).

Thus, further efforts are needed to develop effective approaches of online and offline learning teaching and recommendations for universities and other higher education institutions.

Totally the study highlighted that all instruction modes (traditional, hybrid, online) may be of equally good quality which depends on teachers’ attitude and relevant skills.

The study is somehow limited by the fact that teaching quality was assessed regardless the nature of the course taught itself, only gender and academic rank were taken into consideration. This more detailed analysis will be a topic of future research.

## Acknowledgements

Each of the authors contributed to the article writing and study design. Concept, data collection and analysis were performed by Malgorzata Rataj and the introduction literature review and conclusion by Iryna Berezovska.

## References

1. Almusharraf, N., Khahro, S. (2020). Students Satisfaction with Online Learning Experiences during the COVID-19 Pandemic. *International Journal of Emerging Technologies in Learning (iJET)*, 15(21), 246-267. <https://www.learntechlib.org/p/218355/>.
2. Basuony, M.A.K., EmadEldeen, R., Farghaly, M., El-Bassiouny, N., Mohamed, E.K.A. (2021). The factors affecting student satisfaction with online education during the COVID-19 pandemic: an empirical study of an emerging Muslim country. *Journal of Islamic Marketing*, Vol. 12, No. 3, pp. 631-648. doi:10.1108/JIMA-09-2020-0301.
3. Berniak-Wozny, J., Rataj, M., Plebanska, M. (2021). The Impact of Learning Mode on Student Satisfaction with Teaching Quality: Evaluation of Academic Staff Teaching before and during Covid-19. *European Research Studies Journal*, Vol. XXIV, Iss. 3B, 722-738, 2021. doi: 10.35808/ersj/2497
4. Fatani, T.H. (2020). Student satisfaction with videoconferencing teaching quality during the COVID-19 pandemic. *BMC Med. Educ.*, 20, 396. doi: 10.1186/s12909-020-02310-2.
5. Gantasala, V.P., Gantasala, S.B., Al Tawil, T.N., Prasad, P. (2022). Quality of learning experience, student satisfaction and perceived overall experience in the COVID-19 context. *Journal of Applied Research in Higher Education*, Vol. 14, No. 1, pp. 507-520. doi:10.1108/JARHE-12-2020-0440.
6. Hettiarachchi, S., Damayanthi, B., Heenkenda, S., Dissanayake, D., Ranagalage, M., Ananda, L. (2021). Student Satisfaction with Online Learning during the COVID-19 Pandemic: A Study at State Universities in Sri Lanka. *Sustainability*, 13(21), 11749. doi:10.3390/su132111749.
7. Karadag, E., Su, A., Ergin-Kocaturk, H. (2021). Multi-level analyses of distance education capacity, faculty members' adaptation, and indicators of student satisfaction in higher education during COVID-19 pandemic. *Int. J. Educ. Technol. High. Educ.* 18, 57. doi: 10.1186/s41239-021-00291-w.
8. Keržič, D., Alex, J.K., Balbontín, R., Bezerra, D.S., Cheraghi, M., Dobrowolska, B. et al. (2021). Academic student satisfaction and perceived performance in the e-learning environment during the COVID-19 pandemic: Evidence across ten countries. *PLoS ONE*, 16(10), e0258807. doi: 10.1371/journal.pone.0258807.
9. Lavrysh, Y., Lytovchenko, I., Lukianenko, V., Golub, T. (2022). Teaching during the wartime: Experience from Ukraine. *Educational Philosophy and Theory*, doi: 10.1080/00131857.2022.2098714.
10. Nikou, S., Maslov, I. (2023). Finnish university students' satisfaction with e-learning outcomes during the COVID-19 pandemic. *International Journal of Educational Management*, Vol. 37, No. 1, pp. 1-21. doi:10.1108/IJEM-04-2022-0166.
11. Rajabiian, M., Saeedi, M., Khakshour, A., Saeidi, K., Alipour-Anbarani, M. (2023). Iranian

- Students' Satisfaction with Virtual Education during the COVID-19 Pandemic: A Systematic Review. *Medical Education Bulletin*, 4, 1, 611-625. doi: 10.22034/meb.2023.387312.1074
12. Rodriguez-Segura, L., Zamora-Antuñano, M.A., Rodriguez-Resendiz, J., Paredes-García, W.J., Altamirano-Corro, J.A., Cruz-Pérez, M.Á. (2020). Teaching Challenges in COVID-19 Scenery: Teams Platform-Based Student Satisfaction Approach. *Sustainability*, 12(18), 7514. Doi:10.3390/su12187514.
  13. Semenets, A., Vakulenko, D., Berezovska, I. (2020). Education During the COVID-19 Lockdown: Does the Pandemic Extend the Scope of Distance Learning? *Hands-on Science. Science Education. Discovering and understanding the wonders of Nature*. M.F. Costa, B.V. Dorrió (Eds.). Hands-on Science Network, 165-169.
  14. Surahman, E., Sulthoni, E. (2020). *Student Satisfaction toward Quality of Online Learning in Indonesian Higher Education During the Covid-19 Pandemic*. 6th International Conference on Education and Technology (ICET), Malang, Indonesia, pp. 120-125, doi: 10.1109/ICET51153.2020.9276630.
  15. Tsekhmister, Y. (2022). Education of the future: from post-war reconstruction to EU membership (Ukrainian case study). *Futurity Education*, 2(2), 42-52. <https://doi.org/10.57125/FED/2022.10.11.28>
  16. Younas, M., Noor, U., Zhou, X., Menhas, R., Qingyu, X. (2022). COVID-19, students satisfaction about e-learning and academic achievement: Mediating analysis of online influencing factors. *Frontiers in psychology*, Vol. 13, 948061. doi:10.3389/fpsyg.2022.948061.



## ACTIVITIES SUPPORTING INCREASED PHYSICAL ACTIVITY OF EMPLOYEES AS AN ELEMENT OF BUILDING A SUSTAINABLE ORGANIZATION – A CASE STUDY

Izabela RÓŻAŃSKA-BIŃCZYK<sup>1\*</sup>, Piotr KĘDZIA, Anna MASZOREK-SZYMALA

<sup>1</sup> University of Lodz, Faculty of Management, Human Resources Management Department 1;  
izabela.rozanska@uni.lodz.pl, ORCID: 0000-0001-5324-2853

<sup>2</sup> University of Lodz, Faculty of Educational Sciences, Sport Teachers Training Centre;  
piotr.kedzia@now.uni.lodz.pl, ORCID: 0000-0003-1708-5373

<sup>3</sup> University of Lodz, Faculty of Educational Sciences, Sport Teachers Training Centre;  
anna.szymala@now.uni.lodz.pl, ORCID: 0000-0003-1386-7079

\* Correspondence author

**Purpose:** The objective of the argument in this paper is to present a summary of the implementation of the Free the Energy! project, the main goal of which was to promote physical activity as one of the important components of a healthy lifestyle and one of the elements of building a sustainable organization.

**Design/methodology/approach:** In the theoretical part of the paper, the definitions of the concept of sustainable development and sustainable organizations, as well as physical activity as one of the main components of a healthy lifestyle, are presented synthetically. The research part presents a summary of the implementation of the Free the Energy! project, the main goal of which was to promote physical activity as one of the important components of a healthy lifestyle and one of the elements of building a sustainable organization. The empirical research conducted independently by members of the research team in the form of a case study was devoted to achieving the research objectives. The following selection methods were used: document analysis (regulations, University of Lodz strategy, project reports) and semi-structured, in-depth interviews conducted with participants of running training carried out as part of the “Free the Energy!”

**Findings:** The analysis of the research results confirms the achievement of the goals of Free the Energy! project. The project activities achieved the main goals, i.e. promoting physical activity as one of the main components of a healthy lifestyle and one of the elements of building a sustainable organization. Additionally, the activities undertaken as part of the project had a positive impact on improving the image of the University of Lodz.

**Social implications:** Building awareness among the academic community of what sustainable development is and how to implement sustainable development goals.

**Practical implications:** The results of the research discussed in the paper have many practical implications, which may be an indication for other universities of what selected initiatives to undertake in the area of sustainable development.

**Originality/value:** The paper reveals new aspects that play a crucial role in shaping sustainable universities.

**Keywords:** Healthy lifestyle, promotion of physical activity, sustainable development, sustainable organizations.

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

## 1. Introduction

Popularizing the idea of a healthy lifestyle by promoting one of its most important elements, i.e. physical activity, and the organization's activities in disseminating it in accordance with the principles of sustainable development constitute both a challenge and an opportunity for employers. Employers, through the above-mentioned activities, can shape good relationships with their employees by promoting activities to improve the quality of life in the workplace. Physical activity contributes to a higher level of personal well-being, as well as the improvement of psycho-physical health and the quality of work. In addition, there are also limitations, including costs of sickness absence, whether the level of professional satisfaction of employees increases, and at the same time, taking such actions by organizations is a way to increase the level of organizational culture and build a positive image inside and outside the organization. **This study makes an original and innovative contribution to the literature by proposing solutions that universities can implement in the area of promoting a healthy and active lifestyle among employees, as one of the important elements of implementing sustainable development. The formulated conclusions show successful solutions at the University of Lodz and how effectively this concept can be implemented into the practice of any organization.**

In the near future, an essential action in every organization will be to transform them into sustainable organizations. We should expect an increasing number of legal regulations related to sustainable development. Sustainable development for conscious organizations should be included not only in their strategy, but should also be reflected in the real actions of the employer and employees. Sustainable development goals cannot be achieved unless activities are carried out in organizations to educate employees in this area, and one of the elements of building a sustainable organization is promoting the idea of a healthy lifestyle and enabling employees to take actions consistent with this idea. Sustainable development and the promotion of a healthy lifestyle among employees are different, but complementary concepts.

In the theoretical part of the paper, the definitions of the concept of sustainable development and sustainable organizations, as well as physical activity as one of the main components of a healthy lifestyle, are presented in a synthetic way. The research part presents a summary of the implementation of the Free the Energy! project, the main goal of which was to promote physical activity as one of the important components of a healthy lifestyle and one of the elements of building a sustainable organization. The paper also highlights the significant role that activities supporting increased physical activity of employees play in building a sustainable

organization. It was also noted that implementing such activities increases the value of the organization by implementing the sustainable development in practice.

## **2. Sustainable Development and sustainable organizations – literature review**

The concept of sustainable development gained popularity after defining the connections between economic development and the development of social relations and the environment and natural resources. These demands were reflected in the Declaration of the United Nations Conference on the Human Environment adopted on June 16, 1972, in which work was undertaken to define the so-called sustainable development in the political, ecological, economic, and social context (Stockholm Declaration of the United Nations Conference on the Human Environment 1972).

The definition of sustainable development was developed in the report entitled: *Our Common Future – Brundtland 1987* (WCED, 1987), which has since brought the concept into the global spotlight (Imran et al., 2011). A milestone on the way to building sustainable development was the Earth Summit in 1992 in Rio de Janeiro. The global agreement was signed by 179 countries. Two key documents were then created: the Rio Declaration - a document describing the general concept of sustainable development (Rio Declaration (1992), and Agenda 21 - a document presenting ways, principles, and processes of putting this ideology into practice (Agenda 21, 1992)). Agenda 21 includes a program of actions to improve the quality of human life today and for future generations. It is an action plan for sustainable global development for the 21<sup>st</sup> century, containing a set of 2500 recommendations for states, governments, intergovernmental and international organizations and societies. To make this concept more binding and applicable, it is necessary for many entities to participate at various levels of society (Baumgartner, Rauter, 2017). Sustainability should become a reality for everyone (Sachs et al., 2022).

Another important document related to sustainable development is the detailed Agenda for Sustainable Development 2030 (*Transforming our world: The 2030 Agenda for Sustainable Development*, 2015), which contains 17 Sustainable Development Goals (SDG) and 169 detailed tasks. The Agenda begins a new era in the national action and international cooperation, committing all countries to take a number of development actions. These are actions aimed at economic growth, increasing prosperity and meeting the health, educational, and social needs of people while protecting the environment. The seventeen Sustainable Development Goals are a guide and a list of things to do for the planet and people (*Transforming our world: The 2030 Agenda for Sustainable Development*, 2015). From a business perspective, the ultimate impact of the SDGs is to establish ‘sustainable, innovative, and people-centric’

economies. Therefore, the mission of every organization should be to ensure that its employees are healthy and well educated, as well as to increase employee awareness of what sustainable development is and how each citizen can contribute to achieving SDG goals. This document is called “an agenda of the people by the people, and for the people – and this will ensure its success.” Therefore, the double role of the human factor is clearly indicated, both as the initiator and beneficiary of the implementation of SDG objectives. At the organizational level, the people who can contribute most to their implementation are mainly managers and personnel department employees responsible for human resources management (Chams, García-Blandón, 2019).

Today, organizations should operate in accordance with the principles of sustainable development and it should be included in their value system (Wirtenberg et al., 2007). Management staff faces a challenge to develop, in addition to economic aspects, also social and ecological aspects in the company's activities (Brinkmann, 2016; Gimenez et al., 2012). Sustainable organizations are those which resources, activities, and products are subordinated to the principles of sustainability. A fully sustainable organization conducts sustainable operations based on sustainable resources. These resources include people, infrastructure in the form of buildings and structures, its durable and nondurable equipment, including machines and devices, and all input goods. The activities of a sustainable company result in sustainable products. Organizations that operate in accordance with this concept are called sustainable enterprises. Their domain is sustainable management, an integral part of which is sustainable personnel (Pabian, 2017).

Agenda 21 also highlights the significant role of sport in achieving the Sustainable Development Goals and for social progress, noting, among other things, that sport highlights the importance of health, education, and inclusive societies. The document lists the following advantages of sport: "promoting peace and tolerance, strengthening the sense of unity between people around the world, developing teamwork and competitiveness, teaching teamwork, respect for other people, and fostering the establishment of friendly relationships. Sport also fights discrimination, eliminates differences between countries, and integrates societies. Moreover, it is becoming more and more popular and mobilizes everyone, both women and men. Regular exercise is a key element of a healthy lifestyle. Sport improves concentration, teaches concentration, influences academic and work results" (Agenda 21, 1992).

### **3. Physical activity is one of the main components of a healthy lifestyle**

Today, more and more organizations are taking action to provide their employees with the best possible working conditions by taking care of the so-called employee well-being. These types of activities have been promoted in the global economy for many years.



In 1994, the World Health Organization published the document "Global strategy on occupational health for all: The way to health at work". Already then, it was suggested to employers that they should carry out multidimensional campaigns to protect employees' health (World Health Organization, 1994).

Defining the concept of health is difficult. The difficulty in defining the essence of health is reflected in the large number of definitions of this concept. The Ottawa Charter defines health as a core value for achieving complete physical, mental, and social well-being. An individual or group must be able to recognize their expectations and needs that determine this well-being, as well as have the skills and opportunities to implement them (Charter, 1986).

According to the World Health Organization, health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. This terminology has been expanded to include the ability to lead an effective social and economic life, as well as the spiritual scope (The preamble to the Constitution of the World Health Organization, 1946).

The state of health depends on many factors. The concept of health areas was presented in 1974 by M. Lalonde in a publication "A New Perspective on the Health of Canadians" (Lalonde, 1974).

M. Lalonde distinguished four groups of factors affecting the health of the population: the area of biology and genetics, behavior and lifestyle, environmental (which includes economic, social, cultural and physical factors) and the area of organization of the health care system. The most responsible for our health is our lifestyle, it occupies over 50%. Then, 21% is assigned to environmental factors, followed by biological components of 16%, and healthcare, it oscillates within 10% (Hancock, 2003).

Definition of lifestyle developed by the World Health Organization underlines the importance of factors that influence lifestyle. According to it, a lifestyle is a way of living based on identifiable patterns of behavior that are determined by the interplay between personal characteristics of the individual, social interactions, and socio-economic and environmental living conditions (World Health Organization, 1998). Lifestyle is also defined as a set of everyday behaviors characteristic of a certain social community or a specific individual. It is a specific "way of being" that distinguishes a given community or individual from others (Jensen, 2007).

There are many lifestyle components. The most important lifestyle components are: practicing sports, non-professional interests; participating in sociopolitical life; social activities; care about appearance, diet (diet followed, eating habits) (Jensen, 2007; Giddens, 2012).

Lifestyle is, therefore, a fundamental issue for health and conditioning of physical well-being. Choosing the right lifestyle can be achieved when a person has the appropriate knowledge of this sphere and significance (Korporowicz, 2004).

Lifestyle has many adjective connotations that reflect modern and detailed concepts of a human lifestyle. One of them is a healthy lifestyle.

The concept of a *healthy lifestyle* occurs in various fields of science, for example, medicine, sociology, psychology, management, and quality sciences. WHO defines a healthy lifestyle as: “a way of living that reduces the risk of serious illness or premature death (...) and helps you enjoy more aspects of life. Health is not just about avoiding disease, it is also about physical, mental and social well-being” (World Health Organization 1999).

Healthy lifestyle behaviors have been consistently associated with reduced all-cause mortality, and increased lifespan and wellbeing (Larsson et al., 2017).

A healthy lifestyle is a concept relating to an individual characteristic way of being, including physical activity, an appropriate, balanced diet, and the elimination of stimulants (Korzeniowska, Puchalski, 2019; Ostaszewski, 2008).

Physical activity is one of the most important factors of a healthy lifestyle. Physical activity can be undertaken in many different ways: walking, cycling, sports and active forms of recreation (for example, dance, yoga, tai chi). Physical activity can also be undertaken at work and around the house. All forms of physical activity can provide health benefits if undertaken regularly and of sufficient duration and intensity (World Health Organization, 2019).

Regular physical activity is proven to help prevent and treat noncommunicable diseases (NCDs) such as heart disease, stroke, diabetes and breast and colon cancer. It also helps to prevent hypertension, overweight and obesity and can improve mental health, quality of life and well-being (World Health Organization, 2019). People who play sports are athletic and slim, they also have better memory and are able to focus better due to the greater amount of oxygen supplied to the brain. Regular physical activity is the most effective and the cheapest means of preventing many somatic diseases, it also has a positive effect on mental health because it copes well with fatigue and stress reduction. Activity that is properly tailored to personal needs has a positive effect on people of all ages (Haskell, 2006; Fukukawa et al., 2004).

Despite the entire range of health-promoting measures, it is the specification and development of guidelines for a healthy lifestyle that creates the greatest chances for a significant improvement in the health situation of the entire society. The experiments of countries that have successfully implemented them show significant results. The concept of implementing a healthy lifestyle as an opportunity to improve the health of the population is very desirable and beneficial (Fortunka, 2020).

In summary, health promotion means social and political activities at the individual and collective level, the aim of which is to raise awareness of health of society, disseminate a healthy lifestyle, and create conditions conducive to health. It is a process of activation that, among others, local communities, politicians, experts, professionals have undertaken to achieve lasting changes (reduction of behaviors that are risk factors and the spread of health-promoting behaviors) and the introduction of changes in the environment that reduce or eliminate the environmental causes of health threats (Jethon, Grzybowski, 2000).

The concept of health promotion at work has evolved, i.e. introducing health into the philosophy and practice of the organization, into its goals, values, promoted behavioral patterns, functioning norms, management method, company image, etc. (Korzeniowska, Puchalski, 2019).

The organizational level refers to the creation of a health-friendly culture in the workplace. Typically, these are activities included in the company's strategic documents, but they can also be grass-roots activities of employees, which constitute good practices in this area, are very popular and have been accepted by the company's managers. An example of such a solution are activities increasing the physical activity of employees at the University of Lodz through the implementation of the "Free the Energy!" project.

#### **4. Methodology**

The analysis of good practices in companies requires the use of qualitative methods that allow for in-depth knowledge on a specific topic and getting to the heart of the problem. They do not focus on the representativeness of the results, but are aimed at understanding the essence of a given phenomenon.

Therefore, empirical research conducted independently by members of the research team in the form of a case study was devoted to achieving the research objectives. The case study method was chosen based on the assumption that the role of management sciences is primarily to propose solutions to specific management problems to be applied by organizations. Therefore, case studies that present good management practices should be the basic method and main goal of management sciences (Sudoł, 2012).

The research procedure was used to determine whether the company (University of Lodz) uses effective practices to support employees to increase physical activity as one of the components of a healthy lifestyle and one of the elements to build a sustainable organization. The following selection methods were used: document analysis (regulations, University of Lodz strategy, project reports) and semi-structured, in-depth interviews conducted with participants of running training carried out as part of the "Free the Energy!" project in 2023.

##### **The "Free the Energy!" project - employee initiative**

For the first time in 2020, the University of Lodz announced internal recruitment for teams consisting of university employees that represented the University of Lodz in the annual Poland Business Run charity run. Interest in participating in the race exceeded the expectations of the university authorities: instead of the originally planned five teams, the University of Lodz was ultimately represented by as many as 10 teams, i.e. a total of 50 employees. Furthermore, on the initiative of employees participating in the Poland Business Run and with the support of

the university, running training sessions were organized during which employees prepared for the Lodz edition of the Poland Business Run under the supervision of a professional trainer - dr. Piotr Kędzia from the Sports Pedagogy Training Centre, Faculty of Educational Sciences, University of Lodz, Olympic athlete from Athens and Beijing in the 4x400 m relay. These training sessions met with great interest from employees. As a result, apart from the real benefits from running training, additional value was observed in the form of integration of the academic community (scientific and administrative staff), expansion of cooperation with the Academic Sports Association Lodz (some of the training took place at the AZS Lodz athletics stadium), as well as an increase in employees' expectations towards the organization of exactly this type of running initiatives.

The initiators and implementers of the "Free the Energy!" project there were mainly three employees of the University of Lodz representing the Science Centre, the Faculty of Educational Sciences, the Faculty of Management, who, taking part in trainings preparing for the Poland Business Run and observing the interest of the participants in these trainings, decided to find a project that would allow the continuation of this initiative. An employee from the Science Centre reviewed currently available projects that would fit into the assumptions of the training sessions. The employees wrote a project that was positively and received funding from the Program of the Minister of Science and Higher Education entitled Social Responsibility of Science to support activities promoting sports.

The project "Free the Energy!" was addressed to employees of the University of Lodz, i.e. teaching and research staff, teaching staff and administrative staff. The project was implemented from October 1, 2020 to September 30, 2022.

The project activities had two main goals: promotion of physical activity as the main component of a healthy lifestyle and one of the elements of building a sustainable organization.

Detailed goals of the project:

- promoting a healthy and active lifestyle among University of Lodz employees,
- improving the psychophysical condition of the participants.
- increased knowledge and skills of University of Lodz employees in the field of rational physical activity, correct body posture, and healthy eating habits.
- stimulating the integration of the academic community.

Program activities included running training, increasing knowledge in the field of health prevention, and organizing a university running event.

The assumption was that achieving specific project effects would be possible by popularizing running as one of the basic forms of physical activity, knowledge of corrective and therapeutic exercises to correct body posture defects, creating a healthy workplace and developing healthy eating habits. Important effects of implementing project activities also include improving general physical fitness parameters, i.e. mobility, strength, endurance, speed, power, and motor coordination.

In addition, the project activities perfectly coincided with the celebration of the 75<sup>th</sup> anniversary of the establishment of the University of Lodz, which took place in 2020. A joint run of employees representing various scientific disciplines, students of various faculties, and administrative employees from various organizational units. It was one of the best forms of integration, healthy competition, and promotion of a healthy lifestyle. Moreover, it contributed to an increase in the sense of belonging to a large academic community and an increase in the employee's identification with the university.

The University of Lodz, being one of the largest employers in Lodz and the Lodz region (approx. 4,000 employees - scientists, educators and administrative staff as well as participants of doctoral schools), has been taking actions for many years to encourage employees to be more physically active and practice sports regularly. The University of Lodz's activities in this area are based both on "systemic" solutions (university-wide offer) and initiatives of individual departments. Employees of the University of Lodz have the opportunity to use funds intended for the promotion of sports and recreation from the Company's Social Benefits Fund for, among others: FitProfit cards entitling to unlimited use of sports and recreation services in facilities throughout the country, sections (sailing, cycling and hiking) organizing rallies and trips, swimming pool tickets, and other sports activities at the Centre for Physical Education and Sports of the University of Lodz. In addition, each year the youth program includes sports events. Faculty initiatives deserve special recognition, such as faculty sports picnics combined with competitions (e.g. for the Dean's Cup) or tournaments.

In the years 2016-2018, research was carried out at the University of Lodz aimed, among others, at examining the opinions of employees on the university's promotion of a healthy lifestyle: physical activity and sport (Syper-Jędrzejak, 2019). At that time, it had 442 employees, including 250 women. The results obtained confirmed the positive assessment of the university's initiatives to promote sports - up to 87.5% of responses. However, it turned out that not all employees are fully familiar with the university's sports and recreation promotion offer. The respondents had the poorest understanding of sports competitions and contests (as many as 33.5% answered "I don't know"). This was probably due to the fact that this area of the University of Lodz is dominated by local initiatives (faculty competitions, tournaments, and sports picnics), and it can be assumed that such information reaches primarily the circle of people interested in it.

In addition, some departments were less active in this area, translating into the level of knowledge and interest of the employees working there. The survey showed that the prevailing opinion among employees was that there should be more university-wide initiatives addressed to the entire academic community. Running was particularly popular among University of Lodz employees.

The implementation of the project is extremely important for the academic community of the University of Lodz (the project is an initiative of the employees of the University of Lodz and at the same time a response to the needs of the employees, which resulted from the research

conducted by M. Syper-Jędrzejak and interviews conducted with employees of the University of Lodz), but also for the authorities of the University of Lodz, because the activities promoting a healthy lifestyle among the academic community and aimed at integrating the academic community were intended to increase the attractiveness of working conditions and the level of employee satisfaction, which is particularly important in the case of the HR Excellence in Research title held by the University of Lodz. This is a prestigious distinction received by the University of Lodz in 2017 when it joined the European Commission program as part of the Research Human Resources Strategy. The logo is awarded to European institutions that provide scientists with, among others: the best possible working conditions.

The project is also in line with the Lodz goals of the University 2021-2030 Strategy. This document emphasizes that the University of Lodz is focused on achieving sustainable development goals and integrating the academic community. In the above-mentioned strategy, in achieving the goal: "Strengthening the image of the University of Lodz as a university boldly taking up the challenges of modern times" there is an important provision "University of Lodz supports activities aimed at strengthening social responsibility, shaping social sensitivity and perpetuating the ideas of sustainable development" and "the university initiates and actively participates in cultural and social activities taking place in its surroundings and strengthening its position and image. In the document, one of the strategic goals of the University is "...continuously supporting the sense of belonging and community by building and developing an organizational culture orientated towards human well-being and the values of the university. This is the primary goal of all activities carried out by the authorities and staff of the University of Lodz. We want to continue to create a friendly place of work and study for the entire University community and support it by proposing activities that integrate and build a sense of identity with the Alma Mater (Strategy of the University of Lodz 2021-2030).

## Results

Description of the goals and effects of the project (including practical applications).

For one of the first tasks to be achieved in the project "Free the Energy!" it was necessary to build the turnout. It should be noted that the project was launched in a difficult period, the so-called second wave of the COVID-19 epidemic. The adopted strategy to promote outdoor running as a way to counteract the negative effects of epidemic restrictions turned out to be right. Over three months, over a dozen people participated in the classes, of which nearly 10 were regular participants. Thus, we managed to build not only attendance but also retention. It is also worth mentioning that not a single case of coronavirus was recorded in the group of participants.

In terms of training goals, significant achievements include organizing knowledge in the area of training theory, correct execution of movement patterns, and the ability to appropriately use training methods and means. Thanks to this approach, participants reduced the risk of injury and, moreover, made their physical activity more thought-out and diverse.

During the project implementation period, 101 running training sessions were conducted, which amounted to 151.5 training hours. Based on prepared training plans, University of Lodz employees ran nearly 400 kilometers from October to December. A total of 14 people took part in the training, i.e. 7 administrative employees and 7 teaching and research employees.

5 km control tests were periodically organized. These tests made it possible to determine the participants' endurance level and set realistic and individualized training goals. Another important element of improving the training process was working on improving the running technique. Methodical work on learning and improving individual phases of the running step and analysis of the video material contributed to conscious work on implementing correct movement habits.

Information about the implementation of the "Free the Energy!" project is transmitted through publicly available media. At the very beginning of the project, on 30 September 2020, a detailed description of the activities carried out was published in the Newsletter of the University of Lodz (No. 558), encouraging members of the academic community to participate in the project. Moreover, on October 7, 2020, project manager dr. Piotr Kędzia took part in a radio broadcast on Student Radio "Zak", which was devoted to a discussion on the goals of the project. A permanent platform for disseminating information used to promote and provide news from training sessions is the Facebook social network. Every week, after each training session, a post with a photo appears in a specially created group. Currently, this group has 90 members, employees of the University of Lodz. Information about the project was also posted on the website of the University of Lodz, and periodically this information appears in the faculty newsletters of the University of Lodz.

In addition to achievements in the form of attendance and improvement of the training process, the integration of the academic community is undoubtedly a great value achieved in the project. Trainings carried out, in addition to working on physical fitness work, have also become a place to make new friends, conduct discussions on various current topics, share specialist knowledge in the scientific fields represented by project participants, an opportunity to symbolically celebrate calendar holidays together, and inspiration to undertake various activities and also teaching and research initiatives.

It should be noted that the project is continued through the "Free the Energy 2.0!" project, which has the same goals and group of recipients and is implemented in the period from October 1. 2022 – September 30. 2024.

During its implementation, in addition to running events, the project members also carried out other activities that promote sports, including:

- The success related to the project implementation of the "Free the Energy!" inspired the project manager to take another initiative to promote physical activity. The project manager wrote a project titled: "Train with the University of Lodz! Run for health", which was also positively evaluated and received funding from the Program of the Minister of Science and Higher Education entitled Social responsibility of science -

Popularization of science and promotion of sport (project implementation date: 01/01/2022-31/12/2023). In this project, the group of recipients has been expanded; i.e. the project was addressed to members of the academic community of the University of Lodz, as well as other willing residents of the voivodeship. It was assumed that over a 2 years, a total of 60 participants would receive support in the form of running training. Running training takes place once a week, for 1.5 hours, in the city park, under the supervision of an experienced coach Piotr Kędzia. However, the interest in the training exceeded the expectations of the project authors. The weekly attendance lists show that in 2022, a total of 78 people (34 women and 44 men) participated in the training. Through systematic training, participants strengthened their muscular, circulatory, respiratory and immune systems and prevented many lifestyle diseases. Moreover, training in a group and in the open air promoted the development of interpersonal contacts, reduced stress levels, taught time management and facilitated contact with nature. The park enabled continuous and intermittent training. Moreover, an additional advantage was the possibility of using the park's infrastructure for exercises, e.g. benches to develop strength and mobility, or the use of trees for exercises for a healthy spine.

- On June 7, 2021 in the Lagiewnicki Forest as part of the "Free the Energy!" project, a jubilee run was held to mark the 75<sup>th</sup> anniversary of the University of Lodz. The event was organized in the form of a sports picnic for the entire university community. It had a special character because it expressed intergenerational communication and the spirit of perseverance in the era of fighting the epidemic. The main 5 km race was completed by 127 people and the children's race by 46 young sports enthusiasts. The best male and female runners were awarded in three categories, and all participants received, among others: a commemorative T-shirt and a medal. There was a friendly atmosphere during the event. The participants feasted together, and the children benefitted from the playground and animations, and took part in competitions for souvenir prizes related to the University of Lodz. Everyone was treated to a barbecue and other snacks. The event was a great organizational success. Already during the event, many participants asked whether it would be a cyclical event.
- On May 15, 2022, the next University of Lodz Run "Free the Energy!" took place under the honorary patronage of the Rector of the University of Lodz. It was the second edition of the cross-country run carried out as part of the university-wide project "Free the Energy!". The picnic formula of the competition attracted a wide group of employees, students, and supporters of the University of Lodz. Each participant received a starting package with a T-shirt, a commemorative medal for completing the race, and the opportunity to enjoy a barbecue refreshment. The organizers also took care of attractions for the children. The most important ones included: a run over a distance of approximately 1 km, games and animations, and a prize draw. It is worth highlighting



that up to 45 runners completed the children's race. The main race was held in the Lagiewnicki Forest, on a quite demanding route, the distance of which was approximately 5 km. 165 competitors took part in the race. Similarly to last year, the classification included women and men in the open, employee, and student categories. All the people who took a place on the podium also received prizes.

- On July 10, 2022, the first edition of the University Athletics Picnic was organized as part of the "Train with UŁ" project! "I am running for health." The competition took place at the AZS Łódź stadium. The event program included running competitions over distances of 60 m and 1000 m and the Swedish relay. Each participant could participate in any number of competitions. Individual runs over the above-mentioned distances were held in individual age categories: 6-7 years, 8-9 years, 10-11 years, 12-13 years, and 14-15 years, 16-17 years, 18 years and older. On the day of the event, there was a total of 295 people on the starting list (170 men and 125 women), which means that the limit of participants planned in the application, which was 300 people, was practically used.
- On July 2, 2023, the second edition of the University Athletics Picnic took place as part of the 'Train with University in Łodz' project! „I am running for health". The competition took place at the AZS Lodz stadium. The event program included running competitions over distances of 60 m and 1000 m and the Swedish 100x200x300x400 m relay. Each participant could participate in any number of competitions. Individual runs over the above-mentioned distances were held in the following age categories: 6-7 years, 8-9 years, 10-11 years, 12-13 years, 14-15 years, 16-17 years, 18 years and older. On the day of the event, there were a total of 147 people on the starting list (83 men and 64 women), which means that the limit of participants planned in the application was reached used.
- On October 1, 2023, a running event was held entitled "Cross Five of the University of Lodz", a run carried out as part of the project "Train with the University of Lodz! "I am running for health". The main 5 km race was completed by 251 runners, the children's race by 40 participants, and the youth race by 66 participants. All registered participants received a starter package with a T-shirt, a commemorative medal, cosmetics, and refreshments. Furthermore, children could use the playground and other attractions. Statuettes and university gifts were prepared for the best runners participating in three races. At the end of the competition, a voucher was drawn among all participants for a weekend stay for two people in the Beskid Niski.
- On June 30, 2024, in the Lagiewnicki Forest as part of the "Free the energy!" project, another University of Lodz run. The event was organized in the form of a sports picnic for the entire university community. For people working and studying at the University of Lodz, there was a main run of 5 km, for children - a run of 200 m, and for young people - a run of 1 km. 141 runners (women and men) took part in the 5 km run and the

children's race by 28 young sports enthusiasts. Cups for the first three places were awarded to the winners in the open category, UŁ employees and students. All participants received, among others: a commemorative T-shirt and a medal.

Other activities promoting sport and sustainable development carried out by project participants:

- Since 2020, teams consisting of University of Lodz employees represent the university in the annual charity run organized by Poland Business Run. In 2022, the team "Free the Energy!" was established, consisting of runners participating in training as part of the project. In 2023, the University of Lodz was represented by a total of ten 5-person relay teams (31 women and 19 men). In the 2023 edition of the race, we managed to gather a team composed of the fastest running university employees. 4 of the team members are participants in the Free the Energy!) project. In the final competition, the "Greyhounds of the University of Lodz" team took the 18<sup>th</sup> place out of 4,293 teams from all over Poland and the 3<sup>rd</sup> place among mixed teams.
- Participants in the "Free the Energy!" project also regularly participate in running competitions organized in Poland, including: CITY TRAIL (5 participants), Lowicz Autumn Half Marathon (3 participants), Szakala Autumn Festival (5 participants), Lodz Mountain Runs (2 participants), Rossman Run along Piotrkowska Street (5 participants), DOZ-Marathon (5 participants), Run New Year's Eve Lodz (5 participants), Athens Marathon Greece (1 participant) and compete in the Polish, European and World Masters Championships (1 participant).
- Thanks to the cooperation and determination of the participants of the "Free the Energy!" project, and "Free the Energy 2.0!" The running section at the University of Lodz was established in September 2023, with 37 members enrolled. The Running Section brings together amateurs and professionals, running fans, who have the right to use the Company Social Benefits Fund of the University of Lodz, in particular, employees of the University of Lodz and eligible members of their families. The Running Section aims to popularize running as a form of exercise available to everyone, improve the level of health and physical fitness of the Running Section members, integrate the academic community of the University of Lodz, and promote the University of Lodz as a company that cares about the sustainable development of its employees. The Running Section pursues its goals through the following activities: organizing running training for members of the Running Section, organizing sports camps for members of the Running Section, co-financing the participation of members of the Running Section in running events organized in Poland by co-financing entry fees, purchasing running T-shirts with the University of Lodz logo and organizing competitions, running for the academic community of the University of Lodz.

- The integration of project members and common interests also led to activities popularizing science and sports by organizing an expert panel entitled "Speed, strength, success - sport as a catalyst for social development" at the 16<sup>th</sup> European Economic Forum - Lodz 2023 (12/06/2023). The panel aimed to discuss the role of sport in a healthy lifestyle and the development prospects of the Lodz Voivodeship. During the meeting, the speakers presented their experiences as players, scientists and social activists involved in matters of physical culture and sports. Good practices and challenges in the promotion of physical activity as a component of a healthy lifestyle were discussed (including the Free the Energy! project) and the use of sports activity in the promotion of cities and regions.

The analyses of the research results presented below were based on semi-structured, in-depth interviews that were conducted with participants of running training as part of the Free the Energy! project. The respondents' statements concern their reflections and experiences in the implementation of the project's goals.

The study was conducted in September and October 2023. 14 project participants, 8 women, and 6 men took part in the study. These are people aged 38 to 54, 6 research and teaching employees, 1 teaching employee, and 7 administrative employees.

Due to the limited space for presenting research results, when categorizing the data obtained during the interview, we tried to select the most illustrative and significant ones related to the individual goals of the project. This meant that the presented analyses did not quote all respondents' statements, but only those that best fit the scope of the information sought.

Based on the analysis of respondents' statements, the prevailing opinions are that the Free the Energy! project promotes the University of Lodz as a company that cares about the sustainable development of its employees.

*This is an excellent promotion of the idea of work-life balance.*

*The University of Lodz, as the project implementer, offers running training to its employees, creating friendly conditions for physical activity and integration, and taking care of the well-being of its employees.*

*Only thanks to the huge commitment of the creators and organizers of the project (university employees) can the University of Lodz appear as such a company. These people consistently point to the University of Lodz as an institution closely associated with the project. As part of organized sports events, facilities belonging to the University of Lodz are also used, which additionally (positively) affects the image of the university.*

*The implementation of the Free the Energy! project is also consistent with the goals formulated in the University of Lodz strategy. Although the project's activities focus on promoting physical activity, physical activity has a positive impact on the mental and physical health of the employees who participate in this project, and this is an important element of building a sustainable organization.*

The analysis of the statements shows that the project definitely promotes a healthy and active lifestyle among the employees of the University of Lodz.

*The project promotes a healthy and active lifestyle not only by organizing training sessions, but also by organizing family sports competitions, which allows the promotion of an active lifestyle of entire families.*

*Definitely YES, design activities promote a healthy and active lifestyle! Training meetings are not only about performing specific exercises and tasks. Participants also receive a really large dose of knowledge about the benefits of an active lifestyle, but also about health problems that may result from the lack of such activity.*

*The training and competitions organized are a specific offer to promote a healthy lifestyle.*

*I have been working at the university for more than 15 years and this is the first such well-thought-out initiative that actually promotes a healthy lifestyle for the entire academic community. These activities are also professionally prepared by specialists in this field, after all, the coach is an Olympic champion!*

The respondents emphasized in their statements that the project objectives in terms of improving the psychophysical condition, increasing knowledge and skills in rational physical activity, correct body posture, and healthy eating habits had been achieved.

*Training under the supervision of a professional trainer not only improved my performance and physical fitness, but also increased my awareness of a healthy lifestyle.*

*Thanks to my participation in the Free the Energy! project, I gained knowledge about running techniques, stretching, rolling, building fitness, regeneration after training, preparing for competitions, but I also learnt how to choose sports clothing and footwear.*

*Each training session is an opportunity to acquire extensive knowledge about rational physical activity, proper body posture, and healthy eating habits. All consultations provided by the trainer are extremely valuable, as they have significantly expanded my knowledge of physical activity.*

*As a project trainer, I had the opportunity to learn from the participants. In sports theory, this is one of the best ways to acquire knowledge.*

*By participating in training, I increased my awareness of my abilities and limitations in the field of running activities. As a result, I improved my sports results but it also encouraged me to continue working on myself. These trainings not only "free the energy", but also "clear the mind" of negative thoughts.*

*Professional training and the knowledge transferred during it allowed for added value in the area of psychophysical condition.*

*The best recommendation of the acquired knowledge on improving psychophysical condition, increasing skills in rational physical activity, correct body posture, and healthy eating habits is that none of the project participants had any injuries throughout the duration of the project, most of us improved our running results (regularly checked by the trainer), and I also lost more than 5 kg!*

One of the most important advantages of this project, which was particularly noted by respondents, is the integration of the academic community.

*This project showed that it is not just about running. It turned out that the project participants integrated very well and very quickly, that thanks to this project we were able to get to know each other, i.e. employees from different faculties or departments, and that we could support each other in difficult moments, e.g. the pandemic or the outbreak of war in Ukraine. It turned out that thanks to the first project, we started cooperation in writing the second project and the continuation of the "Free the Energy!" project, we also write joint scientific papers and share knowledge.*

*Integration thanks to the project takes place on various levels: in the social field - people simply liked each other, made friends, and started meeting each other outside of work; in the professional field - they started cooperation on other projects and even united in the Running Section of the University of Lodz. Integrated research workers and administrative workers. We can also mention intergenerational integration: in addition to adult employees, their children also took part in the running competitions carried out as part of the project.*

*On the one hand, the project gave us the opportunity to get to know each other. Getting to know employees of various professional levels and people performing various functions at our university. The training brought together people with similar/common interests. The approach of the Trainer is extremely important here, as he consistently refers to our group as a "Team". This, in my opinion, makes us feel really part of one group and also closer to each other. This also translates into friendships outside of training.*

*Integration is a huge advantage of these trainings. I take part in the training because I simply like being with the project participants, we like each other. We exchange knowledge, talk about current topics not only related to professional work, and support each other. While running, you can listen to interesting lectures from participants, e.g. on archaeology, economics, or trends in management or sports. The good "spirit" of our group is the Coach, who is able to lead our team very well. We also meet outside of training and this proves the great integration of our group.*

## **5. Discussion**

The analysis of the research results confirms the achievement of the goals of Free the Energy! project. The project activities achieved the main goals, i.e. promoting physical activity as one of the main components of a healthy lifestyle and one of the elements of building a sustainable organization. The specific objectives of the project were also achieved: promoting a healthy and active lifestyle among employees of the University of Lodz; improving the psychophysical condition of participants; increasing employees' knowledge and skills in

rational physical activity, correct body posture and healthy eating habits, and stimulating the integration of the academic community. Statements of project participants and analysis of documentation (mainly project reports) confirm the thesis that universities that support their employees in taking up physical activity, and thus a healthy lifestyle, contribute to better mental and physical well-being, social integration, better achievements at work, increased professional satisfaction of employees and, at the same time, greater identification with the university, which is important from the point of view of the university's strategy and challenges for contemporary sustainable organizations.

The challenge in the future is to build a larger turnout of project participants. One of the weaknesses is perhaps too little information about the availability of training for employees of the University of Lodz.

It should be emphasized that the success associated with the implementation of the "Free the Energy!" project inspired the authors of the project to take further initiatives aimed at promoting a healthy lifestyle, including further projects, the creation of a running section at the University of Lodz, and participation in popular science events popularizing science and sport.

The implementation of the project also significantly contributed to the integration of the academic community of the University of Lodz and the promotion of the University of Lodz as a company that cares about the sustainable development of its employees.

The obtained results inspire further research work in identifying good practices in promoting a healthy lifestyle that are part of building sustainable organizations; they also constitute the basis for formulating many valuable applications for organizations such as universities in the implementation of similar programs.

## **6. Summary**

The synthetic review of the literature on sustainable development, physical activity as one of the main components of a healthy lifestyle, and the presentation of activities that support increased physical activity of employees as an important element in building a sustainable organization indicate that this is an extremely important topic of research in modern organizations. Healthy employees play a key role in the sustainable development of an organization. Therefore, special emphasis should be placed on activities that promote a healthy lifestyle in organizations.

Physical activity and the 2030 Sustainable Development Goals, investing in policies that promote walking, cycling, sport, active recreation and play can directly contribute to achieving many of the 2030 Sustainable Development Goals. Policies on physical activity have multiplicative health benefits, social and economic and will directly contribute to achieving SDG3 (good health and well-being) as well as other goals, including SDG2 (end all forms of

malnutrition); SDG4 (quality of education); SDG5 (gender equality); SDG8 (decent work and economic growth), SDG9 (industry, innovation and infrastructure); SDG10 (reducing inequality); SDG11 (sustainable cities and communities); SDG12 (responsible production and consumption); SDG13 (climate action); SDG15 (life on land); SDG16 (peace, justice and strong institutions) and SDG17 (partnerships) (World Health Organization, 1994).

Poor health of employees and, consequently, of society leads to a slowdown in the dynamics of economic development. Therefore, it is so important to promote a healthy lifestyle among employees, with particular emphasis on physical activity. Promoting a healthy lifestyle is one in the basic elements of implementing sustainable development. As part of the implementation of sustainable development, it is necessary to adapt the market economy to the culture of a healthy lifestyle (Róžańska-Bińczyk, 2021).

## References

1. Agenda 21 (1992). Available from: <https://sustainabledevelopment.un.org/outcomedocuments/agenda21>
2. Baumgartner, R.J., Rauter, R. (2017). Strategic perspectives of corporate sustainability management to develop a sustainable organization. *Journal of Cleaner Production*, 140, pp. 81-92.
3. Brinkmann, S. (2016). *Diagnostic cultures: A cultural approach to the pathologization of modern life*. Routledge.
4. Chams, N., García-Blandón, J. (2019). On the importance of sustainable human resource management for the adoption of sustainable development goals. *Resources, Conservation and Recycling*, 141, pp. 109-122.
5. Charter, O. (1986, November). Ottawa Charter for health promotion. *First International Conference On Health Promotion*, Vol. 21, pp. 17-21.
6. Fortunka, K.B. (2020). Factors affecting human health in the modern world. *Journal of Education, Health and Sport*, 10(4), pp. 75-81.
7. Fukukawa, Y., Nakashima, C., Tsuboi, S., Kozakai, R., Doyo, W., Niino, N., Shimokata, H. (2004). Age differences in the effect of physical activity on depressive symptoms. *Psychology and aging*, 19(2), p. 346.
8. Giddens, A. (2012). *Nowoczesność i tożsamość. „Ja” i społeczeństwo w epoce późnej nowoczesności*. Warszawa: PWN.
9. Gimenez, C., Sierra, V., Rodon, J. (2012). Sustainable operations: Their impact on the triple bottom line. *International Journal Of Production Economics*, 140(1), pp. 149-159.
10. Hancock T. (2003). Health, human development and the community ecosystem: three ecological models. *Health Promotion International*, 8, 1, pp. 41-47.

11. Haskell, W.L. (2006). Dose-Response Issues in Physical Activity, Fitness, and Health. In: C. Bouchard, S.N. Blair, W.L. Haskell (eds.), (pp. 303-317). *Physical Activity and Health. Champaign: Human Kinetics*.
12. *HR Excellence in Research*. Uniwersytet Łódzki. Available from: <https://www.uni.lodz.pl/o-uniwersytecie/hr-excellence-in-research>
13. Imran, S., Alam, K., Beaumont, N. (2011, January). *A holistic conceptual framework for sustainable tourism management in protected areas*. 2011 Cambridge Business and Economics Conference Proceedings. University of Southern Queensland.
14. Jensen, M. (2007). Defining lifestyle. *Environmental Sciences*, 4(2), pp. 63-73.
15. Jethon, Z., Grzybowski, A. (eds.) (2000). *Medycyna zapobiegawcza i środowiskowa*. Warszawa: Wydawnictwo Lekarskie PZWL.
16. Korporowicz, L. (2004). The consumption of sensations in a transformation society. In: M. Marody (ed.), *Change or stagnation?* (p. 83). Warsaw: Scholar.
17. Korzeniowska, E., Puchalski, K. (2019). *Co firmy powinny wiedzieć, by skutecznie promować zdrowe odżywianie i aktywność fizyczną pracowników?* Raport z wyników reprezentatywnego badania 1000 pracowników średnich i dużych firm w Polsce, opracowany przez Instytut Medycyny Pracy im. prof. dra J. Nofera, Krajowe Centrum Promocji Zdrowia w Miejscu Pracy, w ramach umowy z Ministerstwem Zdrowia na realizację zadania publicznego określonego w Narodowym Programie Zdrowia na lata 2016-2020. Available from: <https://promocjazdrowiawpracy.pl/wp-content/uploads/2019/10/raport2019.pdf>
18. Lalonde, M. (1974). *A new perspective on the health of Canadians*. Available from: [www.phac-aspc.gc.ca/ph-sp/phdd/pdf/perspective.pdf](http://www.phac-aspc.gc.ca/ph-sp/phdd/pdf/perspective.pdf)
19. Larsson, S.C., Kaluza, J., Wolk, A. (2017). Combined impact of healthy lifestyle factors on lifespan: two prospective cohorts. *Journal of Internal Medicine*, 282(3), pp. 209-219.
20. Ostaszewski, K. Prevention of the use of psychoactive substances. In: B. Woynarowska (ed.), *Health education* (pp. 483-548). Warsaw: PWN.
21. *Our Common Future – Brundtland 1987* (WCED, 1987). Available from: <http://www.un-documents.net/our-common-future.pdf>
22. Pabian, A. (2017). Zrównoważone przedsiębiorstwo jako rezultat zmian organizacyjnych. *Przegląd Organizacji*, 8(931), pp. 11-16.
23. *Rio Declaration* (1992). United Nations Conference on Environment and Development, Rio de Janeiro. Available from: [https://daccess-ods.un.org/access.nsf/Get?OpenAgent&DS=A/CONF.151/26/Rev.1\(vol.I\)&Lang=E](https://daccess-ods.un.org/access.nsf/Get?OpenAgent&DS=A/CONF.151/26/Rev.1(vol.I)&Lang=E)
24. Różańska-Bińczyk, I. (2021). Promocja zdrowego stylu życia pracowników jako ważnego elementu zrównoważonego rozwoju. In: I. Mendryk (ed.), *Zarządzanie zasobami ludzkimi w nowej przestrzeni fizycznej i społecznej* (pp. 540-553). Warszawa: Difin.
25. Sachs, J.D., Kroll, C., Lafortune, G., Fuller, G., Woelm, F. (2022). *Sustainable development report 2022*. Cambridge University Press.



26. Stockholm Declaration of the United Nations Conference on the Human Environment (1972). Available from: <https://wedocs.unep.org/bitstream/handle/20.500.11822/29567/ELGP1StockD.pdf>
27. *Strategy of the University of Lodz 2021-2030*. Available from: [https://www.bip.uni.lodz.pl/fileadmin/user\\_upload/Strategia\\_Uniwersytetu\\_%C5%81%C3%B3dzkiego\\_2021-2030.pdf](https://www.bip.uni.lodz.pl/fileadmin/user_upload/Strategia_Uniwersytetu_%C5%81%C3%B3dzkiego_2021-2030.pdf)
28. Sudoł, S. (2012). *Nauki o zarządzaniu. Podstawowe problemy i kontrowersje*. Warszawa: PWE.
29. Syper-Jędrzejak, M. (2019). *Corporate wellness w organizacji. Uwarunkowania, model wymiarów działań, możliwości rozwoju*. Wydawnictwo Uniwersytetu Łódzkiego.
30. *The preamble to the Constitution of the World Health Organization* (1946). Available from: [http://whqlibdoc.who.int/hist/official\\_records/constitution.pdf](http://whqlibdoc.who.int/hist/official_records/constitution.pdf)
31. *Transforming our world: The 2030 Agenda for Sustainable Development* (2015). Available from: <https://sdgs.un.org/2030agenda>
32. Wirtenberg, J., Harmon, J., Russell, W.G., Fairfield, K.D. (2007). HR's role in building a sustainable enterprise: Insights from some of the world's best companies. *People and Strategy*, 30(1), p. 10.
33. World Health Organization (1994). *Global strategy on occupational health for all: The way to health at work*. Available from: [https://www.who.int/occupational\\_health/publications/globstrategy/en/](https://www.who.int/occupational_health/publications/globstrategy/en/)
34. World Health Organization (1998). The World Health Report 1998: Life in the 21st century a vision for all. In: *The world health report 1998: life in the 21st century A vision for all* (pp. 241-241).
35. World Health Organization (1999). *Healthy living: what is a healthy lifestyle?* (No. EUR/ICP/LVNG 01 07 02). Copenhagen: WHO Regional Office for Europe. Available from: [https://apps.who.int/iris/bitstream/handle/10665/108180/EUR\\_ICP\\_LVNG\\_01\\_07\\_02.pdf](https://apps.who.int/iris/bitstream/handle/10665/108180/EUR_ICP_LVNG_01_07_02.pdf)
36. World Health Organization (2019). *Global action plan on physical activity 2018-2030: more active people for a healthier world*.



## APPLICATION OF THE ECM ALGORITHM TO THE ESTIMATION OF THE LIKELIHOOD FUNCTION IN FINANCIAL AUDITING

Grzegorz SITEK

Uniwersytet Ekonomiczny w Katowicach, Katedra Statystyki, Ekonometrii i Matematyki;  
grzegorz.sitek@ue.katowice.pl, ORCID: 0000-0002-7191-8631

**Purpose:** The book amounts are treated as values of a random variable whose distribution is a mixture of the distributions of the correct amount and the true amount contaminated by error. The mixing coefficient is equal to the proportion of the items with non-zero errors amounts. Below we consider a problem of testing appropriately formulated statistical hypotheses about admissibility of the total or the mean accounting errors. Hypotheses can be verified by the likelihood ratio test. In this paper, we show how to estimate parameters of the likelihood function.

**Design/methodology/approach:** The book amounts are treated as values of a random variable whose distribution is a mixture of the distributions of the correct amount and the true amount contaminated by error. The mixing coefficient is equal to the proportion of the items with non-zero errors amounts. Below we consider a problem of testing appropriately formulated statistical hypotheses about admissibility of the total or the mean accounting errors. Hypotheses can be verified by the likelihood ratio test. In this paper, we show how to estimate parameters of the likelihood function.

**Findings:** The work presents formulas for the parameters of the likelihood function. These parameters were obtained using the ECM algorithm.

**Originality/value:** The problem of estimating the average audit error is very common in economic research. A method for estimating the average audit error based on the likelihood function was proposed. The parameters of the likelihood function were estimated using the ECM algorithm.

**Keywords:** ECM algorithm, likelihood ratio test, mixture of probability distribution.

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

### 1. Introduction

Letting  $X_i$  denote the book amount of the  $i$ th item in the account  $X_U = \sum_{i=1}^N x_i$  called the population book amount, at regular periods, an auditor samples  $n$  line items from the account and compares them against correct amounts. Therefore, let  $Y_i$  denote the audited amounts for the  $i$ th line item and let  $\tau_i = X_i - Y_i$  denote the error amount. Notice that the total book amount

is known to the auditor. The fundamental problem is the problem of constructing confidence limits for mean or totals in finite populations, when the underlying distribution is highly skewed and contains a substantial proportion of zero values. This situation is often encountered in statistical applications such as statistical auditing, reliability and insurance. The most distinctive feature of accounting data is the large proportion of line items without error, while an audit sample may not yield any nonzero error amounts. For analyses of such data, which most observations are zero, the classical interval estimation of the total error amount based on the asymptotic normality of the sampling distribution is not reliable. In auditing practice, auditors are often more interested in obtaining lower or upper confidence limits than in obtaining two-sided confidence intervals. Independent public accountants are very often concerned in estimating the lower confidence bound for the total audited amount. An auditor wants to avoid overestimating this bound because of the potential legal liability that may follow from this. Stringer (1963) and Kaplan (1973) shows, that the accounting populations are highly positively skewed, and there is considerable diversity in the characteristics of error amounts in accounting populations across the accounting subsystem. There are several distributions that also exhibit the same form of the distribution observed in accounting populations. These include the Gamma, Log-normal, Weibull, and Beta distributions. The error rates are usually very low, which render many existing statistical procedures inappropriate for estimating and hypothesis testing of error rates and error amounts. There are two main types of audit tests for which the acquisition of information can profitably make use of statistical sampling. The first audit test, collecting data to determine the rate of procedural errors of a population of transactions is called a compliance test. The second, collecting data for evaluating the aggregate monetary error in the stated balance, is called a substantive test of details. Inference on the total error amount is usually based on confidence intervals. Of course, they are related to testing problems. The decision-making process in auditing is treated as a problem of testing statistical hypotheses about admissibility of the total or the mean accounting errors. This approach lets us control not only significance level (risk of incorrect rejection), but also probability of the type II error appearing (risk of incorrect acceptance). Substantive tests of details are concerned with the examination of the correctness of recorded monetary values in a financial statement. These tests provide direct evidence about the accuracy of total recorded monetary values. The auditor either applies substantive tests of detail extensively, or applies compliance tests to see if reliance on those controls are efficient and effective in reducing the tendency of material error in accounts. In compliance tests, the variable of interest is an error rate (proportion of transactions for which the internal control operates wrongly). Samples of transactions are used to make inferences about the error rate.

Wywiał (2018) proposed following model. Let  $U$  be the population of accounting documents of size  $N$  with given accounting totals. Some of the documents contain errors. In the population  $U$  there are given accounting totals (values)  $x_i$  for each element  $i \in U$ . Let  $x^T = [x_1, \dots, x_N] \in R_+^N$  be the observation of a random vector  $X^T = [X_1, \dots, X_N]$ . We denote

the true book values (without errors) by  $y_i, i \in U$  and let  $y^T = [y_1, \dots, y_N] \in R_+^N$  be the random vector observation  $Y^T = [Y_1, \dots, Y_N]$ . Vector of accounting values contaminated by errors  $w^T = [w_1, \dots, w_N]$  will be an observation of the random vector  $W^T = [W_1, \dots, W_N]$ . Finally, let  $Z^T = [Z_1, \dots, Z_N]$ , where  $Z_i = 0$  ( $Z_i = 1$ ) if  $X_i = Y_i$  ( $X_i \neq Y_i$ ).

In practice, all values of  $X$  are known before auditing process. Observations  $x$  of  $X$  are treated as a specific auxiliary data. Auditing process leads to observation of values  $Z_i, Y_i$  and  $W_i, i \in U$ . Let  $\bar{X} = \frac{1}{N} \sum_{i \in U} X_i, \bar{Y} = \frac{1}{N} \sum_{i \in U} Y_i, \bar{W} = \frac{1}{N} \sum_{i \in U} W_i$ . Their values will be denoted  $\bar{x}, \bar{y}, \bar{w}$ .

Let an auditor arbitrary selects the sample  $s$  of the size  $n$  from  $U$ . Hence,  $X_s$  is the subvector of  $X, n \leq N$ . The random vector  $X_s$  is observed in  $s$  where the objects are controlled. After the auditing process the sample  $s$  is split into two disjoint sub-samples  $s_0$  and  $s_1$  where  $s = s_0 \cup s_1$ . The set  $s_1$  is of size  $n_1 = k$  and the set  $s_0$  is of size  $n_0 = n - k$ . In the sub-sample  $s_0$  here are observed accounting amounts without errors. Before auditing process, we have observations of the following data:

$$X = (X_i: i \in U) = (X_s, X_{U-s}),$$

where

$$X_s = (X_i: i \in s), X_{U-s} = (X_i: i \in U - s).$$

After the auditing process, we have observations of the following data:

$$T_U = (T_s, X_{U-s}), T_s = (X_i, Z_i): i \in s) = (Y_{s_0}, W_{s_1}).$$

Values  $T, T_U, X, X_s, X_{U-s}, Y_{s_0}$  and  $W_{s_1}$  are denoted respectively by  $t, t_U, x, x_s, x_{U-s}, y_{s_0}$  and  $w_{s_1}$ . In the following work, we assume that  $y_{s_0} = y_s$  and  $w_{s_1} = w_s$ .

Let  $\tau = E(\bar{X} - \bar{Y})$  be the expected mean accounting error. Audit purpose is inference on  $\tau$  or on the expected total accounting error  $N\tau = E(\sum_{i \in U} X_i - \sum_{i \in U} Y_i)$ . In particular, when we assume that  $\tau_0$  is the admissible mean accounting error then the inference reduces to testing the following hypothesis:

$$H_0: \tau = \tau_0, H_1: \tau > \tau_0, \quad (1)$$

where  $\tau_1$  is unadmissible level of the mean accounting error.

## 2. A mixture of three probability distributions as a model for generating accounting values

Let  $F_0(y|\theta_0)$  be the probability distribution function of the random variable  $Y$ , whose values are true accounting and  $\theta_0 \in \Theta_0$  where  $\Theta_0$  is the parameter space. The distribution function of  $W$  is denoted by  $F_1(w|\theta_1)$ , where  $\theta_1 \in \Theta_1$ . Moreover, let  $\Theta = \Theta_0 \cup \Theta_1$ . We assume that an accounting errors appears with probability  $p$ . We can write  $Z = 1$  when an accounting error occurs  $P(Z = 1) = p$  and  $Z = 0$  when it does not occur  $P(Z = 0) = 1 - p$ . According to the

well-known total probability theorem we have:  $F(x) = F(x|Z = 0)P(Z = 0) + F(x|Z = 1)P(Z = 1)$  and finally

$$F(x|\theta) = (1 - p)F_0(x|\theta_0) + pF_1(x|\theta_1), \quad (2)$$

where  $\theta = \theta_0 \cup \theta_1$  and  $\theta \in \Theta = \Theta_0 \cup \Theta_1$  is the parameter space.

Hence, the probability distribution of the observed accounting amounts is a mixture of the distribution function  $F_0(x|\theta_0)$  of the true amounts and the distribution function  $F_1(x|\theta_1)$  of the amounts contaminated by errors. When the random variables  $Y$  and  $W$  are continuous, by differentiating both sides of equation (2) we have

$$f(x|\theta) = (1 - p)f_0(x|\theta_0) + pf_1(x|\theta_1). \quad (3)$$

Therefore, the probability density of the observed accounting amounts is a mixture of density  $f_0(x|\theta_0)$  of the true amounts and density  $f_1(x|\theta_1)$  of the amounts contaminated by errors. Let  $R$  and  $Y$  be independent and  $R$  is the accounting error. Hence  $W = Y + R$ ,  $X = Y + ZR$ ,  $X = (1 - Z)Y + ZW$ .

The basic moments of the random variable  $X$  are:

$$E(X) = (1 - p)E(X|Z = 0) + pE(X|Z = 1) = (1 - p)E(Y) + pE(W). \quad (4)$$

$$V(X) = p(1 - p)(E(W) - E(Y))^2 + pV(W) + (1 - p)V(Y). \quad (5)$$

In the context of model approach our purpose is to test the hypothesis about the expected value of the following difference of the sum of observed in the population accounting amounts and the sum of the true values.

$$\tau = E(\bar{X} - \bar{Y}) = E(X) - E(Y) = p(E(W) - E(Y)), \quad (6)$$

or

$$\tau(\theta) = E(X|\theta) - E(Y|\theta_0) = p(E(W|\theta_1) - E(Y|\theta_0)). \quad (7)$$

The well-known gamma probability distribution we denote by  $G(\alpha, \beta)$  where parameters  $\alpha > 0$  and  $\beta > 0$  are called scale and shape parameters. The shape of gamma density distribution does not depend on the scale parameter because its skewness and kurtosis coefficients are equal to  $\frac{2}{\sqrt{\beta}}$  and  $\frac{6}{\beta}$  respectively. Wywiał (2018) considered the model based on a mixture of gamma distributions. Let  $Y \sim G(a, c)$  and  $R \sim G(b, c)$  be independent random variables. The advantage of this model is that the density function for the sum of gamma distributions can be determined. Based on the above assumption, the random variable  $W = Y + R \sim G(a + b, c)$ . Using the previous considerations, we obtain

$$f(x|a, b, c) = (1 - p)f_0(x|a, c) + pf_1(x|a, b, c), \quad (8)$$

where

$$f_1(x|a, b, c) = \frac{c^{a+b}}{\Gamma(a+b)} x^{a+b-1} e^{-cx}, x > 0, \quad (9)$$

$$f_0(x|a, c) = \frac{c^a}{\Gamma(a)} x^{a-1} e^{-cx}, x > 0. \quad (10)$$

From formulae (4) and (5) we obtain

$$E(X) = \frac{a+pb}{c}, V(X) = \frac{a+pb+p(1-p)b^2}{c^2}. \quad (11)$$

For more on the use of gamma decomposition to model accounting values, see the articles by Frost and Tamura (1986) or Tamura (1988). The book amounts are treated as values of a random variable which distribution is a mixture of the distributions of correct amount and the distribution of the true amount contaminated by error. Distributions of correct amount and true amount contaminated by error are right-skewed because small book amounts are more frequent than large book amounts. It is convenient to assume that the book values are additive function of true accounting amounts and accounting errors. Hence, we can expect that the above proposed quite simple model describes accounting data well.

### 3. Testing on the basis of the likelihood function

Wywił (2018) considered the following likelihood function:

$$L(t|\theta) = L(t_s|\theta)L(x_{U-s}|\theta), \quad (12)$$

where

$$L(t_s|\theta) = \prod_{i \in S} p^{z_i} f_1^{z_i}(x_i|\theta_1) (1-p)^{1-z_i} f_0^{1-z_i}(x_i|\theta_0), \quad (13)$$

$$L(x_{U-s}|\theta) = \prod_{i \in U-s} f(x_i|\theta). \quad (14)$$

If  $z_i = 0$  ( $z_i = 1$ ) then  $x_i = y_i$  ( $x_i = w_i$ ). The logarithm of the likelihood function (12) is given by the formula

$$l(t|\theta) = k \ln(p) + (n-k) \ln(1-p) + \sum_{i \in S_1} \ln(f_1(x_i|\theta_1)) + \sum_{i \in S_0} \ln(f_0(x_i|\theta_0)) + \sum_{i \in U-s} \ln(f(x_i|\theta)). \quad (15)$$

Hypotheses (1) can be verified by means of the well-known likelihood ratio test on the basis of the following statistic:

$$\lambda = \frac{\sup_{\theta \in \Theta, \tau(\theta) = \tau_0} L(D|\theta)}{\sup_{\theta \in \Theta} L(D|\theta)}. \quad (16)$$

We can expect that when hypothesis  $H_0$  is true and  $n, N, N-n, n_0$  and  $n-n_0$  are sufficiently large then statistic  $t = -2 \ln(\lambda)$  is well approximated by the chi-square distribution with one degree of freedom (Silvey 1959). Hypothesis  $H_0$  is rejected if  $t$  is significantly large.

#### 3.1. Mixture of two gamma distributions with the same scale parameter

We consider a mixture of two gamma distributions with the same scale parameter denoted by the symbol  $c$ . For this mixture, the logarithm of the likelihood function (15) is written as

$$l = k \ln(p) + (n-k) \ln(1-p) + N \ln(c) + k b \ln(c) - k \ln(\Gamma(a+b)) - (n-k) \ln(\Gamma(a)) + (a-1) \sum_{j \in U} \ln(x_j) + b \sum_{j \in S_1} \ln(x_j) - c \sum_{j \in U} x_j + \sum_{j \in U-s} \ln\left(\frac{1-p}{\Gamma(a)} + \frac{p(cx_j)^b}{\Gamma(a+b)}\right). \quad (17)$$

In order to determine the parameter estimators  $a$ ,  $b$ ,  $c$  and  $p$  we calculate the derivatives of equation (17). In financial auditing, the case  $U = s$  is practically absent. The sample size  $n$  is usually a few percent of the population size  $N$ . These estimators can be obtained using the ECM algorithm. The ECM algorithm (Meng and Rubin (1993)) is an efficient combination of the CM and EM algorithms (McLachlan and Peel, (2000)). It replaces the maximization step of EM with a set of conditional maximization steps, and thus splits a difficult maximization problem into several easier ones.

### 3.2. ECM algorithm

Based on the previous expressions we write the following likelihood function

$$L = \prod_{i=1}^k \mathbf{p} \frac{c^{(a+b)} w_{s_i}^{(a+b-1)} e^{-cw_{s_i}}}{\Gamma(a+b)} \prod_{i=k+1}^n (\mathbf{1} - \mathbf{p}) \frac{c^a y_{s_i}^{(a-1)} e^{-cy_{s_i}}}{\Gamma(a)} \prod_{i=n+1}^N \left[ \mathbf{p} \frac{c^{(a+b)} x_{(U-s)_i}^{(a+b-1)} e^{-cx_{(U-s)_i}}}{\Gamma(a+b)} + (\mathbf{1} - \mathbf{p}) \frac{c^a x_{(U-s)_i}^{(a-1)} e^{-cx_{(U-s)_i}}}{\Gamma(a)} \right]. \quad (18)$$

We then determine the logarithm of the likelihood function (18). To simplify the notation, we introduce the variable  $d = a + b$

$$\begin{aligned} l = & k \ln(\mathbf{p}) + (n - k) \ln(\mathbf{1} - \mathbf{p}) + kd \ln(c) - c \sum_{i=1}^k w_{s_i} \\ & + (d - 1) \sum_{i=1}^k \ln(w_{s_i}) - k \ln(\Gamma(d)) + (n - k) a \ln(c) - \\ & c \sum_{i=k+1}^n y_{s_i} + (a - 1) \sum_{i=k+1}^n \ln(y_{s_i}) - (n - k) \ln(\Gamma(a)) + \\ & \sum_{i=n+1}^N \ln \left[ \mathbf{p} \frac{c^d}{\Gamma(d)} x_{(U-s)_i}^{d-1} e^{-cx_{(U-s)_i}} + (\mathbf{1} - \mathbf{p}) \frac{c^a}{\Gamma(a)} x_{(U-s)_i}^{a-1} e^{-cx_{(U-s)_i}} \right]. \end{aligned} \quad (19)$$

To determine the parameter estimators  $a$ ,  $d$ ,  $c$  and  $p$  it is necessary to calculate the partial derivatives of the function (19) and solve the system of equations numerically. These estimators can be obtained using the ECM algorithm.

#### Step E.

$$\hat{\gamma}_i = \frac{\hat{p} \frac{c^d}{\Gamma(d)} x_{(U-s)_i}^{d-1} e^{-cx_{(U-s)_i}}}{\hat{p} \frac{c^d}{\Gamma(d)} x_{(U-s)_i}^{d-1} e^{-cx_{(U-s)_i}} + (\mathbf{1} - \hat{p}) \frac{c^a}{\Gamma(a)} x_{(U-s)_i}^{a-1} e^{-cx_{(U-s)_i}}}. \quad (20)$$

#### Step CM.

The logarithm of the likelihood function (20) is written as follows

$$\begin{aligned} Q(a, d, c, p) = & \sum_{i=n+1}^N ((\mathbf{1} - \hat{\gamma}_i)(a \ln(c) + (a - 1) \ln(x_{(U-s)_i}) - \ln(\Gamma(a)) - cx_{(U-s)_i}) + \\ & \hat{\gamma}_i(d \ln(c) + (d - 1) \ln(x_{(U-s)_i}) - \ln(\Gamma(d)) - cx_{(U-s)_i}) + \hat{\gamma}_i \ln(\mathbf{p}) + (\mathbf{1} - \hat{\gamma}_i) \ln(\mathbf{1} - \mathbf{p})) \\ & k \ln(\mathbf{p}) + (n - k) \ln(\mathbf{1} - \mathbf{p}) + kd \ln(c) - c \sum_{i=1}^k w_{s_i} + (d - 1) \sum_{i=1}^k \ln(w_{s_i}) - k \ln(\Gamma(d)) + \\ & (n - k) a \ln(c) - c \sum_{i=k+1}^n y_{s_i} + (a - 1) \sum_{i=k+1}^n \ln(y_{s_i}) - (n - k) \ln(\Gamma(a)). \end{aligned} \quad (21)$$

Determining the partial derivatives of a function (21)

$$\begin{aligned} \frac{\partial Q}{\partial a} = & \sum_{i=n+1}^N (\mathbf{1} - \hat{\gamma}_i)(-\psi^{(0)}(a) + \ln(c) + \ln(x_i)) + \\ & \sum_{i=k+1}^n \ln(y_i) - \psi^{(0)}(a)(n - k) + \ln(c)(n - k) = 0. \end{aligned} \quad (22)$$



$$\begin{aligned} \frac{\partial Q}{\partial d} &= \sum_{i=n+1}^N \hat{\gamma}_i (-\psi^{(0)}(d) + \ln(c) + \ln(x_{(U-s)_i})) + \\ &\sum_{i=1}^k \ln(w_{s_i}) - \psi^{(0)}(a)k + \ln(c)k = 0. \end{aligned} \quad (23)$$

The previous two equations can be solved numerically using the Newton-Raphson method.

$$\begin{aligned} \frac{\partial Q}{\partial c} &= \sum_{i=n+1}^N (1 - \hat{\gamma}_i) \left( \frac{a}{c} - x_{(U-s)_i} \right) + \sum_{i=n+1}^N \hat{\gamma}_i \left( \frac{d}{c} - x_{(U-s)_i} \right) - \\ &\sum_{i=k+1}^n y_{s_i} - \sum_{i=1}^k w_{s_i} + \frac{a(n-k)}{c} + \frac{dk}{c} = 0. \end{aligned} \quad (24)$$

After transformations, we obtain the estimator of the parameter  $c$

$$\hat{c} = \frac{d(k + \sum_{i=n+1}^N \hat{\gamma}_i) + a(n-k + \sum_{i=n+1}^N (1 - \hat{\gamma}_i))}{\sum_{i=k+1}^n y_{s_i} + \sum_{i=1}^k w_{s_i} + \sum_{i=n+1}^N x_{(U-s)_i}}. \quad (25)$$

$$\frac{\partial Q}{\partial p} = \sum_{i=n+1}^N -\frac{1 - \hat{\gamma}_i}{1-p} + \sum_{i=n+1}^N \frac{\hat{\gamma}_i}{p} - \frac{n-k}{1-p} + \frac{k}{p} = 0, \quad (26)$$

$$\hat{p} = \frac{k + \sum_{i=n+1}^N \hat{\gamma}_i}{N}. \quad (27)$$

Let  $a_{y_s}$ - is the shape parameter obtained by the maximum likelihood method from the observation vector  $y_s$ ,  $c_{y_s}$ - is the scale parameter obtained by the maximum likelihood method from the observation vector  $y_s$ ,  $d_{w_s}$ - is the shape parameter obtained by the maximum likelihood method based on a vector of observations  $w_s$ ,  $c_{w_s}$ - is a scale parameter derived by the maximum likelihood method from a vector of observations  $w_s$ . The estimators thus obtained constitute a vector of starting parameters for the ECM algorithm  $(a_0, d_0, c_0, p_0) = (a_{y_s}, d_{w_s}, \frac{c_{y_s} + c_{w_s}}{2}, \frac{k}{n})$ .

If the number of erroneous values  $k$  in the drawn sample is small, it may not be possible to use the maximum likelihood method for estimating the starting parameters. In this case, the method of moments can be used. The above-described ECM algorithm will not work if the  $k = 0$ .

### 3.3. Parameter estimation of a mixture of gamma distributions when the hypothesis $H_0$ is true

In this case, we estimate the parameters  $a_{H_0}$ ,  $c_{H_0}$  i  $p_{H_0}$ , because the parameter  $b$  then a function of the parameters  $\tau_0$ ,  $c$  and  $p$  ( $b = \frac{c\tau_0}{p}$ ).

$$\begin{aligned} L &= \prod_{i=1}^k p \frac{c^{(a+\frac{c\tau_0}{p})} w_{s_i}^{(a+\frac{c\tau_0}{p}-1)} e^{-cw_{s_i}}}{\Gamma(a+\frac{c\tau_0}{p})} \prod_{i=k+1}^n (1-p) \frac{c^a y_{s_i}^{(a-1)} e^{-cy_{s_i}}}{\Gamma(a)} \\ &\prod_{i=n+1}^N \left[ p \frac{c^{(a+\frac{c\tau_0}{p})} x_{(U-s)_i}^{(a+\frac{c\tau_0}{p}-1)} e^{-cx_{(U-s)_i}}}{\Gamma(a+\frac{c\tau_0}{p})} + (1-p) \frac{c^a x_{(U-s)_i}^{(a-1)} e^{-cx_{(U-s)_i}}}{\Gamma(a)} \right]. \end{aligned} \quad (28)$$

We then determine the logarithm of the likelihood function (28)

$$\begin{aligned}
 l = & k\ln(p) + (n - k)\ln(1 - p) + k(a + \frac{c\tau_0}{p})\ln(c) - c \sum_{i=1}^k w_{s_i} \\
 & + (a + \frac{c\tau_0}{p} - 1) \sum_{i=1}^k \ln(w_{s_i}) - k\ln(\Gamma(a + \frac{c\tau_0}{p})) + (n - k)a\ln(c) - \\
 & c \sum_{i=k+1}^n y_{s_i} + (a - 1) \sum_{i=k+1}^n \ln(y_{s_i}) - (n - k)\ln(\Gamma(a)) + \\
 & \sum_{i=n+1}^N \ln[p \frac{c^{\frac{a+c\tau_0}{p}}}{\Gamma(a+\frac{c\tau_0}{p})} x_{(U-s)_i}^{\frac{a+c\tau_0}{p}-1} e^{-cx_{(U-s)_i}} + (1 - p) \frac{c^a}{\Gamma(a)} x_{(U-s)_i}^{a-1} e^{-cx_{(U-s)_i}}].
 \end{aligned}
 \tag{29}$$

Parameter estimators  $a$ ,  $c$  and  $p$  can be determined by maximising the function (29) in the R environment with the nlm function. The starting parameters for the nlm function are chosen as follows  $(a_0, c_0, p_0) = (a_{y_s}, \frac{c_{y_s} + c_{w_s}}{2}, \frac{k}{n})$ .

### 4. Simulation study of the power of the likelihood ratio test

In the first step, the critical test values were determined by simulation. Then, in a second step, the test power was determined in a simulation manner for the previously determined critical values. For a mixture of gamma distributions, the following hypothesis was tested:

$$H_0 : \tau = \tau_0 = 50, H_1 : \tau = \tau_1 > \tau_0.$$

**Table 1.**  
*Power of the likelihood ratio test. A mixture of gamma distributions*

$\tau_1$	$p$	$\alpha$	N						
			80	120	160	200	400	600	
1,01 $\tau_0$	0,1	0,05	0,047	0,05	0,05	0,05	0,05	0,051	0,052
		0,1	0,098	0,101	0,099	0,102	0,101	0,107	
		0,2	0,203	0,199	0,190	0,203	0,206	0,206	
	0,2	0,05	0,045	0,04	0,047	0,05	0,05	0,062	
		0,1	0,092	0,09	0,102	0,095	0,10	0,108	
		0,2	0,187	0,189	0,203	0,204	0,2	0,205	
	0,3	0,05	0,047	0,049	0,05	0,051	0,055	0,064	
		0,1	0,1	0,1	0,099	0,103	0,106	0,106	
		0,2	0,22	0,22	0,209	0,205	0,207	0,206	
1,03 $\tau_0$	0,1	0,05	0,06	0,058	0,05	0,057	0,056	0,057	
		0,1	0,102	0,111	0,102	0,11	0,109	0,11	
		0,2	0,207	0,2	0,199	0,203	0,207	0,209	
	0,2	0,05	0,05	0,04	0,048	0,057	0,05	0,053	
		0,1	0,096	0,097	0,093	0,101	0,104	0,107	
		0,2	0,187	0,191	0,2	0,197	0,206	0,211	
	0,3	0,05	0,05	0,046	0,049	0,053	0,05	0,056	
		0,1	0,097	0,094	0,099	0,107	0,105	0,113	
		0,2	0,2	0,19	0,199	0,203	0,208	0,209	

Cont. table 1.

1,05 $\tau_0$	0,1	0,05	0,05	0,059	0,054	0,051	0,054	0,054
		0,1	0,101	0,112	0,114	0,119	0,116	0,119
		0,2	0,202	0,2	0,206	0,206	0,21	0,211
	0,2	0,05	0,045	0,05	0,05	0,049	0,05	0,053
		0,1	0,098	0,097	0,096	0,099	0,1	0,103
		0,2	0,203	0,199	0,194	0,195	0,199	0,209
	0,3	0,05	0,051	0,052	0,05	0,053	0,052	0,054
		0,1	0,1	0,102	0,102	0,101	0,1	0,102
		0,2	0,205	0,2	0,203	0,204	0,209	0,212
1,075 $\tau_0$	0,1	0,05	0,059	0,058	0,054	0,62	0,07	0,072
		0,1	0,114	0,115	0,115	0,113	0,12	0,121
		0,2	0,207	0,2	0,209	0,205	0,21	0,21
	0,2	0,05	0,052	0,05	0,05	0,075	0,089	0,062
		0,1	0,103	0,1	0,096	0,112	0,116	0,115
		0,2	0,203	0,2	0,198	0,202	0,206	0,205
	0,3	0,05	0,056	0,055	0,051	0,05	0,05	0,06
		0,1	0,105	0,1	0,102	0,103	0,1	0,109
		0,2	0,197	0,2	0,202	0,204	0,204	0,206

Source: own calculations.

Parameters were used to generate a mixture of gamma distributions:  $a = 2$ ,  $c = 0,002$ . For the mixing parameters  $p = 0,1$ ,  $p = 0,2$ ,  $p = 0,3$  the corresponding parameters were determined  $b = \frac{c\tau_1}{p}$ . The results showing the power of the test are contained in Tables 1-2 and graphically interpreted in Figures 1-4.

The power diagrams are approximated by a broken line. The highest power is obtained for the mixing parameter  $p = 0,1$  which corresponds to the value of the parameter  $b = \frac{50 \cdot 0,002}{0,1} = 1$ . The test power for  $\tau_1 = 1,3\tau_0 = 65$  and  $\alpha = 0,2$  is 0,477. In this case, the difference in the mean value of the documents with errors and the mean value of the documents without errors is  $\bar{w} - \bar{y} = 500$ . The lowest power is obtained for the mixing parameter  $p = 0,3$ , which corresponds to the value of the parameter  $b = \frac{50 \cdot 0,002}{0,3} = \frac{1}{3}$ . In this case, the difference of the average value of the documents with errors and the average value of the documents without errors is  $\bar{w} - \bar{y} = 150$ .

**Table 2.**

*Power of the likelihood ratio test. A mixture of gamma distributions*

$\tau_1$	p	$\alpha$	n					
			80	120	160	200	400	600
1,1 $\tau_0$	0,1	0,05	0,065	0,064	0,065	0,066	0,069	0,078
		0,1	0,12	0,119	0,124	0,135	0,139	0,143
		0,2	0,2	0,22	0,22	0,215	0,219	0,23
	0,2	0,05	0,05	0,054	0,055	0,05	0,052	0,071
		0,1	0,106	0,114	0,111	0,117	0,106	0,132
		0,2	0,212	0,209	0,213	0,211	0,212	0,228
	0,3	0,05	0,06	0,055	0,054	0,051	0,051	0,065
		0,1	0,112	0,111	0,128	0,122	0,12	0,134
		0,2	0,227	0,218	0,217	0,224	0,227	0,229

Cont. table 2.

1,15 $\tau_0$	0,1	0,05	0,07	0,075	0,082	0,098	0,1	0,109
		0,1	0,12	0,122	0,137	0,134	0,157	0,182
		0,2	0,214	0,218	0,231	0,256	0,254	0,294
	0,2	0,05	0,066	0,063	0,062	0,07	0,079	0,109
		0,1	0,112	0,113	0,111	0,128	0,138	0,162
		0,2	0,207	0,204	0,203	0,226	0,239	0,267
	0,3	0,05	0,057	0,059	0,053	0,064	0,089	0,101
		0,1	0,109	0,109	0,108	0,123	0,156	0,161
		0,2	0,229	0,218	0,223	0,237	0,257	0,264
1,2 $\tau_0$	0,1	0,05	0,406	0,429	0,46	0,077	0,09	0,151
		0,1	0,131	0,139	0,139	0,144	0,157	0,23
		0,2	0,224	0,222	0,231	0,229	0,275	0,335
	0,2	0,05	0,056	0,054	0,053	0,066	0,077	0,136
		0,1	0,124	0,12	0,13	0,127	0,149	0,187
		0,2	0,219	0,216	0,211	0,246	0,272	0,333
	0,3	0,05	0,057	0,054	0,058	0,053	0,074	0,099
		0,11	0,104	0,1	0,111	0,116	0,145	0,175
		0,2	0,23	0,218	0,251	0,234	0,269	0,293
1,3 $\tau_0$	0,1	0,05	0,09	0,123	0,127	0,133	0,163	0,235
		0,1	0,154	0,195	0,218	0,219	0,261	0,326
		0,2	0,258	0,281	0,327	0,341	0,394	0,477
	0,2	0,05	0,083	0,08	0,08	0,1	0,12	0,204
		0,1	0,144	0,142	0,145	0,162	0,225	0,309
		0,2	0,249	0,247	0,247	0,282	0,376	0,443
	0,3	0,05	0,054	0,055	0,055	0,07	0,098	0,177
		0,1	0,11	0,104	0,133	0,16	0,181	0,299
		0,2	0,231	0,225	0,249	0,261	0,314	0,434

Source: own calculations.

Figures 1-2 show that the test is unconstrained because the power of the test is not less than the significance level. The Power increases in an approximately linear manner. Figure 4 shows that the increment in test power as a function of sample size is slow. As the sample size increases by 100, the power of the test increases by 0.05.

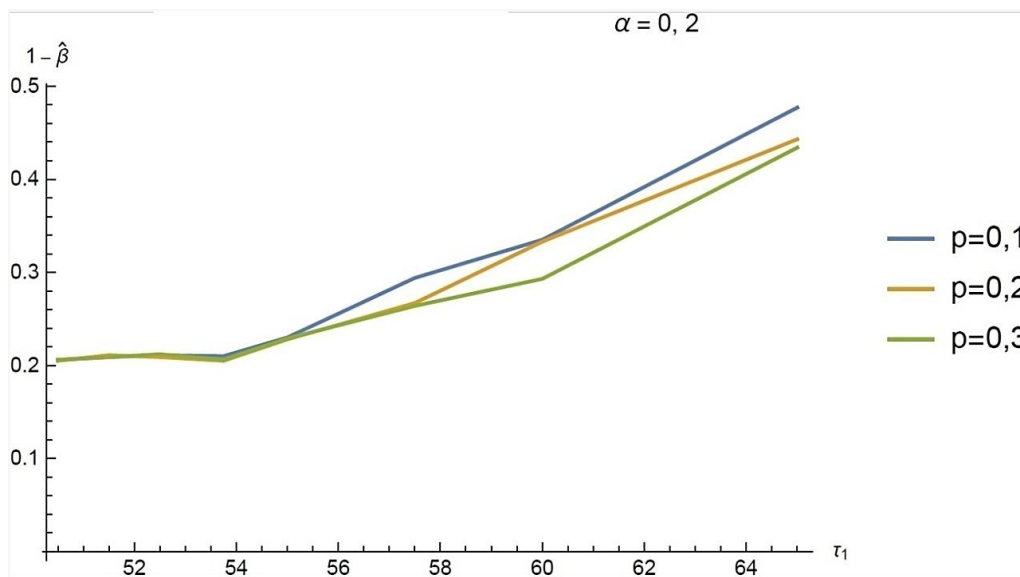
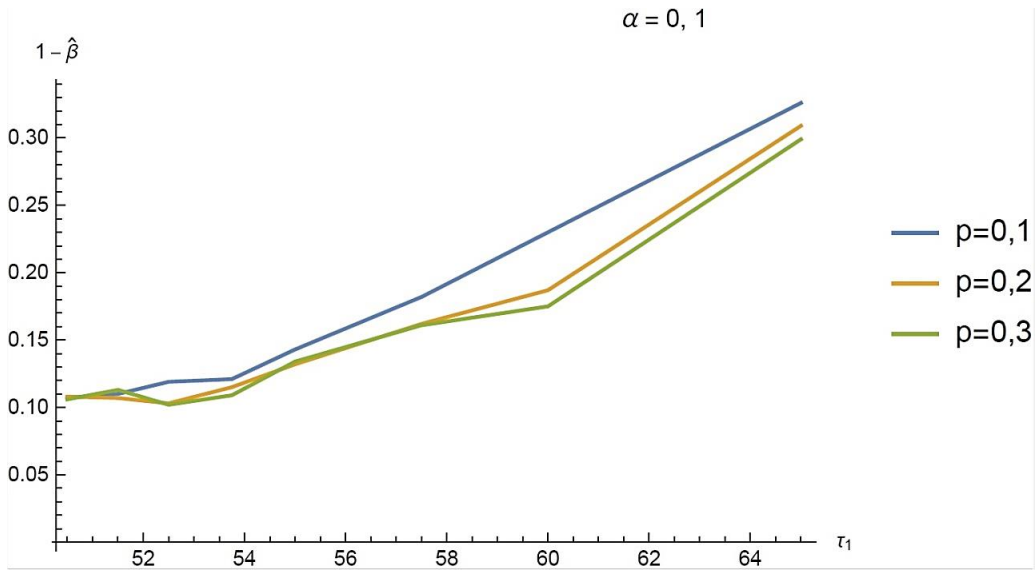


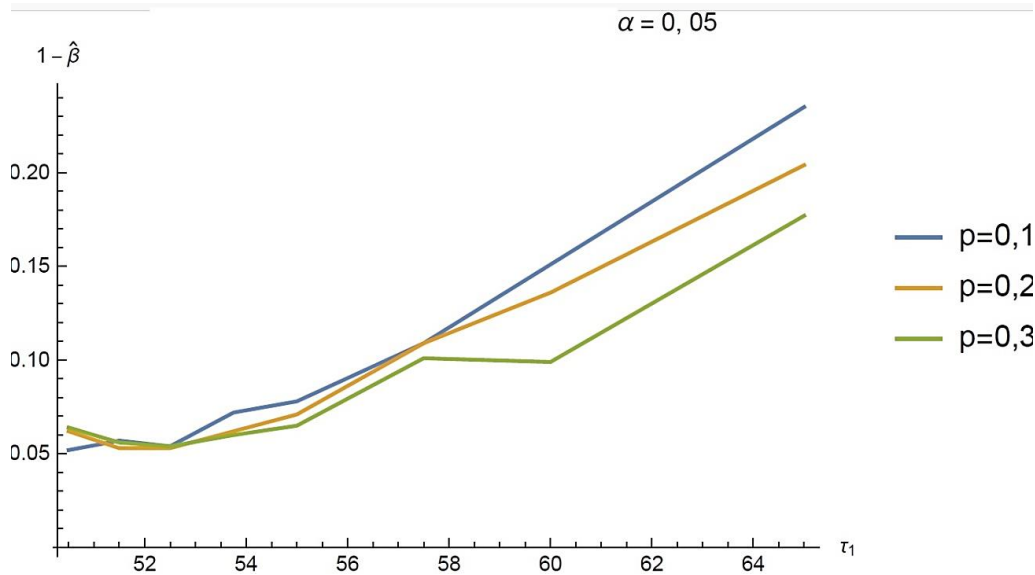
Figure 1. Test power depending on  $\tau_0$  and mixing parameters for a mixture of gamma distributions,  $\alpha = 0,2, \tau_0 = 50$ .

Source: Based on Tables 1 and 2.



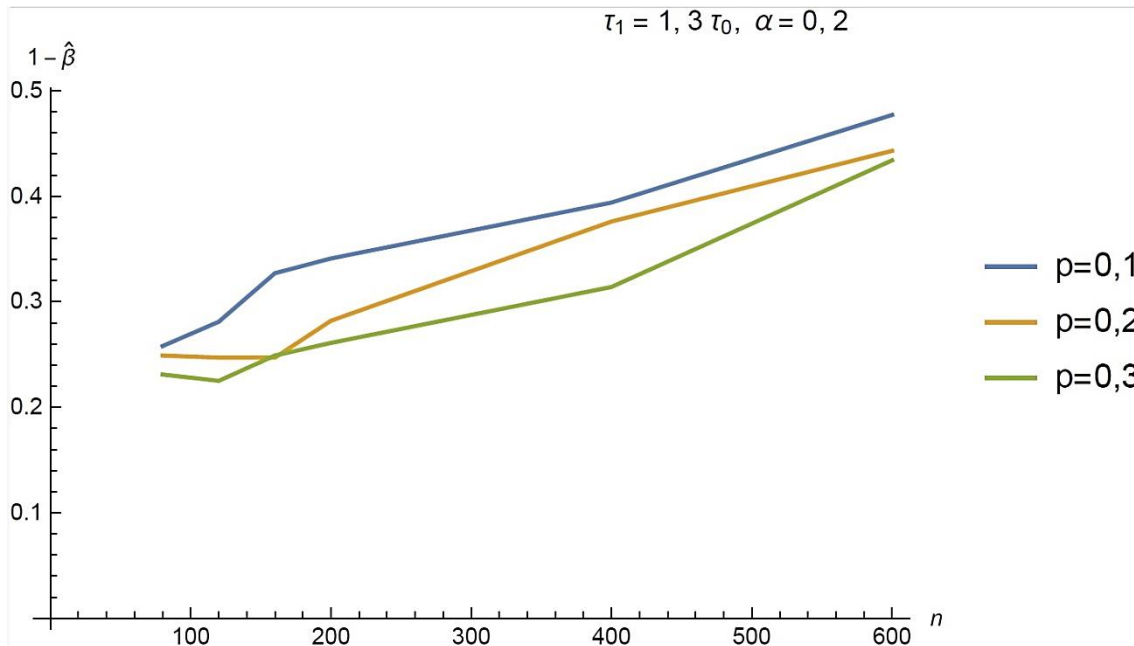
**Figure 2.** Test power depending on  $\tau_0$  and mixing parameters for a mixture of gamma distributions,  $\alpha = 0,1, \tau_0 = 50$ .

Source: Based on Tables 1 and 2.



**Figure 3.** Test power depending on  $\tau_0$  and mixing parameters for a mixture of gamma distributions,  $\alpha = 0,05, \tau_0 = 50$ .

Source: Based on Tables 1 and 2.



**Figure 4.** Test power as a function of sample size and mixing parameters for a mixture of gamma distributions,  $\alpha = 0,2$ ,  $\tau_1 = 1,3\tau_0$ .

Source: Based on Tables 1 and 2.

## 5. Conclusions

In this paper, we show how to estimate parameters of the likelihood function. Particularly, the results let us construct confidence intervals or the statistics to testing hypotheses on the mean or the total amount error with assumed risk of incorrect rejection  $H_0$  (significant level).

The considered maximum likelihood estimators are usually the solutions of the systems of the non-linear equations. In order to calculate those solutions, some numerical methods have to be used.

In the first step, the critical test values were determined by simulation. Then, in a second step, the test power was determined in a simulation manner for the previously determined critical values. For a mixture of gamma distributions, the following hypothesis was tested:  $H_0 : \tau = \tau_0 = 50, H_1 : \tau = \tau_1 > \tau_0$ .

Parameters were used to generate a mixture of gamma distributions:  $a = 2$ ,  $c = 0,002$ . For the mixing parameters  $p = 0,1$ ,  $p = 0,2$ ,  $p = 0,3$  the corresponding parameters were determined  $b = \frac{c\tau_1}{p}$ . The results showing the power of the test are contained in Tables 1-2 and graphically interpreted in Figures 1-4.

The power diagrams are approximated by a broken line. The highest power is obtained for the mixing parameter  $p = 0,1$  which corresponds to the value of the parameter  $b = \frac{50 \cdot 0,002}{0,1} = 1$ . The test power for  $\tau_1 = 1,3\tau_0 = 65$  and  $\alpha = 0,2$  is 0,477. In this case,

the difference in the mean value of the documents with errors and the mean value of the documents without errors is  $\bar{w} - \bar{y} = 500$ . The lowest power is obtained for the mixing parameter  $p = 0,3$ , which corresponds to the value of the parameter  $b = \frac{50 \cdot 0,002}{0,3} = \frac{1}{3}$ . In this case, the difference of the average value of the documents with errors and the average value of the documents without errors is  $\bar{w} - \bar{y} = 150$ . Figures 1-2 show that the test is unconstrained because the power of the test is not less than the significance level. The Power increases in an approximately linear manner. Figure 4 shows that the increment in test power as a function of sample size is slow. As the sample size increases by 100, the power of the test increases by 0.05.

The presented model has some limitations in practical application. If the number of erroneous values  $k$  in the drawn sample is small, it may not be possible to use the maximum likelihood method for estimating the starting parameters. In this case, it may not be possible to estimate the average audit error or the estimate may be incorrect. This model can be used in other cases where the population is heterogeneous and a mixture of different distributions needs to be used to describe it.

## References

1. Frost, P.A., Tamura, H. (1986). Accuracy of auxiliary information interval estimation in statistical auditing. *Journal of Accounting Research*, 24, 57-75.
2. Kaplan, R.S. (1973). Statistical Sampling in Auditing with Auxiliary Information Estimators. *Journal of Accounting Research*, 238-258.
3. McLachlan, G., Peel, D. (2000). *Finite Mixture Models*. New York: Wiley.
4. Meng, X.L., Rubin, D.B. (1993). Maximum likelihood estimation via the ECM algorithm: A general framework. *Biometrika*, 80, 267-278.
5. Silvey, S.D. (1959). The Lagrangian multiplier test. *The Annals of Mathematical Statistics*, 30, 2, 389-407.
6. Stringer, K.W. (1963). *Practical Aspects of Statistical Auditing*. Preceeding of Business and Economic Statistics Section of the American Statistical Association, 405-411.
7. Tamura, H. (1988). Estimation of rare errors using judgement. *Biometrika*, 75, 1-9.
8. Wywi l, J.L. (2016). *Contributions to Testing Statistical Hypotheses in Auditing*. Warsaw: PWN, 91-95.
9. Wywi l, J.L. (2018). Application of two gamma distributions mixture to financial auditing. *Sankhy  B: The Indian Journal of Statistics*.





## THE ROLE AND COMPETENCIES OF MANAGERS IN CONTEMPORARY PROCESS-PROJECT ORGANIZATIONS

Ida SKUBIS<sup>1\*</sup>, Jolanta BIJAŃSKA<sup>2</sup>

<sup>1</sup> Silesian University of Technology; ida.skubis@polsl.pl, ORCID: 0000-0002-2447-9832

<sup>2</sup> Silesian University of Technology; jolanta.bijanska@polsl.pl, ORCID: 0000-0002-2247-0623

\* Correspondence author

**Purpose:** The reason for addressing the issue of the roles and competencies of managers of process-project organizations was the results of literature research. Based on them, it was found that there is a cognitive gap in this area, although it is emphasized that processes and projects are complementary elements of modern organizations. The main objective of the study was to identify the roles and competencies of managers that are important in a process-project organization. Its implementation was carried out within the framework of two sub-objectives: 1) to synthesize theoretical considerations on the roles and competencies of managers in modern organizations, including process-project organizations, 2) to assess the importance of managerial roles and competencies in process-project organizations.

**Design/methodology/approach:** The formulated main objective was achieved in the course of two stages of research. The first step involved a literature study, while the second one consisted of interviewing 152 managers in the process-design organizations.

**Findings:** During the course of the research it was established that so far a lot of theoretical considerations have been presented in the field of traditional and contemporary managerial roles and competencies. Based on the studies of 152 cases, it was concluded that there is knowledge and experience in practice to identify the roles and competencies that managers of process-project organizations should fulfill. As part of the discussion, it should be noted that the assessment of roles and competencies dedicated to managers of process-project organizations varies depending on their process-project maturity and internationalization.

**Research limitations/implications:** The opinion of the research group of 152 internationalized companies from the Silesian Voivodeship may differ from others, especially non-internationalized entities. The survey also did not take into account the respondents' business focus and size.

**Practical implications:** The research results obtained, based on the knowledge and experience of 152 organizations, can provide a basis for determining the roles and competencies of managers for organizations that want to move to a process-project orientation.

**Originality/value:** The scientific value of the publication is to define the roles and competencies of managers of process-project organizations. The addressee of the publication can be both academics and management practitioners.

**Keywords:** process-project organization, managers, role, competence, management.

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

## 1. Introduction

The art of management is constantly changing, adapting to the ongoing economic, technical and technological and social changes that imply new expectations about the role and competencies of managers. The literature presents many descriptions of traditional and contemporary roles and a set of requirements relating to the competencies that managers should have. This publication, against the background of a synthetic characterization of traditional managerial roles and competencies, presents those that are dedicated to modern organizations, operating under conditions defined by increasing globalization, turbulent changes, the growing importance of knowledge and the psychosocial needs of employees. In the context of these conditions, attention was paid to a feature of modern organizations, which is the focus on processes and projects, implying the emergence of process-project organizations.

The impetus for addressing the issue of the roles and competencies of managers of such organizations came from the results of a literature study. Based on them, it was found that there is a cognitive gap in this area, although it is emphasized that processes and projects are complementary elements of modern organizations, determining their proper functioning and future development (Nowosielski, 2017, 2018; Lichtarski, Osbert-Pociecha, 2019; Bitkowska, 2019; Sliż, 2021). The article presents the results of the research, representing new knowledge about the roles and competencies of managers of process-project organizations, allowing (at least partially) to fill this cognitive gap. The results of this research may be of interest not only to representatives of the scientific community, but also to business practice.

## 2. Objectives and scope of the study and methods used

The main objective of the research was to identify the roles and competencies of managers that are important in process-project organizations. To achieve this goal, the scope of the research included two stages, targeting the formulated sub-objectives, which were carried out using various methods.

The 1st stage of the research was aimed at synthesizing the existing considerations not only in terms of traditional managerial roles and competencies, but especially those of today, including those relating to process and project organizations. Achieving this sub-goal was possible based on the study of the literature on the subject, and especially the application of methods of its analysis and synthesis. The results of this stage are presented in sec. 3.1.

The 2nd stage of the research was aimed at assessing the importance of contemporary managerial roles and competencies in process-project organizations. It was possible to achieve this sub-goal on the basis of interviews (CAPI, CATI) conducted with the chief executives of

152 Polish process-project companies that cooperate with foreign entities. This made it possible to indicate the importance of the roles and competencies that should characterize the managers of process-project organizations. The results of this stage are presented in sec. 3.2.

### **3. Research results and their discussion**

#### **3.1. Traditional and contemporary roles and competencies of managers in management theory**

In the literature, the roles and competencies of modern managers are often considered in terms of the development of management science. It is believed that until the end of the 19th century, during the period known as the entrepreneurial orientation, the roles of managers were limited, and boiled down to helping the entrepreneur hire the right employees, giving them specific tasks based on a prior analysis of industrial operations, or identifying possible problems. The same was true of competencies. They were usually limited to intuition and experience, which was supposed to support management talent (Stańczyk-Hugiet, 2010).

This situation was changed by the effects of the industrial revolutions. From the middle of the 20th century, there was an intense increase in the rate and productivity of labor, the development of industrialization and the diversification of markets on a national and international scale. The conditions of business at the time determined the development of traditional organizations, characterized by hierarchical structures. For such structures, a clear division was adopted between superiors and subordinates, occupying a higher and lower place in the hierarchy, respectively, and the roles and competencies of managers were defined. Noteworthy here, among others, is F.W. Taylor's description of eight roles, divided into two groups (office - four administrative roles of officials and workshop - four roles of production foremen), ordering the directions of issuing orders, taking into account the principle of unity of command. In addition, it is worth distinguishing the roles defined by H. Fayol, relating to the functions of planning, organizing, coordinating, leading and controlling (Kieltyka, 2016). Relevant competencies were defined for the presented roles. It was believed that lower-level managers should be primarily technically skilled, while high-level managers should be conceptually and managerially skilled.

At the same time, it was assumed that with the transition from small to large enterprises, the importance of technical talents diminishes, while conceptual and managerial skills, necessary for thinking holistically and abstractly about the organization and its future directions, increase. Attention has also been paid to diagnostic competence, defined as a manager's ability to imagine the most appropriate response in a given situation, as well as communication competence (Bednarska-Wnuk, 2012; Skubis et al., 2023a). It is worth noting that the indicated traditional roles were associated with the use of an autocratic style of leadership, which required managers

to maintain a great distance in their dealings with employees, to be assertive, to avoid explaining their actions or decisions independently, and to be disciplined, among other things, in the formulation of orders and strict control of employees.

H. Mintzberg's work "The Nature of Managerial Work" can be considered a breakthrough in the consideration of managerial roles and competencies. It describes the work of managers and the requirements placed on them, while relaxing the rules of the autocratic style of management, mainly by considering the psychosocial needs and creative potential of employees. H. Mintzberg identified ten roles and corresponding managerial competencies, which he divided into three categories (Schermerhorn, 2008). In the category:

- Interpersonal distinguished roles: 1) representational, 2) leadership, and 3) liaison, the performance of which required the ability to interact with the environment, direct, motivate, evaluate employees, and coordinate activities inside and outside the organization,
- information distinguished roles: 4. observer, 5. promoter, 6. advocate, and 7. entrepreneur, the performance of which required the ability to track trends and the doings of competitors and analyze them, gather and disseminate information within the organization, communicate information to the environment and professional groups, and stimulate the development of employees, encourage their initiative or present ideas,
- decision maker distinguished the roles of 8. antidisruptor, 9. resource disposer, 10. negotiator, the performance of which required the ability to prevent and constructively resolve conflicts, manage the organization's resources, conduct discussions, and negotiate inside and outside the organization to find satisfactory solutions.

The roles proposed by H. Mintzberg were the starting point for further considerations, in which they were modified and expanded. Over time, it began to be emphasized that the manager of the 21st century should, first of all, play the role of a professional prepared for his profession (Dąbek, 2002), able to solve complex, non-routine problems, but not on his own but with the participation of employees, which was associated with a gradual transition to a democratic style of management. Such a manager should be characterized by perceptual, organizational, intellectual, forecasting, motivational, decision-making and intuitive competencies (Kieltyka, 2016). At the same time, it should be emphasized that the indicated role is complemented by other roles, resulting from the contemporary conditions of the organization, which mainly include 1) globalization, 2) turbulent changes, 3) meeting the psychosocial needs of employees, 4) the growing importance of knowledge.

Re 1) Progressive globalization implies internationalization of business activities, which is now a basic condition for development that does not apply only to large corporations. The possibilities of modern information and communication technologies mean that even the smallest organizations can become international and operate in the global space. This situation defines another role of a manager - managing in an international environment, which requires new competencies. Such a manager should be characterized not only by good knowledge of at

least one foreign language or new telecommunications technologies, but also by competencies that allow him to effectively and efficiently manage international, multicultural teams, sometimes virtual, which involves distributed leadership (Ancona, Bresman, 2013). Among the competencies that such a manager should be characterized by are understanding and acceptance of the diversity of national cultures, which is related to emotional competence - emotional and social intelligence, which is expressed, among other things, in the ability to create interpersonal bonds and empathy (Kieltyka, 2016; Kuc, Zemigala, 2010; Skubis et al., 2023c). In addition, especially in the aspect of virtual teams, the manager is required to have the ability to motivate employees at a distance, or to exercise control over the effect of the entire team (Stankiewicz-Mróz, 2019). In the context of internationalization, another role of the manager is also pointed out - that of an explorer (Morgan, 2022), who should be characterized by curiosity about people who differ from him in culture and views, as well as the ability to notice and retain outstanding talent in the organization, regardless of their nationality.

Re 2) Today's world of turbulent change is becoming a catalyst for a manager to realize another role - that of a change agent. The importance of this role determines the accuracy of responding to the changes taking place in the environment, by creating the right conditions for accepting their effects on the organization, as well as overcoming the fears and resistance of employees that may arise. This determines managerial competencies, which include the ability to cope with changing conditions (Kotter, 2005), to consult and communicate during the planning and implementation of changes in the organization, as well as to provide adequate support to employees and stimulate them to actively participate in changes (Bednarska-Wnuk, 2012; Skubis et al., 2023b). It is worth emphasizing at this point that the modern manager should also be the initiator of change in the organization, including in crisis situations. Then he should play the role of a rescuer (Kieltyka, 2016), who should be characterized by a defensive attitude, a focus on organizational renewal, as well as the ability to select and implement an appropriate strategy. Initiating change in an organization also refers to its permanent development (Błaszczuk, 2004). This emphasizes the previously defined role of the manager-entrepreneur (Rakowska, 2007), who is now required not only to be able to solve large-scale problems, but also to be highly creative. This competence is the primary vehicle for new ideas and initiatives or the premise for a new look at existing ideas (Błaszczuk, 2004). This means that a modern manager should be open to new things and ready to learn (Stor, 2010), as well as characterized by the ability to stimulate employees to stimulate and develop their own creativity (Hon et al., 2014). In the context of openness to new things, it is worth pointing to the development of artificial intelligence (AI) and machine learning technologies, which will have a very big impact on the functioning of any organization and its members in the near future (Morgan, 2022). Hence, managers are increasingly required, among other things, to have the ability to overcome anxiety (their own and that of their employees) related to, among other things, fears of job loss and general dehumanization, in favor of seeing AI as an ally and learning about areas where it performs better than humans (e.g., making calculations faster and analyzing multiple variables).

A manager should emphasize the advantages of AI, but at the same time stress that its increasing use will not make humans redundant, as they have many competencies unavailable to AI. This involves the ability to create the right organizational culture, in which the use of empathy, sensitivity, values, as well as unlocking human potential and building mutual trust are important (Brown, 2019).

Re 3) Interest in the psychosocial needs of employees is not new, and it is based on the postulate of providing satisfying conditions conducive to effective work, which originated as a result of E. Mayo's research at Hawthorne, conducted within the framework of the traditional concept of human relations (Bieńkowska, 2013). With the passage of time, there has been a growing realization that energetic, creative, enthusiastic employees are the main source of value creation for an organization and determine competitive advantage to a greater extent than technological or financial factors (Juchnowicz, 2012; Bijańska, Wodarski, 2020). Thus, there has been a shift from personnel administration to management of employees understood as value-creating capital, which has implied new opportunities for motivation, based on psychosocial influence on employees, contributing to an increase in their commitment (Alajlani et al., 2010). With some simplification, it can be said that the essence of this impact is empowerment, consisting of, among other things, delegating responsibility and empowering decision-making, encouraging autonomy in the choice of work methods, building a culture of trust and learning (Grajewski, 2016; Skubis, Wodarski 2023; Zhang, Bartol, 2017, Charbonnier-Voirin, El Akremi, 2011). Empowerment implies a new role of the manager-democrat, also called the role of servant leadership (Grudzewski et al., 2010). This role is not based on a formal managerial position in the organizational hierarchy, but on informal authority, characterized by the respect and trust of employees, which stems from credibility in action and competence relating to the ability to apply a democratic style of leadership and methods supporting it (Bijańska, Wodarski, 2020). Such a manager should also be characterized by a system of values, which he should not only promote, but also initiate (Świątek-Barylska, 2010).

Re 4) The 21st century is identified with the era of knowledge. It is believed, knowledge management in an organization is the primary source of competitive advantage, and knowledge resources are counted among the most valuable assets of an organization (Stańczyk-Hugiet, 2010). Under such conditions, the modern manager is required to acquire, create and use knowledge, which involves the role of knowledge promoter, also called designer, priest, knowledge agent, etc. (Perechuda, 2009), which requires supporting knowledge sharing and learning processes in the organization (Akella, 2006; Roth, 2003). This corresponds with the aforementioned servant leadership, especially in terms of mentoring and coaching. Mentoring defines the relationship between an experienced manager and employees to provide support (e.g., by sharing knowledge and advice), shaping professional development and desirable role models (Hezlett, Gibson, 2007). It requires communication, friendliness and the ability to inspire trust and persuasion. Coaching, on the other hand, is aimed at intensive and systematic training of employees, consequently leading to improved organizational performance (Segers et al.,

2011). It requires the ability to mobilize employees to develop their knowledge and talents along a career path.

It should be noted that the functioning of modern organizations in the conditions presented has influenced their reorientation towards processes and projects. This has led to the development of the fields of process and project management. They have defined project managers and process owners, for whom the desired competencies have been defined. Thus, project managers should be characterized by competencies in the day-to-day management of a project so that it produces outputs at a set time, budget, quality, risk and benefit, which requires the ability to plan, coordinate the schedule, lead the team (including team building, motivating, conflict resolution), and think strategically to ensure that the organization derives maximum benefit from the project outcome (Grzesik, Piwowar-Sulej, 2013; Brajer-Marczak, Piwowar-Sulej, 2017; Podgórska, 2018). In turn, process owners should be characterized by the ability to apply knowledge from the field of process management, for the effective and efficient implementation of a specific process. In particular, this should refer to the ability to define the goal or goals to be pursued by the process, identify the resources necessary for its implementation, design the process (modeling the course and defining the metrics for its evaluation), measure the results and supervise the process to ensure the correctness of its course, respond to extraordinary deviations, as well as motivate the process performers and encourage them to make proposals to improve the process. In addition, the process owner is required to be able to formulate proposals and initiate and carry out changes in the course of the process, communicate with owners of other processes, verify the place of the process in the organization's process structure, and represent the process to the organization's top management (e.g. Grajewski, 2016; Brajer-Marczak, Piwowar-Sulej, 2017).

With the passage of time, it began to be emphasized that processes and projects are complementary elements of any modern organization, which are usually implemented together (Nowosielski 2017, 2018; Lichtarski, Osbert-Pociecha, 2019; Bitkowska, 2019; Sliż, 2021). This has led to the need to integrate process and project management into a single concept of a process-project organization, the importance of which has begun to be emphasized in the context of proper functioning and the development and achievement of competitive advantage in the future.

A review of the literature on the subject allows us to conclude that there is a cognitive gap in the concept of process-project organization. Its partial supplement is provided by considerations in the area of holistic view of processes and projects in management, which are included in the book "Process-Project Organization" (Sliż, 2021), considered by its reviewers to be the first in this area, covering Polish and foreign achievements.

So far (including in this book) little attention has been paid to the roles and competencies of managers of process-project organizations. However, it has been pointed out that in these organizations, the management of a particular process or project is not the responsibility of its owner or manager. Indeed, the "leader" in a process or project can be any employee who, in a particular situation, is the right person for it. Thus, we are talking about the role of a leader

of a process or project team, who at the same time may be a member of his or another team. It is assumed that such a leader operates in an environment oriented towards self-organization and self-control of colleagues, and his leadership is characterized by impermanence and transitivity.

It should be emphasized that the manager of a process-project organization fulfills different roles and has different competencies from the leaders of process or project teams. As mentioned, there is a cognitive gap in the literature in this regard, but it has been pointed out that the proper functioning of process-project organizations requires ambidextrous leadership (Zacher, Rosing, 2015; Constant et al., 2020; Sliż, 2021). This leadership, which takes into account the use of the executive and intellectual potential of all process and project teams (with appropriate support and motivation), is expressed by the process-project organization manager's desire to achieve balance in two layers:

- 1) operational, which includes the ability to implement incremental changes by expanding knowledge or implementing improvements to enable incremental upgrades over the course of operational processes and reactive projects,
- 2) exploratory, encompassing the ability to refine new knowledge, seeking the novelty needed for radical innovation in the course of exploratory processes and proactive projects.

In addition, it can be assumed that the roles and competencies of managers of process-design organizations should be related to the determinants of the success of these organizations, which can include (Sliż, 2021):

- 1) customer orientation, implying the need to manage processes and projects aimed at generating results (products/services) in line with the expectations of external and internal customers, which is combined with the ability to design processes and projects according to the model called COPCIS, from its components: Customers, Outputs (products/services), Process or Project, Competences, Inputs, Suppliers, as well as the ability to create an organizational culture that emphasizes the functioning of the market mechanism inside the organization, in which the modeling of processes and projects for internal customers should be done in the same way as for external customers,
- 2) operate according to business models appropriate to the goals of the exploitation and exploration layers, which is combined with the ability to select, as well as modify, these models to stay ahead of the competition,
- 3) participation and empowerment of employees in the space of exploitative and exploratory layers, which is combined with the ability to create an environment conducive to the expansion of employees' competencies and their generation of initiatives, as well as the implementation of an "employee competency market" in the organization.



### 3.2. Roles and competencies of managers of process-project organizations in practice

In order to identify the most important roles and competencies of managers of process-project organizations, targeted free interviews were conducted with executives of selected companies operating in Poland. Due to access to respondents, it was assumed that the primary condition for their selection for the study would be their headquarters in the Silesian region and internationalization. The sample for the study was selected in a non-random manner - based on the subjective assessment of the researcher, quota - from the population of the quota of representative units (Miszczyk, Walasek, 2013). According to the latest available statistics (Analizy statystyczne GUS, 2024), at the end of 2022, 248 entities in the Silesian province showed involvement in 418 foreign units. Taking this into account, using the sampling calculator (<https://www.naukowiec.org/dobor.html>), taking into account the 95% confidence level, 5% fractional size and 5% maximum error, the research sample size was calculated to be 151. To obtain it, 203 companies were asked to participate in the research. Of these, 175 declared their willingness to participate in the research.

The first step was to assess the level of process-project maturity of these enterprises, based on the corresponding model (Sliż, 2021), which included five levels and was based on the PMMM (project maturity assessment) and MMPM2 (process maturity assessment) models. It was assumed that the survey results would include the responses of managers of companies that are at levels 3, 4 and 5 of process-project maturity. Thus, of the 175 entities assessed, managers of 152 of them participated in the research, specifically:

- 1) 66 entities located at Level 5, defined as “Process-Project Organization” (Sliż, 2021, p. 2011), which means that their:
  - The organizational structure is characterized by a process-project arrangement.
  - Projects are implemented in a process convention.
  - The maturity level of process and project management is high in the space of operational and exploratory layers.
- 2) 45 entities at Level 4, defined as a “Process organization with a high level of project management maturity” (Sliż, 2021, p. 2011), meaning that their:
  - The organizational structure is characterized by a matrix arrangement.
  - Activities aim to implement a pure process structure with project organization or a process-project structure.
  - Executives consciously take advantage of the benefits of implementing process and design solutions, and recognize the need to group and integrate them in the space of operational and exploratory layers.

- 3) 41 entities that are at Level 3, defined as a "Process and Project Oriented Organization" (Sliž, 2021, p. 2010), which means that their:
- Activities are aimed at implementing a matrix organizational structure.
  - The system of measuring the performance of processes and projects is the basis for making management decisions.
  - The operational layer is clearly outlined and management activities are aimed at improving the efficiency and quality of process results.
  - Projects in the exploratory layer are implemented based on formalized process documentation.

Subsequently, the 152 entities selected for the study were evaluated in terms of their degree of internationalization based on the DOI model<sub>INTS</sub><sup>1</sup> (Sullivan, 1994), on a three-point scale (1 - small, 2 - medium, 3 - large degree). In the sample, 39 entities had a high degree of internationalization, 67 had a medium degree, and 46 had a low degree.

To conduct the research, an interview questionnaire was developed that included all of the roles and competencies outlined in para. 3.1, roles and competencies of managers of modern organizations, as it was assumed that they also apply to process-project organizations. The interview questionnaire was sent to the managers of process-project organizations, who are referred to as respondents hereafter. The purpose of sending the questionnaire in advance was to allow the respondents to familiarize themselves with the subject of the interview and to think about whether all the important roles and competencies of the managers of the process-project organization were included. Managers of 7 organizations sent their suggestions for supplementing or changing managerial competencies, which were included in the final version of the questionnaire (Table 1). No comments were made on the defined roles.

**Table 1.**

*Interview questionnaire*

Roles	Assessment of significance*	Role-specific competencies	Assessment of significance*
Professional		Perceptive abilities	
		Organizational abilities	
		Intellectual abilities	
		Predictive abilities	
		Motivational abilities	
		Decision-making abilities	
		Intuitive abilities	

<sup>1</sup> DOI<sub>INTS</sub> = Foreign Sales to Total Sales, Foreign Assets to Total Assets, Overseas Subsidiaries to Total Subsidiaries, Top Managers' International Experience, Psychic Dispersion of International Operations.

Cont. table 1.

Manager in an international environment	Communication skills, including good knowledge of at least one foreign language	
	Good knowledge of new telecommunications technologies	
	Understanding and acceptance of the differences in national cultures	
	Emotional and social intelligence	
	Ability to lead teams, including virtual teams	
	Ability to exercise control over the results of process and project teams	
Discoverer	Curiosity about people, including those who differ from culture and views	
	Ability to spot and retain outstanding talent in the organization, regardless of their nationality	
Change agent	Ability to create conditions in the organization to accept the effects of changes in the environment	
	Ability to deal with changing conditions	
	Ability to communicate while planning and implementing change	
	Ability to stimulate employees to participate in change	
	Seeing change as an ally	
Rescue	Ability to build trust and overcome resistance to change	
	Defensive posture	
	Strong focus on organizational renewal	
Entrepreneur	Ability to select and implement an anti-crisis strategy	
	Ability to solve large-scale problems	
	Creativity, broad-mindedness	
	Openness to new things and willingness to learn them	
Democrat - servant leader	Ability to stimulate employees to develop their creativity	
	Ability to use a democratic leadership style	
	Ability to promote and initiate organizational values	
Knowledge promoter	Ability to create a friendly organizational environment for good work results	
	Ability to acquire, create and use knowledge	
Ambidextrous leader	Supporting knowledge sharing and learning processes	
	Ability to leverage the executive and intellectual potential of all process and project teams	
	Focus on effective and efficient implementation of operational processes and reactive projects, as well as exploratory processes and proactive projects	
Success creator	Strive to achieve a balance in the implementation of operational processes and reactive projects, as well as exploratory processes and proactive projects	
	Ability to see through the interests of the entire organization, rather than just focusing on individual processes and projects	
	Ability to see processes and projects holistically according to the COPCIS model	
	Ability to create an organizational culture that emphasizes the functioning of the market mechanism within the organization	
	Ability to select and modify business models appropriate to the exploitation and exploration layers	
	Ability to create an environment conducive to expanding employees' competencies and generating initiatives by them	
	Ability to implement a "market for employee competence"	

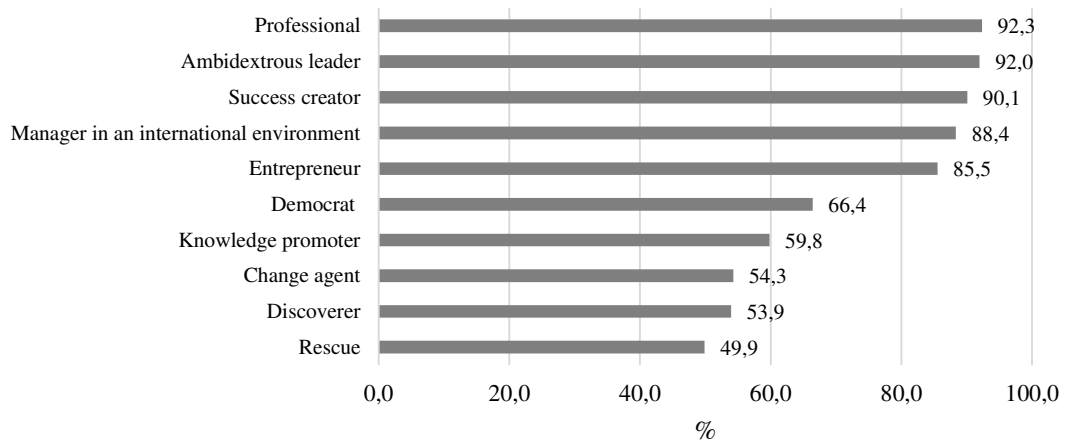
\* Role and competency importance rating scale: 3. high importance; 2. medium importance; 1. low importance; 0. no importance for the organization.

Source: own study.

Interviews were then conducted:

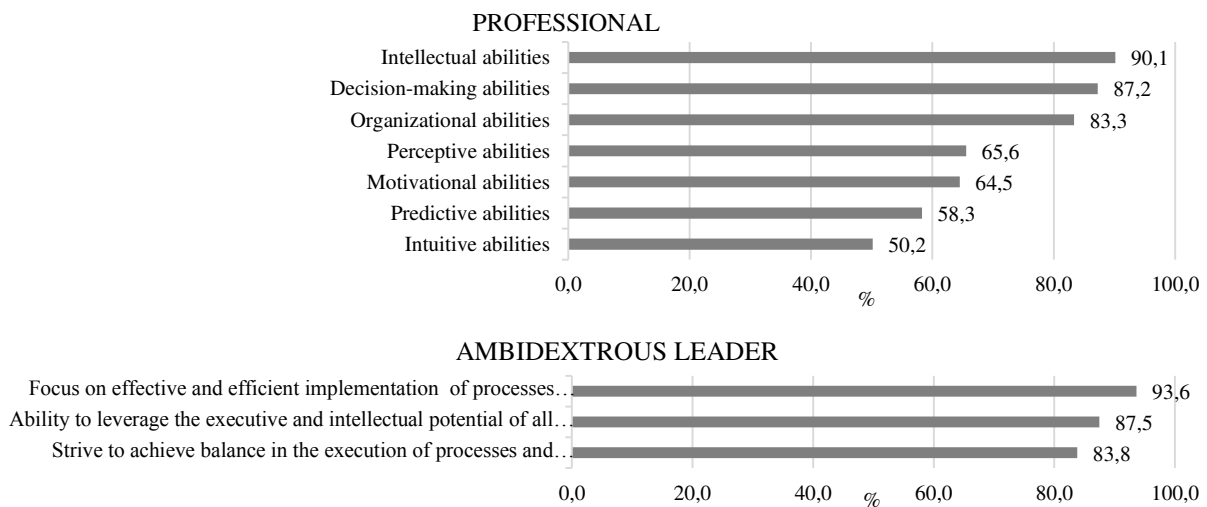
- 1) CAPI (Computer Assisted Personal Interview) with 131 managers, asking them the questions in the questionnaire in a face-to-face meeting,
- 2) CATI (Computer Assisted Telephone Interview) with 21 managers, asking them questions in a questionnaire during a telephone interview.

The choice of the quantitative data collection methods indicated was based on their characteristics, which include rapid acquisition of high-quality information and satisfactory response rates. During the interviews, any doubts of the respondents were clarified, for a clear interpretation of the roles and competencies evaluated. The obtained ratings of the importance of roles and competencies (in points from 0 to 3) were multiplied by the managers' competency factor, related to the level of process-project maturity of the organization they represented (1.0, 0.95, 0.9 sequentially for maturity levels 5, 4, 3), and then summed and converted into percentages. This made it possible to present the importance of the roles (Fig. 1) and the corresponding competencies (Fig. 2).

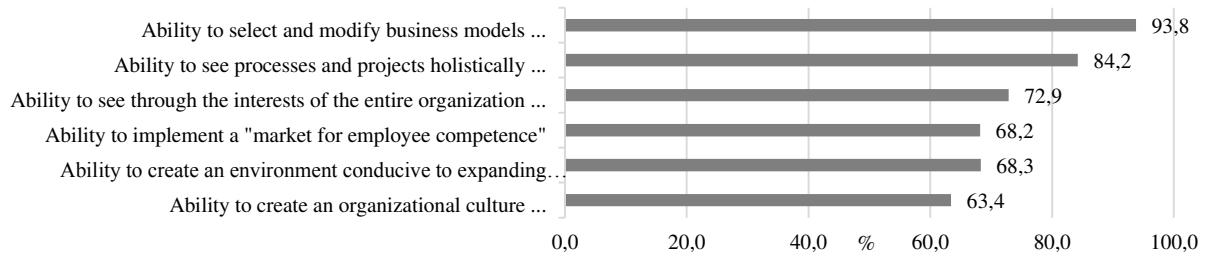


**Figure 1.** Results of the evaluation of the importance of the roles of managers in the process-project organization. 100%=maximum role importance.

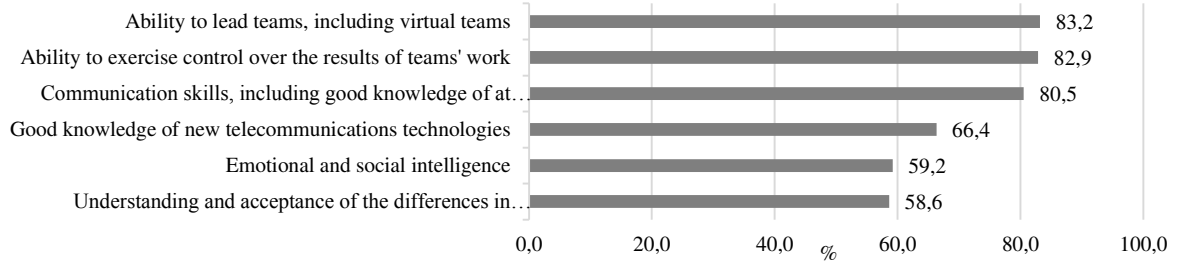
Source: own study.



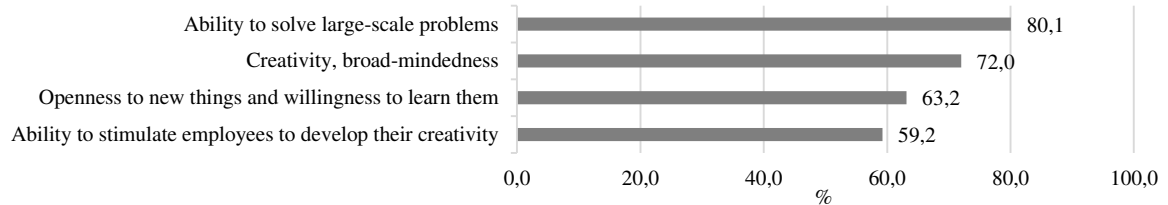
**SUCCESS CREATOR**



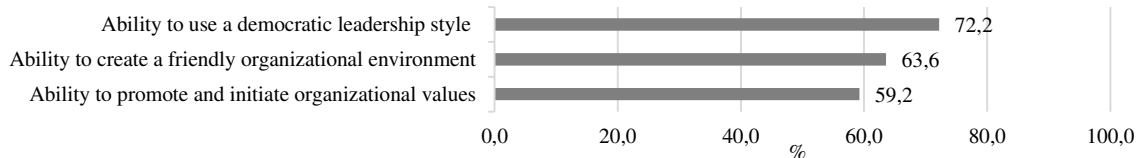
**MANAGER IN AN INTERNATIONAL ENVIRONMENT**



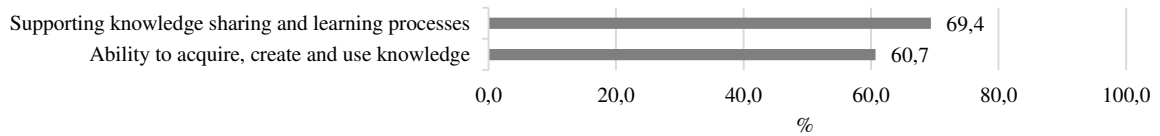
**ENTREPRENEUR**



**DEMOCRAT**

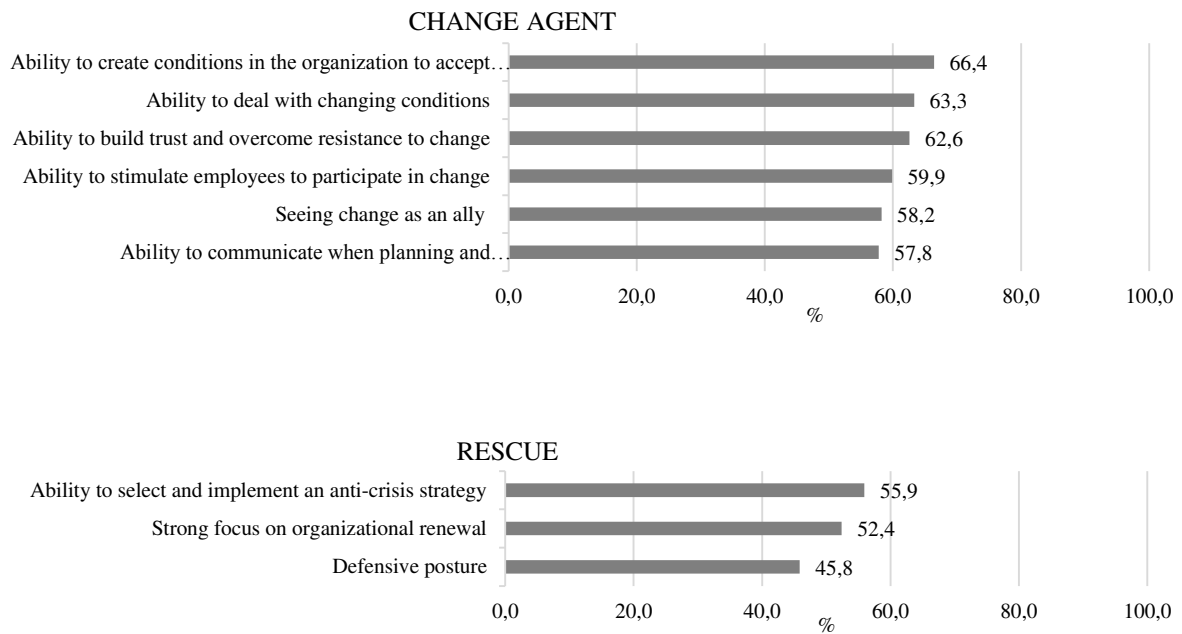


**KNOWLEDGE PROMOTER**



**DISCOVERER**





**Figure 2.** Results of the evaluation of the importance of the competencies of the managers of the process-project organization, in order of the importance of the roles; 100%=maximum importance of the competencies.

Source: own study.

The responses of the respondents show that the roles of professional, ambidextrous leader and success creator are the most important in a process-project organization, followed by the role of manager in an international environment and entrepreneur.

An analysis of the responses shows that the high importance of the role of the ambidextrous leader was indicated by almost 88% of respondents with the highest level of process-project maturity (58 out of 66), and the role of the manager in the international environment by almost 77% of respondents with a high degree of internationalization (30 out of 39).

With regard to competencies, it is worth noting that the importance of many of them does not correlate with the order of importance of the role, e.g., the most important competency of a success creator or ambidextrous leader is more important than the most important competency in the professional role. This is because the high importance of these competencies was indicated by respondents from organizations with the highest level of process-project maturity.

To address the issue of inconsistency in the perceived importance of certain roles and competencies, a ranking was developed to identify the most critical competencies that managers in process-project organizations should possess, independent of their roles (Fig. 3).



**Figure 3.** Results of assessing the importance of managers' competencies in a process-project organization, without considering the related role; 100% = maximum importance of competencies.

Source: own study.

Based on the results of the interviews, it can be concluded that the most important managerial competencies in a process-project organization, as indicated by the majority of respondents, include the following:

- ability to select and modify business models appropriate to the exploitation and exploration layers,
- focus on the effective and efficient implementation of operational processes and reactive projects, as well as exploratory processes and proactive projects,
- intellectual abilities.

According to respondents, the following competencies are also important in process-project organizations:

- ability to leverage the executive and intellectual potential of all process and project teams,
- decision-making abilities,
- ability to see processes and projects holistically according to the COPCIS model,
- strive for a balance in the implementation of operational processes and reactive projects, as well as exploratory processes and proactive projects,
- organizational skills,
- ability to lead teams, including virtual teams,
- ability to exercise control over the results of process and project teams,
- communication skills, including good knowledge of at least one foreign language,
- ability to solve large-scale problems.

Next, respondents indicated the importance of the following competencies:

- ability to look through the interests of the entire organization, rather than just focusing on individual processes and projects,
- ability to apply a democratic leadership style,
- creativity, broad-mindedness,
- ability to spot and retain outstanding talent in the organization, regardless of their nationality,
- supporting knowledge sharing and learning processes,
- ability to create an environment conducive to expanding employees' competencies and generating initiatives by them,
- ability to implement an "employee competency market",
- ability to create conditions in the organization to accept the effects of changes in the environment,
- good knowledge of new telecommunications technologies,
- perceptual abilities,
- motivational skills,
- ability to create a friendly organizational environment for achieving good work results,



- ability to create an organizational culture that emphasizes the functioning of the market mechanism within the organization,
- seeing change as an ally,
- openness to new things and willingness to learn them,
- ability to build trust and overcome resistance to change,
- ability to acquire, create and use knowledge.

According to respondents, competencies of medium importance in process-project organizations included, in turn:

- ability to stimulate employees to participate in change,
- curiosity about people, including those who differ from the culture and views,
- ability to promote and initiate organizational values,
- ability to stimulate employees to develop their creativity,
- emotional and social intelligence,
- understanding and acceptance of the differences in national cultures,
- predictive abilities,
- ability to cope with changing conditions,
- communication skills when planning and implementing change,
- ability to select and implement an anti-crisis strategy,
- strong focus on organizational renewal,
- intuitive abilities,
- defensive posture.

As part of the discussion, it is worth noting that the results obtained do not confirm the opinion of many authors of contemporary research, which emphasizes the vital and often most important importance of the role of the democrat. According to the respondents, it is only in 6th place in the order of importance in a process-project organization (fig. 1). Also, managerial competencies relating to this role were not considered most important, with the ability to apply a democratic leadership style ranked only 14th (fig. 3). It should also be noted that the importance of none of the roles was rated as low (the lowest, slightly below average, was assigned to the role of rescuer). The same was true of competencies - of these, only one (defensive posture), has a slightly lower than average importance. Of course, in the discussion of the results obtained, one can ask about their reliability. The authors of the publication realize that the opinion of a research group that includes only internationalized companies may differ from other, especially non-internationalized entities, for which the managerial roles or competencies related to this aspect of operation have a different meaning. Differences in opinions may also be caused by the respondents' residence in the Silesian province, the Upper Silesian and Zagłębie Metropolitan Area, which includes 41 cities and municipalities with 240,000 companies and enterprises. In other provinces, especially smaller and not so heavily industrialized, opinions may be different. So, it would be worthwhile to conduct research on a larger scale, such as the entire

country, with a properly selected sample, using other research methods, such as CAWI (Computer Assisted Web Interview). The survey also did not take into account the respondents' business focus and size, which may have influenced the answers given. It was only noted that most of them were operating in the industrial processing and services sections of the SME sector.

## Summary

The article presents the results of research, relating to contemporary managerial roles and competencies. It is noted that the current conditions of the functioning of organizations, such as globalization, turbulent changes, the growing importance of knowledge and the psychosocial needs of employees, among others, determine new managerial roles and competencies, different from the traditional ones. It has been noted that the functioning of modern organizations in the conditions presented has influenced their reorientation towards processes and projects, which has affected the emergence of process-project organizations. Since there is a cognitive gap regarding managerial roles and competencies for these organizations, the research process drew a representative sample from the population of organizations working with foreign entities, based in Poland, in the Silesia region.

Then, after assessing the process-project maturity of this sample, 152 entities were selected for further research. CAPI and CATI interviews were conducted with their managers, which made it possible to identify the managerial roles that are most important in process-project organizations. These include, in turn, the roles of professional, ambidextrous leader and success creator, followed by international manager and entrepreneur. On the other hand, managerial competencies of greatest importance in a process-project organization include, in turn, the ability to select and modify business models appropriate to the exploitation and exploration layers, focus on the effective and efficient implementation of exploitation processes and reactive projects, as well as exploratory processes and proactive projects, intellectual capacity, and the ability to use the executive and intellectual potential of all process and project teams, decision-making abilities, the ability to see processes and projects holistically according to the COPCIS model, striving for balance in the implementation of exploitative processes and reactive projects, as well as exploratory processes and proactive projects, organizational abilities, the ability to lead teams, including virtual teams, the ability to exercise control over the results of process and project teams, communication skills, including good knowledge of at least one foreign language, the ability to solve large-scale problems.

As discussed, the opinions of the sample of 152 managers working in internationalized companies may differ from those in non-internationalized entities, where the roles or managerial competencies related to this aspect of operation hold a different significance. Differences in opinions may also be caused by the respondents' residence in Poland, within the Silesian

Voivodeship. Opinions may vary abroad or in other provinces, especially smaller and less industrialized ones. Additionally, the survey did not consider the respondents' business focus and size, which could have affected their answers. The authors plan to conduct further research on a larger scale, including studies outside Poland.

The obtained results bring new knowledge about managerial roles and competencies in modern process-project organizations, which can be valuable for both academic research and management practice. For academics, this publication offers a basis for further exploration of the evolution of managerial roles and competencies, particularly in process-project organizations. For practitioners, on the other hand, the knowledge can be useful, among other things, in the context of competence management, to identify the competence gap or competence profiles of managers of process-project organizations.

## References

1. Akella, D. (2006). Changes in Managerial Work: Tech Managers Dotcom. *Global Business Review*. Vol. 7, Iss. 2, pp. 219-241, doi: 10.1177/097215090600700203
2. Alajloni, M.M., Almashaqba, Z.M.S., Al-Qeed, A.N.M. (2010). The Classical Theory of Organisation and it's Relevance. *International Research Journal of Finance & Economics*. Iss. 41, pp. 60-67.
3. Analizy statystyczne GUS (2024). *Działalność przedsiębiorstw posiadających jednostki zagraniczne w 2022 r.*, pp. 17-21. Warszawa: Główny Urząd Statystyczny.
4. Ancona, D., Bresman, H. (2013). *Zespoły X. Jak budować zespoły, które odnoszą sukces*. Warszawa: Wolters Kluwer S.A.
5. Bednarska-Wnuk, I. (2012). Transformacja ról i umiejętności menedżera. In: K. Januszkiewicz (Ed.), *Zachowania ludzi w organizacji. Uwarunkowania i kierunki ewolucji* (pp. 116-140). Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
6. Bieńkowska, J. (2013). *Psychospołeczne bariery zaspakajania potrzeb pracowników*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
7. Bijańska, J., Wodarski, K. (2020). *Metody zarządzania a kształtowanie zaangażowania pracowników we współczesnych organizacjach: teoria i praktyka*. Toruń: Dom Organizatora.
8. Bitkowska, A. (2019). *Od klasycznego do zintegrowanego zarządzania procesowego w organizacjach*. Warszawa: C.H. Beck.
9. Błaszczak, W. (2004). Kreatywność i przedsiębiorczość jako cechy współczesnego menedżera. In: t. Listwan (Ed.), *Sukces w zarządzaniu kadrami. Perspektywa globalna i lokalna* (pp. 57-68). Wrocław: Akademia Ekonomiczna we Wrocławiu.

10. Brajer-Marczak, R., Piwowar-Sulej, K. (2017). Właściciel procesu, menedżer procesu, kierownik projektu – analiza porównawcza ról i kompetencji. *Marketing i Rynek, No. 4*, pp. 22-31.
11. Brown, B. (2019). *Odwaga w przywództwie*. Warszawa: MT Biznes.
12. Charbonnier-Voirin, A., El Akremi, A. (2011). L'effet de l'habilitation sur la performance adaptative des employés. *Relations Industrielles. Industria Relations. Vol. 66, No. 1*, pp. 122-149.
13. Constant, F., Calvi, R., Johnsen, T. (2020). Managing tensions between exploitative and exploratory innovation through purchasing function ambidexterity. *Journal of Purchasing and Supply Management. Vol. 26. Iss. 4*, pp. 1-32.
14. Dąbek, M. (2002). *Menedżerowie okresu transformacji: problemy, potencjał, rozwój*. Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego.
15. Grajewski, P. (2016). *Organizacja procesowa*. Warszawa: PWE.
16. Grudzewski, W.M., Hejduk, I.K., Sankowska, A., Wańtuchowicz, M. (2010). *Sustainability w biznesie czyli przedsiębiorstwo przyszłości. Zmiany paradygmatów i koncepcji zarządzania*. Warszawa: Poltext.
17. Grzesik, K., Piwowar-Sulej, K. (2013). Kierownik projektu – menedżer czy przywódca. *Zeszyty Naukowe Wyższej Szkoły Bankowej we Wrocławiu. No. 4(36)*, pp. 97-114.
18. Hezlett, S.A., Gibson, S.K. (2005). Mentoring and Human Resource Development: Where We Are and Where We Need to Go. *Advances in Developing Human Resources, Vol. 7, No. 4*, pp. 446-469, doi: 10.1177/1523422305279667
19. Hon, A.H.Y., Bloom, M., Crant, J.M. (2014). Overcoming Resistance to Change and Enhancing Creative Performance. *Journal of Management, Vol. 40, Iss. 3*, pp. 919-94, doi: 10.1177/0149206311415418
20. Juchnowicz, M. (2012). *Zaangażowanie pracowników. Sposoby oceny i motywowania*. Warszawa: PWE.
21. Kiełtyka, L. (2016). Rola menedżera we współczesnych organizacjach. *Przegląd Organizacji. Vol. 8, No. 919*, pp. 4-10.
22. Kotter, J.P. (2005). *Co tak naprawdę robią przywódcy?. Przywództwo*. Harvard Business Review. Gliwice: Helion.
23. Kuc, B., Żemigala, M. (2010). *Menedżer nowych czasów. Najlepsze metody i narzędzia zarządzania*. Gliwice: Onepress.
24. Lichtarski, J., Osbert-Pociecha, G. (ed.) (2019). *Procesy i projekty – ciągłość i zmiana*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
25. Maxwell, J.C. (2008). *Leadership Gold: Lessons I've Learned from a Lifetime of Leading*. HarperCollins Leadership.
26. Miszczak, A., Walasek, J. (2013). Techniki wyboru próby badawczej. *Obronność - Zeszyty Naukowe Wydziału Zarządzania i Dowodzenia Akademii Obrony Narodowej, No. 2(6)*, pp. 101-103.

27. Morgan, J. (2022). *Przywódca przyszłości. 9 postaw i umiejętności przywódców przyszłej dekady*. Poznań: Dom Wydawniczy Rebis.
28. Nowosielski, S. (2017). Procesy i projekty w zarządzaniu zmianą organizacyjną. *Studia i Prace Kolegium Zarządzania i Finansów. Szkoła Główna Handlowa. No. 169*, pp. 67-86.
29. Nowosielski, S. (2018). Procesy i projekty w organizacji. O potrzebie i sposobach współdziałania. *Studia i Prace Kolegium Zarządzania i Finansów. Szkoła Główna Handlowa, No. 169*, pp. 109-129.
30. Osbert-Pociecha, W. (2017). Zdolność organizacji do zmian – dlaczego zmiany wymagają podejścia procesowego i/lub projektowego. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No. 463*, pp. 87-96.
31. Perechuda, K. (2009). Wiodące umiejętności menedżerów wiedzy In: T. Kupczyk (Ed.), *Uwarunkowania sukcesów kadry kierowniczej w gospodarce opartej na wiedzy*. Warszawa.
32. Podgórska, M. (2018). *Kompetencje przywódcze kierownika projektu jako krytyczny czynnik sukcesu w zarządzaniu projektami*. Gliwice: Wydawnictwo Politechniki Śląskiej.
33. Rakowska, A. (2007). *Kompetencje menedżerskie kadry kierowniczej we współczesnych organizacjach*. Lublin: Wydawnictwo Uniwersytetu Marie Curie Skłodowskiej.
34. Roth, J. (2003). Enabling knowledge creation: learning from an R&D organization. *Journal of Knowledge Management, Vol. 7, No. 1*, pp. 32-48, doi: 10.1108/13673270310463608
35. Schermerhorn, J.R. Jr (2008). *Zarządzanie. Kluczowe koncepcje*. Warszawa: PWE.
36. Segers, J., Vloeberghs, D., Henderickx, E., Inceoglu, I. (2011). Structuring and Understanding the Coaching Industry: The Coaching Cube. *Academy of Management Learning and Education, Vol. 10, No. 2*, pp. 204-221, doi: 10.5465/AMLE.2011.62798930
37. Skubis, I., Akahome, J., Wodarski, K. (2023c). Exploring the characteristics, motivation, challenges, and support system of female social entrepreneurs in Nigeria. *Scientific Papers of Silesian University of Technology – Organization and Management Series, No. 180*, pp. 603-628. DOI: <http://dx.doi.org/10.29119/1641-3466.2023.180.31>
38. Skubis, I., Akahome, J., Bijańska, J. (2023a). The brain drain syndrome and the role of responsible leadership in health care service organisation in Nigeria. *Scientific Papers of Silesian University of Technology – Organization and Management Series, No. 176*, pp. 599-615. <http://dx.doi.org/10.29119/1641-3466.2023.176.34>
39. Skubis, I., Akahome, J., Bijańska, J. (2023b). Green innovations in healthcare sector in Nigeria. *Scientific Papers of Silesian University of Technology – Organization and Management Series, No. 176*, pp. 577-598. <http://dx.doi.org/10.29119/1641-3466.2023.176.34>
40. Skubis, I., Wodarski, K. (2023). Humanoid robots in managerial positions – decision-making process and human oversight. *Scientific Papers of Silesian University of Technology, No. 189*, pp. 573-596, DOI: <http://dx.doi.org/10.29119/1641-3466.2023.189.36>
41. Sliż, P. (2021). *Organizacja procesowo-projektowa. Istota. Modelowanie. Pomiar dojrzałości*. Warszawa: Difin.

42. Stańczyk-Hugiet, E. (2010). Czy ekonomia wiedzy powoduje zmianę roli menedżera? In: T. Listwan, S.T. Witkowski (Eds.), *Menedżer w gospodarce opartej na wiedzy* (pp. 678-687). Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
43. Stankiewicz-Mróż, A. (2019). *Przywództwo rozproszone jako paradygmat przywództwa w organizacjach XXI wieku*. Retrieved from: [https://www.researchgate.net/publication/334001028\\_PRZYWODZTWO\\_ROZPROSZONE\\_JAKO\\_PARADYGMAT\\_PRZYWODZTWA\\_W\\_ORGANIZACJACH\\_XXI\\_WIEKU](https://www.researchgate.net/publication/334001028_PRZYWODZTWO_ROZPROSZONE_JAKO_PARADYGMAT_PRZYWODZTWA_W_ORGANIZACJACH_XXI_WIEKU), 2.01.2024.
44. Stor, M. (2010). Kwalifikacje i kompetencje kadry menedżerskiej korporacji międzynarodowej w gospodarce opartej na wiedzy. In: T. Listwan, S.T. Witkowski (Eds.), *Menedżer w gospodarce opartej na wiedzy* (pp. 699-711). Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
45. Stosik, A. (2005). Ewolucja ról menedżerskich w organizacjach entrepreneurskich. In: J. Skalik (Ed.), *Zmiana warunkiem sukcesu. Przeobrażenia metod i praktyk zarządzania* (pp. 522-527). Wrocław: Wydawnictwo Akademii Ekonomicznej we Wrocławiu.
46. Sullivan, D. (1994). Measuring the degree of internationalization of a firm. *Journal of International Business Studies*, Vol. 25, pp. 325-342.
47. Świątek-Barylska, I. (2010). Menedżer w roli inicjatora i propagatora kluczowych wartości organizacyjnych. In: T. Listwan, S.T. Witkowski (Eds.), *Menedżer w gospodarce opartej na wiedzy* (pp. 774-783). Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.
48. Szaban, J. (2000). *Przemiany roli polskich dyrektorów w wyniku zmian ustrojowych. Od dyrektora do euromenedżera*. Warszawa: Wydawnictwo Wyższej Szkoły Przedsiębiorczości i Zarządzania im. Leona Koźmińskiego.
49. Zacher, H., Rosing, K. (2015). Ambidextrous leadership and team innovation. *Leadership & Organization Development Journal*, No. 36(1), pp. 54-68.
50. Zhang, X., Bartol, K.M. (2017). Linking Empowering Leadership and Employee Creativity: The Influence of Psychological Empowerment, Intrinsic Motivation, and Creative Process Engagement. *Academy of Management Journal*, Vol. 53, No. 1, pp. 107-128, doi: 10.5465/amj.2010.48037118.

## SUBSTANTIATION OF THE OPTIMAL LOCATION OF GOODS PRODUCTION USING 3D PRINTING TECHNOLOGIES: A SYSTEM APPROACH

Jerzy STADNICKI<sup>1\*</sup>, Olga NAGAITSEVA<sup>2</sup>

<sup>1</sup> University of Technology, Kielce; yurijs@tu.kielce.pl, ORCID: 0000-0001-7760-1347

<sup>2</sup> Ukrainian Free University, Munich; olga.nagaitseva@gmail.com, ORCID: 0009-0002-6952-6599

\* Correspondence author

**Purpose:** The main purpose of the article is to identify the factors of optimal location of the production of benefits using 3D printing technologies and to develop criteria for identifying within the space of possible placement of potential locations for the production of benefits using 3D printing technologies. This will make it possible to justify the optimal location of the production of benefits using 3D printing technologies based on a system approach.

**Design/methodology/approach:** The correct justification of the optimal location of 3D printing production is possible only based on a system approach that involves considering the competition of other (interchangeable) technologies, as well as the simultaneous justification of production capacity and supply volumes to specific sales markets.

**Findings:** The location factors for producing goods using 3D printing technologies are relatively low prices for electricity and 3D printing materials, as well as a short distance to the sales markets and a developed transport infrastructure between the potential places of production 3D printing and potential sales markets. All locations from the space of possible placement that are characterized by at least one placement factor can be considered attractive locations for the production of benefits using 3D printing technologies, but the locations with the key placement factors for the production of benefits using 3D printing technologies - a short distance to sales markets - are of particular importance.

**Practical implications:** Use of the materials of the research conducted in the article can be of significant practical importance, since the correct substantiation of the optimal location of production using 3D printing technologies will allow to fully utilize the potential efficiency of these perspective technologies, which are promising in terms of increasing the economic security of individual firms, countries and the European Union as a whole.

**Originality/value:** The article identifies the factors of the production location using 3D printing technologies, develops a categorization of attractive places for the production location using 3D printing technologies, and proposes a methodology for determining the pointwise, locally and systemically optimal production technologies.

**Keywords:** system approach; 3D printing technologies; optimal production location; places of potential production location; factors of production location.

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

## 1. Introduction

3D printing is one of the most promising production technologies, the importance of which is constantly growing in various sectors of the economy and this trend is increasing every year (Praveena et al., 2022; Jadhav et al., 2022; Ronchini et al., 2023; Stentoft et al., 2023; Jandyal et al., 2022). Like every promising production technology, 3D printing should be researched in terms of the location factors, since only the optimal production location will allow the full utilization of the potential efficiency of the respective technology. Not an optimal location reduces the potential efficiency of the production technology, which in some cases may make it inappropriate to use it. Obviously, such a situation would lead to significant losses and erroneous conclusions about the efficiency of the technology. Therefore, the issue of substantiation of the optimal location of 3D printing production is important and relevant.

Although 3D printing technology has generated considerable media hype, it has long been ignored in academic circles (with the exception of industry journals focused on technology research). Only in 2015, a scientific article was published that emphasized that 3D printing technologies have the potential to transform the global location of production (Gress, Kalafsky, 2015). Publications that explore the issues of the production location of 3D printing emphasize a clear trend toward the optimal location of 3D printing production in sales markets (Strange, Zucchella, 2017; Costabile et al., 2017; Sasson, Johnson, 2016; Rehnberg, Ponte, 2018; Haefner, Sternberg, 2020; Fraske, 2022). Some researchers are convinced that this trend will lead not only to the return of production from China and other countries with relatively cheap labour to North America and Western Europe (where the massive relocation of the industry once took place) but also to the general decentralization of production in the world (Ben-Ner, Siemsen, 2017). This prediction is based on the fact that the production using 3D printing technologies is characterised by relatively minor spatial differentiation of the costs of production (therefore, locating in a place with minimal costs will not provide significant savings), and locating near sales markets will save on the costs associated with moving goods from the place of production to sales markets.

Other scientists, while agreeing with the forecasts of the global economy reformatting from powerful production facilities in regions with cheap labour to a lot of small production facilities close to sales markets, emphasize that, in addition to logistical advantages (since materials for the production are easier and cheaper to transport than finished goods), the focus at the location on sales markets will allow better satisfaction of customer needs through direct cooperation to respond more quickly to changes in demand and reduce order processing time (Tang, Veelenturf, 2019).

In the same mean, researchers believe that 3D printing has the potential to revolutionize the process of producing and delivering goods to customers by enabling the transition from centralized to decentralized supply chains and reducing the costs associated with transportation



and warehousing (Tang, Veelenturf, 2019). An important factor that will help bring the location of the production using 3D printing technologies closer to sales markets is the factor related to the environmental friendliness of these technologies: compared to the traditional technologies, they reduce contaminants many times over (Bogers et al., 2016). This is an important point, as industries with significant contaminants amount tend to be located in places (countries and regions) with low requirements for environmental protection. The environmental friendliness of 3D printing technologies is changing this situation. Therefore, it is actually generally accepted in the scientific community that long global supply chains will be replaced by cheap production using 3D printing technologies in almost every sales market (Culot et al., 2020; Ancarani, Di Mauro, 2018; Halassi et al., 2019; Gong et al., 2022; Theyel et al., 2018; Busch et al., 2021; Pour et al., 2016).

## **2. Steps of substantiation of the optimal location of the production**

However, this is too general a thesis, since only by solving the problem of the optimal location of the production facilities and their optimal capacity can we get the right answer about the "binding" of production facilities to "their" sales markets. In this case, it is necessary to estimate the size of the sales market: there are many options, from the minimum size (production at the place of consumption, for example, in an apartment) to the maximum size (production for the market of a territorial unit, for example, a city). It can be predicted that some goods will have to be produced at the place of consumption (residence), but for economic reasons (small-scale production is not profitable) and due to safety conditions (noise, environmental contaminants during 3D printing), production will be carried out in the special facilities and in the amount that will provide for the most efficient use of the capacity of the relevant equipment (3D printer).

In order to set the step for the research of the optimal location of the production using 3D printing technologies, we briefly outline our approach to substantiation of the optimal location of goods production (Table 1). Since the components of the sequence of actions shown in Table 1 have been described in detail in previous publications (Stadnicki, Terebukh, 2022; Stadnicki, Bashynska, 2023), in this article we will focus on the positioning of 3D printing in some of the steps of substantiation of the optimal location of the production. Let's start with the space of possible locations. Although 3D printing technologies, regardless of the goods to be produced, are oriented towards sales markets and the space of possible locations of 3D printing production would be relatively minor (it could even be limited to the space of the relevant sales markets), competition with other technologies necessitates a significant expansion of the space of possible locations - to the level of national or even global. But for 3D printing technologies,

the task will be made easier by the fact that even within the expanded space of possible locations, attractive places for production will be only near sales markets.

**Table 1.**

*Steps of substantiation of the optimal location of the production*

Step	Content of the step
1.	Determine what we plan to produce (declaration of intent)
2.	Outline the space for the possible location of the production
3.	Identify potential sales markets and estimate the demand for each of them
4.	From the potential sales markets, form variants of sales markets and calculate the demand for each of them
5.	Form a list of technologies of the production
6.	Identify the factors of the production location
7.	Within the places of a possible production location, identify places that are attractive for the production location
8.	For each place that is attractive for the production location, substantiate the pointwise optimal production technologies, while orienting the location to the appropriate sales market options
9.	Form a list of technologies of transportation between each attractive place for the production and all potential sales markets for the appropriate sales market option
10.	Substantiate the optimal transportation technologies between each attractive place for the production and all potential sales markets for the appropriate sales market option
11.	For each market option from the set of its attractive place for the production, determine the locally optimal place of the production and locally optimal production technologies and transportation
12.	From the locally optimal places of all sales market options, form options for potential systemically optimal places with potentially systemically optimal production technologies and transportation
13.	From the options of the potential systemically optimal places, substantiate the choice of the best one, i.e., the option of systemically optimal places with systemically optimal production technologies and transportation
14.	Evaluate the feasibility of implementing the optimal investment option, i.e. the option of systemically optimal places with systemically optimal production technologies and transportation

Source: Author's development.

Potential sales markets should be identified by taking into account the space of possible locations, which will allow identifying places that will require customs payments when exporting goods produced there, or places on the territory of states that are under various sanctions. Taking into account the transportability of the goods to be produced, it is advisable to aggregate the demand of potential sales markets: with increasing transportability, the space for aggregating demand increases. However, it should be emphasized that aggregation of demand from potential sales markets should be done with caution. It is better to "under-aggregate" than to "over-aggregate". "Under-aggregation" may necessitate additional time and money spent on data collection and processing, but it will guarantee a high-quality result in terms of the optimal location of the production. "Over-aggregation" will save some time and money in data collection and processing, but may lead to mistakes in the optimal location of the production, mistakes that can have very large financial consequences.

Focusing 3D printing production which are close to sales markets can reduce the number of potential sales markets (by ignoring sales markets that are far from the potential places of the production using 3D printing technologies), but again, there are certain risks. For example, ignoring distant sales markets will save time and costs for collecting and processing some data (e.g., data for determining the distance and data to substantiate the choice of the optimal

transportation technology from the places of a potential production using 3D printing technologies to the relevant sales markets for different types of transport), but it may lead to the possibility of accidentally ignoring effective potential sales markets with the corresponding consequences for the quality of decisions on production location.

Sales market options are formed and characterized by the potential sales markets that are part of these sales market options (obviously, some potential sales markets can be part of several sales market options). It is the sales market options that will act as "demand units", the orientation to which, when locating production, will determine the potential production capacity (and, accordingly, unit and total production costs), as well as the directions and volume of transportation (and, accordingly, unit and total transportation costs). Restricting the orientation in substantiation of the optimal location of production to only one particular option of the sales market (regardless of whether it is formed from one or more potential sales markets) would be erroneous (the only exception is when, for some reason, there is only one sales market - in this case, the orientation to it alone is permissible in substantiation the optimal location of the production), since it is not system and does not take into account competitive options.

If the orientation of the production using 3D printing technologies to nearby sales markets reduces the number of potential sales markets, then the number of sales market options will automatically decrease, but again, there are certain risks. Yes, this will save time and money on collection and processing data (for example, calculating production costs for some capacity options and transportation costs to some potential sales markets), but it is a threat with the possibility of accidentally ignoring effective sales market options with the corresponding consequences for the quality of final decisions on the production location.

Regarding the formation of a list of the production technologies. This list, along with 3D printing technologies, will include other technologies for the production of the valued goods, since, as a rule, any goods can be produced using several interchangeable technologies. The technologies on this list are competing and interchangeable, although some of them will be mutually supportive (when the optimal system of places of the production location is characterized by an optimal set of technologies that are mutually supportive in this system since it is the sets of technologies that compete with each other).

### **3. Location factors for production using 3D printing technologies**

Regarding the identification of the production location factors. It is obvious that the strength of the influence of the factors of the production location is proportional to its impact on the criterion of optimal production location, which is the minimum total cost of the production of the required volume of goods and the cost of their movement (including transportation and warehousing costs, as well as, if necessary, customs payments) from the places of the

production to the consumers (sales markets) in the amount of their demand. Since production costs are primarily the costs of resources required, the spatial differentiation of the resource prices, the need for resources, and the quality of resources leads to spatial differentiation of the production costs.

Production using 3D printing technologies is driven by demand:

- 1) 3D printers,
- 2) electricity,
- 3) materials for 3D printing,
- 4) software,
- 5) employees for 3D printing maintenance,
- 6) the space required to organize the production.

The main factor in the spatial differentiation of the production costs using 3D printing technologies will be the spatial differentiation of costs for electricity and 3D printing materials since the situation with other resources will be as follows: in different places, the prices of 3D printers and software will not differ significantly, and the price of work related to the direct operation of the 3D printer will have a small impact on the overall production costs. It follows that places (relevant cities, regions, countries) with relatively low prices for electricity and materials for 3D printing will be attractive for the location of the production using 3D printing technologies.

Table 2 shows the results of the analysis to identify which resources for the production of goods using 3D printing technologies can be factors in the location of such production, and the availability and relatively low price of its resources.

**Table 2.**

*Results of the analysis of resources for 3D printing*

Resources for 3D printing	Share in production costs	Spatial price differentiation	Is location a factor?
3D printers	Significant	Small	No
Electricity	Significant	Small locally; Significant globally	Yes
Materials for 3D printing	Significant	Medium	Yes
Software	Medium	Small	No
Employees for 3D printing maintenance	Small	Significant	No
Space required to organize production	Small	Significant	No

Source: Author's development.

The results of the analysis show that the location factors for producing goods using 3D printing technologies are the relatively low prices of electricity and materials for 3D printing. However, the location factors for producing goods using 3D printing technologies are not only at the step of the production but also at the step of the transportation of goods from the place of production to the sales markets.

The advantage of low prices for electricity and materials for 3D printing can lose value by the high costs of the transportation of goods produced in a place with low prices for these resources to sales markets, compared to the costs of the transportation of goods to an alternative production place near sales markets. The possibility of such a situation (losing value) is due to the fact that, first, finished goods are usually not adapted to the transportation process, so they are subjected to actions aimed at increasing their transportability, which is associated with costs. Secondly, the transportation of goods produced in a place with low prices for electricity and 3D printing materials may involve the need for import customs payments if the relevant place is outside the common customs area (import customs payments for finished goods are usually much higher than import customs payments for resources). For the above reasons, the transportation of resources for 3D printing will require lower costs than the transportation of finished goods. Therefore, the proximity of the place to sales markets is a location factor for producing using 3D printing technologies. Although, obviously, the tendency to approach sales markets will be largely determined by the type of goods, since the ratio of how much cheaper it will be to transport materials than finished goods will strongly depend on the type of goods.

Access to good transportation infrastructure to a certain extent loses value the distance from sales markets. Therefore, a well-developed transportation infrastructure between places of potential production using 3D printing technologies and potential sales markets, which reduces logistics costs, is also a location factor for producing using 3D printing technologies.

According to the results of the analysis, Table 3 shows the location factors for producing using 3D printing technologies.

**Table 3.**

*Location factors for producing using 3D printing technologies*

No. of the factor	Name of the factor
1	Relatively low price of electricity
2	Relatively low prices of materials
3	Access to infrastructure
4	Proximity to sales markets

Source: Author's development.

#### **4. Attractive places for the production location using 3D printing technologies**

Identification of attractive places for the production within a potential location space. Not every attractive place for the production within a potential location space needs to be considered as an attractive production location for every sales market option. Some attractive places for the production within a potential location space may not be suitable in terms of

production volume (taking into account environmental restrictions, and the amount of resources needed) for the location of a large-scale production, i.e., one that is oriented to a market option with significant demand. It is clear that orientation to sales market with high demand, which means high production capacity, will lead to a significantly smaller number of attractive places for the production than orientation to sales market with low demand since low production requires fewer different resources and is less affected by environmental restrictions.

In general, all locations in the space of possible locations that are characterized by at least one of the 4 factors identified (relatively low electricity prices, relatively low material prices, access to good transportation infrastructure, proximity to sales markets) can be considered attractive places for the production of goods using 3D printing technologies (Table 4).

**Table 4.**

*Categories of attractive places for the production using 3D printing technologies*

Category of places	Factors			
	1-comparatively low price of electricity	2-comparatively low prices of materials	3-access to infrastructure	4-proximity to sales markets
1-1	+	-	-	-
1-2	-	+	-	-
1-3	-	-	+	-
1-4	-	-	-	+
2-(1+2)	+	+	-	-
2-(1+3)	+	-	+	-
2-(1+4)	+	-	-	+
2-(2+3)	-	+	+	-
2-(2+4)	-	+	-	+
2-(3+4)	-	-	+	+
3-(1+2+3)	+	+	+	-
3-(1+2+4)	+	+	-	+
3-(1+3+4)	+	-	+	+
3-(2+3+4)	-	+	+	+
4-(1+2+3+4)	+	+	+	+

Source: Author's development.

In this table, the category of place depends primarily on the number of factors (location of the production using 3D printing technologies) that are presented in the respective place. That is, places with only one factor are encoded at the beginning with the digit "1" (1-1, 1-2, 1-3, 1-4); places with two factors are encoded at the beginning with the digit "2" (2-(1+2), 2-(1+3), 2-(1+4), 2-(2+3), 2-(2+4), 2-(3+4)); places where three factors are present are encoded at the beginning with the digit "3" (3-(1+2+3), 3-(1+2+4), 3-(1+3+4), 3-(2+3+4)); places where all four factors are present are encoded at the beginning with the digit "4" (4-(1+2+3+4)). The second component of the place categorization code characterises which factors are present in the respective places.

Attractive places for the production in category 1 will be the least likely to be selected for the location of goods production using 3D printing technologies, as they will be characterized by the presence of only one location factor (4 subgroups: 1-1, 1-2, 1-3, 1-4). However, it should be emphasized that a special subgroup will be formed by places in categories 1-4,

since proximity to sales markets should still be considered a key factor of the location of goods production using 3D printing technologies.

For attractive places for the production of category 2, the probability of being selected for the location of goods production using 3D printing technologies will increase, as it will be characterized by the presence of two location factors (6 subgroups: 2-(1+2), 2-(1+3), 2-(1+4), 2-(2+3), 2-(2+4), 2-(3+4)). The special subgroups among places of category 2 will be 2-(1+4), 2-(2+4), and 2-(3+4), due to the presence of a key factor of the location of goods production using 3D printing technologies - proximity to sales markets.

Attractive places for the production in category 3 will be even more likely to be selected for the location of the production using 3D printing technologies, as it will be characterized by the presence of as many as three location factors (4 subgroups: 3-(1+2+3), 3-(1+2+4), 3-(1+3+4), 3-(2+3+4)). The special subgroups among the locations of category 3 will be 3-(1+2+4), 3-(1+3+4), and 3-(2+3+4), due to the presence of a key factor of the location of goods production using 3D printing technologies, namely, proximity to sales markets.

Obviously, the most likely to be selected for the production location using 3D printing technologies will be attractive places for the production of category 4 (1 subgroup: 4-(1+2+3+4)), as they will be characterized by the presence of all four location factors. However, it should be expected that there may be few places in category 4 (and the situation of its absence is quite possible) places of category 4, so to improve the quality of the analysis, it is advisable to research attractive places of production locations of category 3 (all subgroups), as well as individual subgroups of category 2 (2-(1+4), 2-(2+4) and 2-(3+4)) and even one subgroup of category 1 (1-4).

## **5. Pointwise, locally and systemically optimal production technologies**

Regarding the substantiation of the optimal technologies. Technology competition should be considered in relation to attractive places of production locations and sales market options. Technologies that will be evaluated for particular attractive places of production locations for the relevant sales market option will compete with each other. Technologies that win in the competition of technologies in a particular attractive place (in terms of minimum production costs in the amount of demand of the relevant sales market option) are identified as point-optimal technologies for the relevant attractive places: each attractive place of production locations of each sales market option will have its own point-optimal technology (the number of point-optimal technologies in each attractive place is equal to the number of sales market options that this location will be targeted at).

The following three situations can be found in specific attractive places with regard to point-optimal technologies (which may apply to a single sales market option or to all sales market options):

- 1P) All point-optimal technologies are 3D printing technologies;
- 2P) Some of the point-optimal technologies are 3D printing technologies;
- 3P) All point-optimal technologies are not 3D printing technologies.

Point-optimal technologies in specific attractive places of each sales market option will compete with each other at a distance, creating local spatial competition of technologies. The technology that wins this competition (in terms of the minimum total production costs in the amount of demand of the respective sales market option and transportation costs to potential sales markets of the respective sales market option in the amount of demand of these potential sales markets) of point-optimal technologies in specific attractive places of the sales market option becomes the locally optimal technology. Each sales market option will have its own locally optimal technology (the number of locally optimal technologies is equal to the number of sales market options). The following three situations can occur with respect to locally optimal technologies (which apply only to all sales market options):

- 1L) All locally optimal technologies are 3D printing technologies;
- 2L) Some of the locally optimal technologies are 3D printing technologies;
- 3L) All locally optimal technologies are not 3D printing technologies.

Obviously, the situations of locally optimal technologies depend on the situations of point-optimal technologies in specific attractive places. For example, if a 1P situation is created for all sales market options (all point-optimal technologies in specific attractive places are 3D printing technologies), then a 1L situation (all locally optimal technologies are 3D printing technologies) is inevitable. If, on the other hand, a 3P situation is created for all sales market options (all locally optimal technologies are not 3D printing technologies), then a 3L situation (all locally optimal technologies in specific attractive places are not 3D printing technologies) is inevitable. If a 2P situation is created for all sales market options (some of the point-optimal technologies in attractive places are 3D printing technologies), then each of the above situations is possible for locally optimal technologies: situation 1L (all locally optimal technologies are 3D printing technologies), situation 2L (some locally optimal technologies are 3D printing technologies), and situation 3L (all locally optimal technologies are not 3D printing technologies). The described dependence between the optimal technologies of the "P" and "L" levels is well characterized in Table 5.

Locally optimal technologies of sales market options not only compete but also mutually support each other since its competition takes place as part of options of potential systemically optimal technologies (the set of locally optimal productions, the total capacity of its is equal to systemic demand, forms an option of potential systemically optimal productions). At the same time, a situation may arise when the locally optimal 3D printing technology of a particular sales market option competes not only with other interchangeable locally optimal technologies of



other sales market options but also with other locally optimal 3D printing technologies of other sales market options. To some extent, it is paradoxical that a locally optimal technology (that could be a 3D printing technology) can compete with itself, since it may be present in different competing technology systems.

**Table 5.**

*Dependence between optimal technologies of "P" and "L" levels*

If at the "P" level	Then at the level of "L" are inevitable (+ or "-") or possible ( $\pm$ )		
	1L) All locally optimal technologies are 3D printing technologies	2L) Some of the locally optimal technologies are 3D printing technologies	3L) All locally optimal technologies are not 3D printing technologies
1P) All point-optimal technologies are 3D printing technologies	+	-	-
2P) Some of the point-optimal technologies are 3D printing technologies	$\pm$	$\pm$	$\pm$
3P) All point-optimal technologies are not 3D printing technologies	-	-	+

Source: Author's development.

Competition of sets of locally optimal technologies of sales market options (options of potential systemically optimal technologies) means systemic spatial competition of technologies. At the same time, in each set of locally optimal technologies of the options of sales markets, technologies are actually mutually supported, since together they constitute a single entity - a system of technologies competing with other systems of technologies. In the case of mutual support of technologies within the options of potential systemically optimal technologies, a situation may arise when the locally optimal 3D printing technology of a sales market option is mutually supported not only with other locally optimal 3D printing technologies of other sales market options but also with other locally optimal technologies (which are not 3D printing technologies) of other sales market options.

Obviously, the situations of systemically optimal technologies depend on the situations of locally optimal technologies. Thus, if a 1L situation is created for all sales market options (all locally optimal technologies are 3D printing technologies), then situation 1S (all systemically optimal technologies are 3D printing technologies) is inevitable. If a 3L situation is created for all sales market options (all locally optimal technologies are not 3D printing technologies), then the situation 3S (all systemically optimal technologies are not 3D printing technologies) is inevitable. If a 2L situation is created for all sales market options (some locally optimal technologies are 3D printing technologies), then each of the following situations is possible for systemically optimal technologies: situation 1S (all systemically optimal technologies are 3D printing technologies), situation 2S (some systemically optimal technologies are 3D printing technologies), and situation 3S (all systemically optimal technologies are not 3D printing technologies). The described dependence between the optimal technologies of the "L" and "S" levels is well characterized by Table 6.

**Table 6.***Dependence between optimal technologies of "L" and "S" levels*

If at the "L" level	Then at the "S" level are inevitable (+ or "-") or possible ( $\pm$ )		
	1S) All systemically optimal technologies are 3D printing technologies	2S) Some of the systemically optimal technologies are 3D printing technologies	3S) All systemically optimal technologies are not 3D printing technologies
1L) All locally optimal technologies are 3D printing technologies	+	-	-
2L) Some of the locally optimal technologies are 3D printing technologies	$\pm$	$\pm$	$\pm$
3L) All locally optimal technologies are not 3D printing technologies	-	-	+

Source: Author's development.

## 6. Conclusions

Let us focus on the main points of the article.

- 1) 3D printing is one of the most promising production technologies, but only optimal location will allow to fully utilize the potential efficiency of this technology;
- 2) Although 3D printing technologies, regardless of the goods to be produced, are oriented towards sales markets and its individual space of possible locations would be limited, competition with other technologies necessitates a significant expansion of the space of possible locations;
- 3) When forming the list of production technologies, along with 3D printing technologies, there will be other production technologies of the valued goods (interchangeable, which under certain conditions can become mutually supportive);
- 4) The location factors for producing goods using 3D printing technologies are the relatively low prices of 3D printing materials and electricity, as well as access to good transportation infrastructure and proximity to sales markets;
- 5) The most likely to be selected for the location of production using 3D printing technologies will have attractive places for production with all four location factors. However, in order to improve the quality of the analysis, it is advisable to research attractive places of production locations that have fewer factors of production location: first of all, with the presence of the factor "proximity to sales markets";
- 6) For each place that is attractive for production location, the criterion of minimum production costs for a given capacity (equal to the demand of the relevant sales market option) is used to substantiate the point-optimal production technology (pointwise competition of technologies). Subsequently, it is the spatial competition of point-

optimal technologies (in terms of the minimum total costs of production and movement of goods) that will allow the identification of locally optimal places of production and locally optimal technologies for each sales market option;

- 7) The option of a set of locally optimal places with the lowest total costs (for production and movement of goods to consumers) will be optimal, and the locally optimal places of this option are identified as systemically optimal places where necessary to locate production with appropriate technologies, production with appropriate technologies, which are identified as systemically optimal technologies, and with appropriate capacities, which are identified as the systemically optimal capacities.

Thus, the correct substantiation of the optimal location of the production using 3D printing technologies is possible only based on a systematic approach that takes into account the competition of other (interchangeable) technologies, as well as the simultaneous substantiation of production capacity and supply volumes to specific sales markets. In the future, research in this area should focus on the problem of the range of production, which means that it is necessary to expand the research of the complexity of production in the direction of a "set of goods" that should be produced in appropriate places using appropriate technologies, in appropriate volumes and for appropriate sales markets. The problem of transforming interchangeable competing technologies into mutually supportive technologies deserves thorough scientific research. Another promising area of research in this area is to assess the impact of 3D printing technologies on the spatial organization of the economy as a whole. One of the results of changes in the spatial organization of the economy under the influence of 3D printing technologies will be a decrease in the role and volume of international trade, which should also be the subject of scientific research.

## References

1. Ancarani, A., Di Mauro, C. (2018). Reshoring and Industry 4.0: how often do they go together? *IEEE Engineering Management Review*, 46(2), 87-96. DOI: 10.1109/EMR.2018.2833475.
2. Ben-Ner, A., Siemsen, E. (2017). Decentralization and localization of production: The organizational and economic consequences of additive manufacturing (3D printing). *California Management Review*, 59(2), 5-23. DOI:10.1177/0008125617695284.
3. Bogers, M., Hadar, R., Bilberg, A. (2016). Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological forecasting and social change*, 102, 225-239. DOI: 10.1016/j.techfore.2015.07.024.

4. Busch, H., Muhl, C., Fuchs, M., Fromhold-Eisebith, M. (2021). Digital urban production: how does Industry 4.0 reconfigure productive value creation in urban contexts? *Regional Studies*, 55(10-11), 1801-1815. DOI: 10.1080/00343404.2021.1957460.
5. Costabile, G., Fera, M., Fruggiero, F., Lambiase, A., Pham, D. (2017). Cost models of additive manufacturing: A literature review. *International Journal of Industrial Engineering Computations*, 8(2), 263-282. DOI:10.5267/j.ijiec.2016.9.001.
6. Culot, G., Orzes, G., Sartor, M., Nassimbeni, G. (2020). The future of manufacturing: A Delphi-based scenario analysis on Industry 4.0. *Technological forecasting and social change*, 157, 120092. DOI:10.1016/j.techfore.2020.120092.
7. Fraske, T. (2022). Industry 4.0 and its geographies: A systematic literature review and the identification of new research avenues. *Digital Geography and Society*, 3(3), 100031. DOI: 10.1016/j.diggeo.2022.100031.
8. Gong, H., Hassink, R., Foster, C., Hess, M., Garretsen, H. (2022). Globalisation in reverse? Reconfiguring the geographies of value chains and production networks. *Cambridge journal of regions, economy and society*, 15(2), 165-181. DOI:10.1093/cjres/rsac012.
9. Gress, D., Kalafsky, R. (2015). Geographies of production in 3D: Theoretical and research implications stemming from additive manufacturing. *Geoforum*, 60, 43-52. DOI: 10.1016/j.geoforum.2015.01.003.
10. Haefner, L., Sternberg, R. (2020). Spatial implications of digitization: State of the field and research agenda. *Geography Compass*, 14(12), e12544. DOI: 10.1111/gec3.12544.
11. Halassi, S., Semeijn, J., Kiratli, N. (2019). From consumer to prosumer: a supply chain revolution in 3D printing. *International Journal of Physical Distribution & Logistics Management*, 49(2), 200-216. DOI:10.1108/IJPDLM-03-2018-0139.
12. Jadhav, A., Jadhav, V. (2022). A review on 3D printing: An additive manufacturing technology. *Materials Today: Proceedings*, 62(4), 2094-2099. DOI: 10.1016/j.matpr.2022.02.558.
13. Jandyal, A., Chaturvedi, I., Wazir, I., Raina, A., Haq, M. (2022). 3D printing - a review of processes, materials and applications in industry 4.0. *Sustainable Operations and Computers*, 3, 33-42. DOI:10.1016/j.susoc.2021.09.004.
14. Pour, M., Zanardini, M., Bacchetti, A., Zanoni, S. (2016). Additive manufacturing impacts on productions and logistics systems. *IFAC-PapersOnLine*, 49(12), 1679-1684. DOI:10.1016/j.ifacol.2016.07.822.
15. Praveena, B.A., Lokesh, N., Buradi, A., Santhosh, N., Praveena, B.L., Vignesh, R. (2021). A comprehensive review of emerging additive manufacturing (3D printing technology): Methods, materials, applications, challenges, trends and future potential. *Materials Today: Proceedings*, 52(3), 1309-1313. DOI:10.1016/j.matpr.2021.11.059.
16. Rehnberg, M., Ponte, S. (2018). From smiling to smirking? 3D printing, upgrading and the restructuring of global value chains. *Global Networks*, 18(1), 57-80. DOI: 10.1111/glob.12166.

17. Ronchini, A., Moretto, A., Caniato, F. (2023). Adoption of additive manufacturing technology: drivers, barriers and impacts on upstream supply chain design. *International Journal of Physical Distribution & Logistics Management*, 53(4), 532-554. DOI: 10.1016/j.techfore.2015.02.015.
18. Sasson, A., Johnson, J. (2016). The 3D printing order: variability, supercenters and supply chain reconfigurations. *International Journal of Physical Distribution & Logistics Management*, 46(1), 82-94. DOI:10.1108/IJPDLM-10-2015-0257.
19. Stadnicki, J., Bashynska, Y. (2023). Production of goods: what, where, how, how much and for whom. *Scientific Papers of Silesian University of Technology. Organization & Management*, 179(12), 587-602. DOI: 10.29119/1641-3466.2023.179.31.
20. Stadnicki, J., Terebukh, A. (2022). Rationale of the Optimal Location of Production: a System Approach. *Management and Production Engineering Review*, 13(3), 110-117. DOI: 10.24425/mper.2022.142388.
21. Stentoft, J., Wickstrom, K., Haug, A., Philipsen, K. (2023). Additive manufacturing-enabled innovation in small- and medium-sized enterprises: the role of readiness in make-or-buy decisions. *Industrial Management & Data Systems*, 123(6), 1768-1788. DOI:10.1108/IMDS-11-2022-0700.
22. Strange, R., Zucchella, A. (2017). Industry 4.0, global value chains and international business. *Multinational Business Review*, 25(3), 174-184. DOI:10.1108/MBR-05-2017-0028.
23. Tang, C., Veelenturf, L. (2019). The strategic role of logistics in the industry 4.0 era. *Transportation Research Part E: Logistics and Transportation Review*, 129, 1-11. DOI: 15.1016/j.tre.2019.06.004.
24. Theyel, G., Hofmann, K., Gregory, M. (2018). Understanding manufacturing location decision making: rationales for retaining, offshoring, reshoring, and hybrid approaches. *Economic Development Quarterly*, 32(4), 300-312. DOI:10.1177/0891242418800222.



## MANAGING ENVIRONMENTAL SOCIAL RESPONSIBILITY IN CITIES ACCORDING TO THE YOUNG GENERATION

Katarzyna SUKIENNIK<sup>1\*</sup>, Michał DZIADKIEWICZ<sup>2</sup>

<sup>1</sup> Politechnika Częstochowska, Wydział Zarządzania; katarzyna.sukiennik@pcz.pl,  
ORCID: 0000-0002-0195-7002

<sup>2</sup> Politechnika Częstochowska, Wydział Zarządzania; michal.dziadkiewicz@pcz.pl,  
ORCID: 0000-0001-5450-1669

\* Correspondence author

**Objective:** The subject matter discussed in the article presents a very important issue regarding the environmental social responsibility of the young generation. The main objective is to assess the awareness and social and environmental activities implemented in Poland in the field of environmental social responsibility.

**Project/methodology/approach:** The objective of the work was achieved through theoretical and practical analysis. The article analyzes the results of the conducted research and compares the authors' own research with national studies on the presented subject matter.

**Findings:** The work indicates similarities and differences relating to environmental social responsibility. During the analysis of the collected materials, it was noticed that there is a high level of knowledge in the field of environmental protection and great opportunities and willingness, especially of the young generation, to implement environmental projects.

**Limitations/research implications:** The subject matter discussed in the article is very important and up-to-date, therefore research in this area should be published. However, research opportunities are limited, and significant changes occur from year to year. Therefore, there is a need to carry out repeated tests and to expand the area covered. The authors plan to continue conducting both domestic and international research, which will increase the knowledge of the investigated subject matter.

**Practical implications:** Due to the information provided in the article, entrepreneurs can find out what the social demand for eco-friendly products and initiatives is. They can use this knowledge to increase competitiveness and acquire new customers.

**Social implications:** The presented research will influence public awareness in the field of ecology and environmental protection. Recipients will learn about the state's capabilities in terms of environmental protection and what actions they can implement in their immediate surroundings. The article will allow the assessment of own attitudes towards natural resources and their protection.

**Originality/value:** The added value of the article is the opportunity to learn about attitudes and social awareness in various regions of Poland. The presented subject matter is up-to-date and very important in terms of future activities and the functioning of future generations in the city.

**Keywords:** Environmental social responsibility, ecology, environmental awareness, ecological generation.

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

## **Introduction**

At a time of dynamic changes related to socio-economic development, it is important to hold responsibility for the natural environment. The implementation of modern technological solutions should take into account the public interest. While having in mind making responsible economic decisions and adapting to modern social and environmental standards, traditional management should be combined with environmental management. Modern societies increasingly appreciate the importance of the natural environment and are more willing to take it into account in their development plans. Environmental corporate social responsibility is not only slogans, but also activities aimed at protecting the natural environment, even at the cost of own professional success. Young people, wishing to show care for the natural environment, are involved in many social initiatives that allow them to implement specific corrective actions. The concept of environmental social responsibility allows for striving to gain a competitive advantage in many areas of operation.

## **Principles of environmental social responsibility in theoretical terms**

Modern forms of management of enterprises and institutions oriented towards conscious action in the public and environmental interest, and not only the economic one, can be observed nowadays (Tewari, Bhattacharya, 2022; Gast, Gundolf, Cesinger, 2017). The issue of the natural environment is increasingly appearing in both management theory and practice (Ren, Huang, Liu, Yan, 2022; Arruda, 2017). Enterprises around the world are facing increasing pressure regarding pro-social and pro-environmental activities (Shiu, Yang, 2017; Lamarche, Bodet, 2018). Dynamic changes in the environment, intensifying globalization processes, as well as growing social and environmental requirements result in greater and more frequent involvement in pro-environmental activities (Gonzalez-Perez, 2016; Tliche, 2020). The perspectives of corporate social responsibility and sustainable development create added value in business strategies (Borda et al., 2021; Kim et al., 2021). Enterprises operating in accordance with environmental principles benefit from both internal and external environments (Chi-Shiun Lai et al., 2010; Sullivan, Thomas, Rosano, 2018). An increasing number of enterprises and institutions inform about CSR activities and, when issuing reports on their operations, they take into account the applied CSR principles (Hąbek, Wolniak, 2016; Wenbing Jiang, Wang, Du, 2023). There is a relationship between corporate social responsibility and the financial performance of enterprises (Ali, Danish, Asrar-ul-Haq, 2019; Cubilla-Montilla et al., 2019). The way of conduct of enterprises and their response to climate change is also relevant (Wright, Nyberg, 2017). Climate changes have become serious challenges to the sustainable



development of developing countries (Nureen, Liu, Irfan, Işik, 2023). Environmental awareness is changing as people notice that preventing environmental degradation is simpler and cheaper than repairing the damaged nature later (Butler, Hackney, 2021). Environmental social responsibility is all social activities focusing on compliance with environmental protection regulations and implementing activities to improve life in relation to ecology (Lyon, Maxwell, 2008). The concept of environmental responsibility relates to social initiatives aimed at limiting the negative impact on the natural environment and applying the principles of environmental protection and sustainable development. Environmental social responsibility takes into account the issues of people and the planet that lead to meeting social needs, both current and future. Strong networks of local and global connections operating in accordance with pro-environmental principles are important for modern consumers (Schembera, 2018; Stranieri, Orsi, Banterle, Ricci, 2019; Filho, 2017). Developing environmental attitudes among employees allows for the implementation of new environmental solutions (Giuliano, Mahy, Rycx, Vermeulen, 2017; Salehi-Amiri et al., 2021). The subject matter of environmental social responsibility is particularly noticed by representatives of the younger generation, among whom increased care for the natural environment is an increasingly common phenomenon (Pencarelli et al., 2020). It is acknowledged that the youngest generation, i.e. people born after 2001, particularly care for the natural environment (Fazlagić, 2010; Kurz, Li, Vine, 2019). Generation Z are conscious consumers and initiators of many pro-environmental activities (Alonso-Almeida, Llach, 2019). This is a generation that is very aware, limits its negative impact on the environment and willingly engages in pro-environmental and health-promoting initiatives (Kureshi, Thomas, 2020). The activities they implement allow for reducing the negative economic impact on the natural environment and adhering to the principles of sustainable development (Hur, Kim, Kim, 2018). They want to protect natural resources and surround themselves with nature. According to many scientific studies, people born after 2001 will experience rapid unfavorable climate changes, which are a consequence of operations carried out so far, aimed at economic development (Luten, Ryan, Wakefield, 2021). Failure to take into account the principles of sustainable development for years has made changes in the natural environment around the world occur much faster than expected. Dynamic economic development has contributed to achieving a high standard of living at the cost of the loss of certain natural resources. The change in behavior taking into account environmental protection is a long-term process that requires high social and economic awareness (Shams et al., 2020; Böcker, Meelen, 2017). Nowadays, the compliance with the principles of environmental social responsibility is a social obligation resulting from the awareness of threats to the natural environment.

## Characteristics of the research sample and research methods applied

The article presents the analyzes from the authors' own research conducted in 2021 and 2022 and the research conducted by PBS Sp. z o. o. commissioned by the Ministry of Climate and Environment in 2021 and 2022. All the studies were carried out among both women and men, of different ages, with various levels of education, living in different regions of the country, etc. The quantitative research was used based on traditional and electronic survey questionnaires, as well as computer-assisted telephone interviews.

The first own research conducted in 2021 was addressed to the residents of Częstochowa in the Silesian Voivodeship. 362 respondents took part in the study. The study was conducted using a survey method including single- and multiple-choice closed-ended questions. The objective of the survey was to examine the environmental awareness of the residents and the need to implement pro-environmental solutions in the areas of their residence.

The second own research conducted in 2022 took place with the participation of representatives from various voivodeships from all over Poland and included 605 anonymous respondents. The questionnaire was developed to assess public awareness of the implementation of environmental and economic solutions. The survey was divided into parts concerning pro-environmental and pro-social activities undertaken to build the environmental awareness of residents and individual attitudes of residents in terms of the dissemination of environmental solutions in their own households. In addition, the survey questionnaire shows whether the residents feel the need to promote the principles of sustainable development. The article presents only some of the respondents' answers that directly influenced the accomplishment of the objective of the article.

In the authors' own research, a Likert scale was used, which allowed for measuring the intensity of the respondents' attitude using a bipolar ordinal scale with values from 1 to 5. The answers were given numerical values, maintaining the principle that the assigned values increase in accordance with the nature and direction of the defined feature. A five-point scale was used to measure significance with statements, and the values were described verbally and numerically.

The research conducted by PBS Sp. z o. o. commissioned by the Ministry of Climate and Environment has been carried out as part of a multi-year research program since 2011 ([www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej](http://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej)). Cyclical research allows for tracking the dynamics of changes in Poles' environmental awareness and behavior in many areas and to program activities in terms of environmental education. The research was carried out using the CATI method in 2021 (on a sample of 1004 respondents) and 2022 (on a sample of 600 respondents). The analyzes were carried out using analytic weighting, which means that the collected data are weighted in such a way that the structure of the sample corresponds to the actual structure of urban residents in Poland.

The processing of the obtained research material allowed for the assessment of public awareness in terms of ecology. Based on the literature review, the hypotheses were formulated that were supported by the quantitative research. The main objective of the article was to assess the willingness to implement pro-environmental initiatives among the young generation. The basis for the accomplishment of the objective was the main hypothesis: representatives of the young generation are oriented towards implementing environmental initiatives in cities to obtain future benefits. To justify the main hypothesis, two the sub-hypotheses were formulated.

H1. There is a relationship between pro-environmental activities and age.

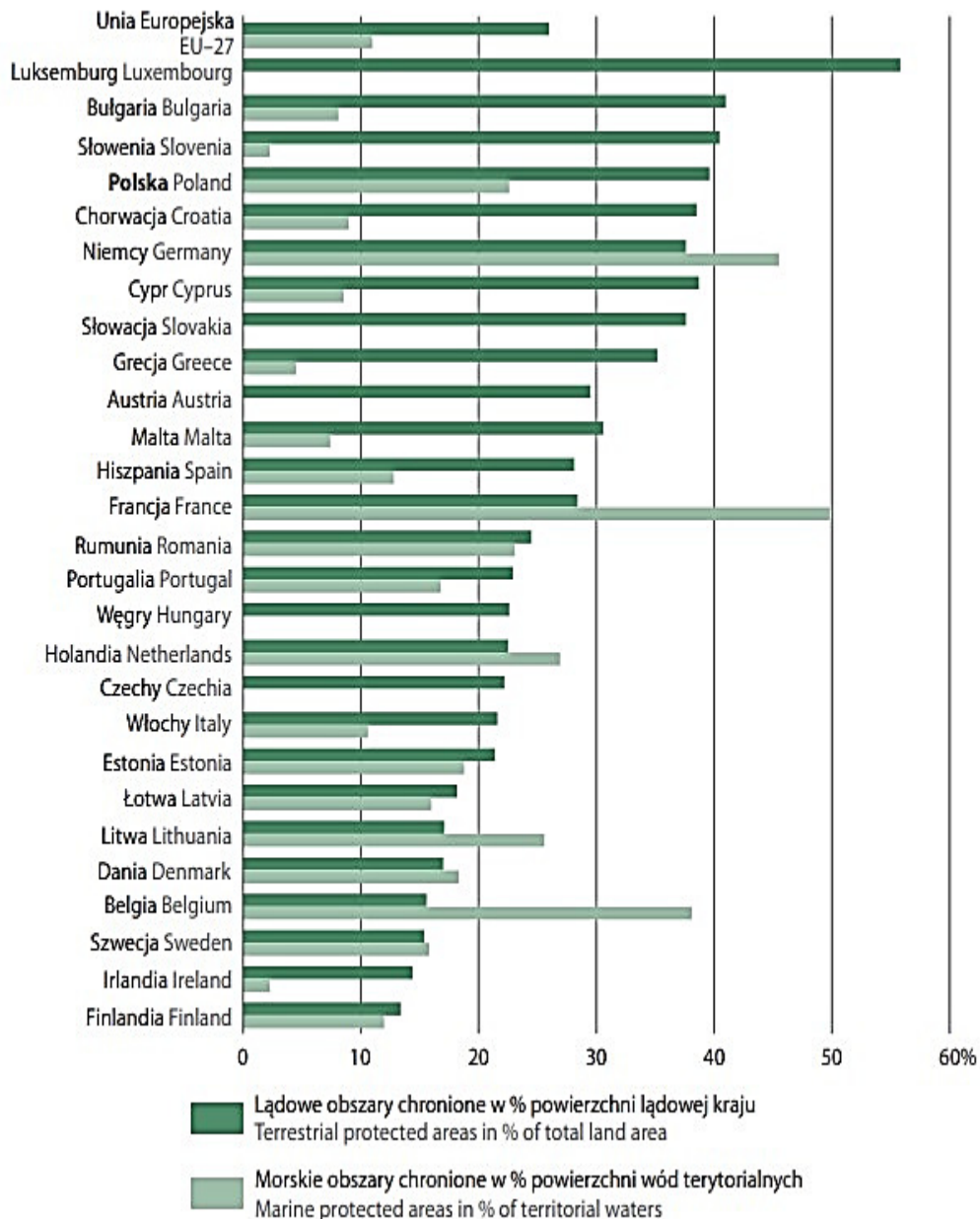
H2. The environmental social responsibility of Generation Z representatives affects their involvement in urban activities.

All the studies cited were analyzed in terms of the respondents' behavior resulting from their age and involvement in pro-environmental activities, especially in cities. Representatives of the young generation point to many initiatives that prove their environmental responsibility.

## **Analysis of the results obtained and discussion/conclusions and recommendations**

The conducted research indicates that environmental social responsibility is increasing every year, which has a positive impact on initiatives undertaken in the field of environmental protection. Poland is one of European Union countries that stands out in terms of biodiversity. The location of Poland and the prevailing climate are of particular importance. Its diversified topography is also relevant. According to the data, the area of legally protected areas in Poland in 2022 was over 10.1 million hectares, which constituted 32.3% of the country's area ([www.stat.gov.pl](http://www.stat.gov.pl)). The size of protected areas in European Union countries in 2022 is presented below.

According to the above data (Fig. 1), Poland is in the 4<sup>th</sup> place among European Union countries in terms of land and territorial water protected areas. Only Luxembourg, Bulgaria and Slovenia have more protected areas. Protected biological diversity is the indisputable wealth of every country. Therefore, actions should be taken to maintain a high level of biodiversity through social initiatives.



**Figure 1.** Size of protected areas in European Union countries in 2022.

Source: The World Bank database <https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/srodowisko/ochrona-srodowiska-2023,1,24.html>

In the survey questionnaire conducted by the authors of the article in 2022, the respondents were asked whether activities aimed at protecting biodiversity were being undertaken in their surroundings. The study covered various regions of Poland, which proves a broad approach to the subject matter. The answers obtained related to both local, regional, nationwide and individual activities implemented by the respondents. The respondents who could point out more than one answer indicated the following actions (Table 1).

**Table 1.***Characteristics of local and individual activities aimed at protecting biological diversity*

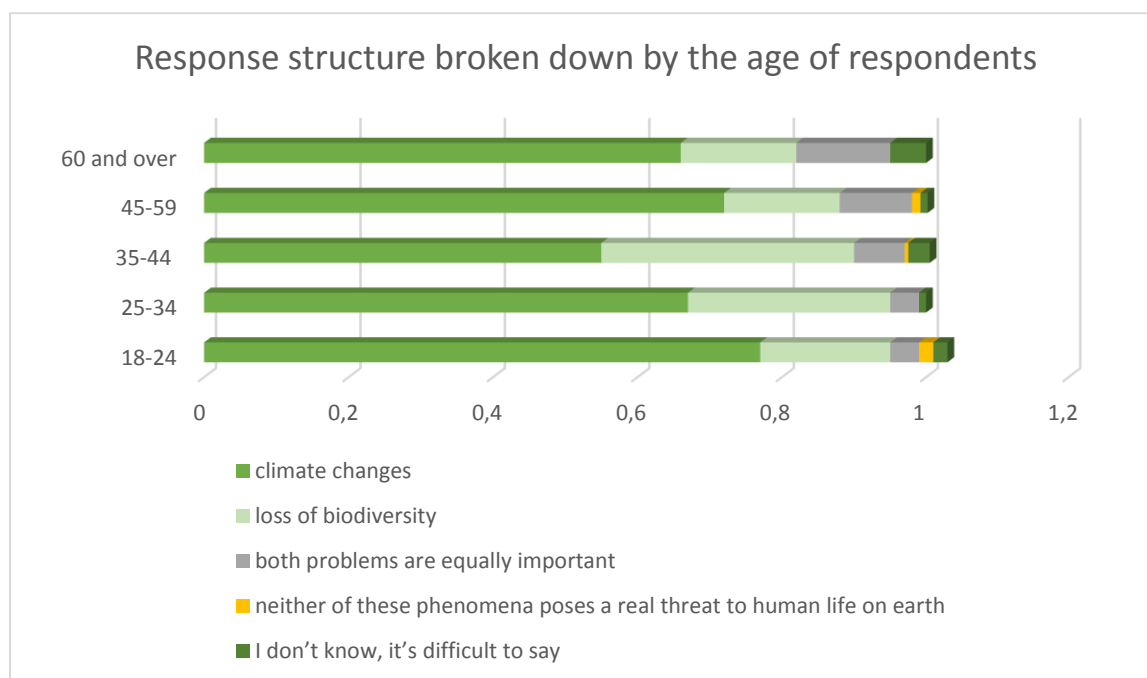
Type of local activities	Response structure	Type of individual activities	Response structure
Expanding green areas (e.g. by rebuilding concrete squares, limiting the expansion of sidewalks, etc.)	21.75%	Possessing wild landscape features	7.69%
Increasing water-absorbing utility surfaces (e.g. parking lots, sidewalks made of water-permeable material - grids)	10.74%	Reducing the use of chemicals in the garden in favor of liquid manure, herbal extracts, etc.	15.94%
Creating flowering gardens	11.62%	Creating a flowering garden	20.40%
Creating façade gardens	5.97%	Growing herbs	19.78%
Creating flower meadows	10.43%	Creating a flower meadow	10.25%
Reducing deforestation and forest degradation	5.36%	Constructing houses for insects	10.75%
Caring for old trees	12.07%	Installing nesting boxes on trees	10.38%
Planting new trees	18.93%	-	-
Renaturalization (rewilding) of the landscape	3.13%	Renaturalization of part of the plot - "giving it back to wildlife"	4.82%

Source: Own study, N = 605.

The above data from Table 1 indicate the activities that are the most important for the respondents to maintain biodiversity and influence the protection of the natural environment in their surroundings. The top-rated activities undertaken as part of local initiatives are the following: expanding green areas (21.7%) and planting new trees (18.93%), affecting the environmental and visual effect for the respondents. Residents of many regions, especially cities, see the need to implement initiatives that have a positive impact on the natural environment. Among individually implemented initiatives, the top-rated values were establishing flowering gardens (20.4%), growing own herbs (19.78%) and reducing the use of chemicals in the garden in favor of natural products (15.94%). Most of the activities are implemented locally and individually to ensure biodiversity and maintain the appropriate condition of the natural environment in urban spaces.

According to the research conducted in 2021 commissioned by the Ministry of Climate and Environment, almost two thirds (64%) of the respondents claim that biodiversity on Earth has decreased over the last 50 years. When asking the respondents what they thought was a bigger problem for preserving human life on Earth, the following results were obtained (Fig. 2).

The data in Fig. 2 indicate that representatives of the younger generation in particular notice that climate change is the biggest problem (77% of the respondents' answers). Environmental threats relating to sustaining human life on Earth should be a socio-economic priority in all countries around the world.



**Figure 2.** Assessing global issues for preserving life on Earth.

Source: <https://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej>.

All actions focused on minimizing global problems may start with local operations. Therefore, there is a need to restore the natural state of the environment. According to the cited study, the biggest problems in city centers in Poland are too few green areas, concrete spaces, etc. Detailed data are presented in Table 2.

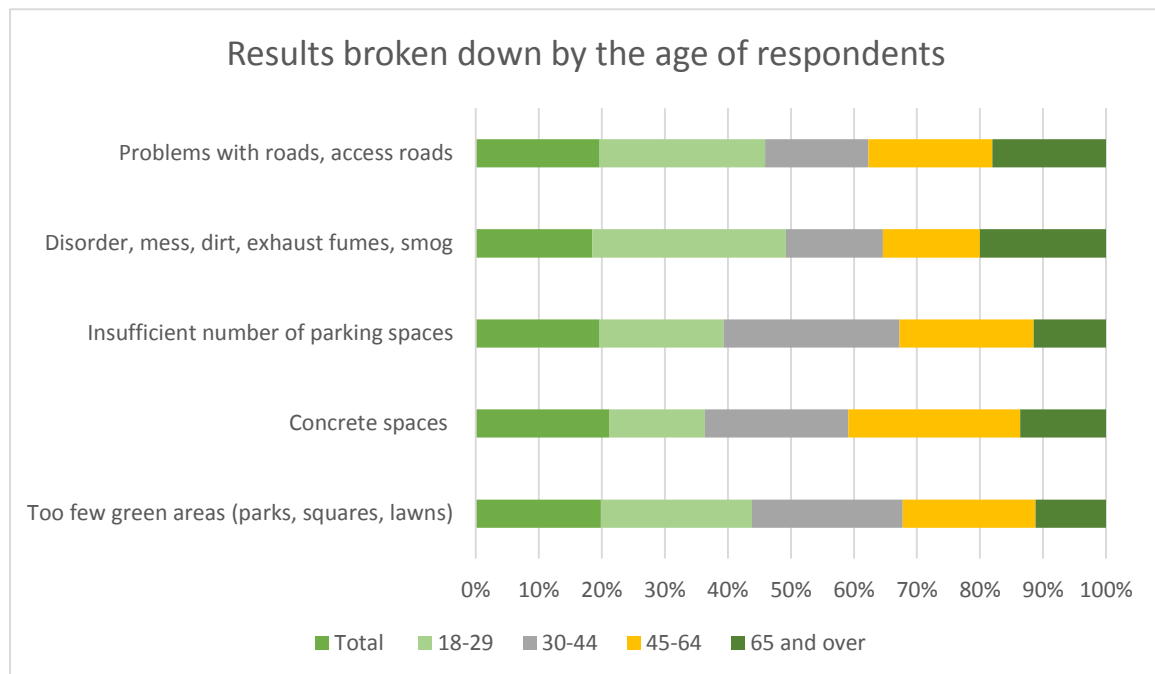
**Table 2.**

*Response structure in terms of the most significant problems in city centers in Poland*

Indicated problems	Response structure
Too few green areas (parks, squares, lawns)	48%
Concrete spaces	14%
Insufficient number of parking spaces	12%
Disorder, mess, dirt, exhaust fumes, smog	12%
Problems with roads, access roads	12%
Lack of infrastructure - benches, baskets, playgrounds, etc.	11%
Traffic jams	11%
Lack/too few bicycle paths and bicycle racks	6%
Lack/or poor condition of representative spaces (town square, squares, promenades)	5%
Difficulties in pedestrian movement	4%
Too many buildings	4%
Tree felling	2%
Renovations	2%
Troublesome overheating of squares and streets in summer	1%
Frequent flooding after downpours/storms	1%
Other problems	7%
No problems	8%
I don't know, it's difficult to say	9%

Source: Survey among city dwellers concerning urban greenery, Warszawa 2022.  
<https://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej>, N = 600.

All the problems in Table 2 show that the recent years of social activity oriented towards economic development without taking into account environmental needs have resulted in many unfavorable changes in urban spaces. According to the respondents, the lack of natural infrastructure has a negative social impact. Below is the structure of the five most frequently indicated answers, broken down by the age of the respondents (Fig. 3).



**Figure 3.** Response structure broken down by the age of respondents.

Source: Survey among city dwellers concerning urban greenery, Warszawa 2022.  
<https://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej>, N = 600.

According to the respondents, too few green areas in cities is a problem for 58 respondents in the 18-29 and 30-44 age group, while for the representatives of the 45-64 age group, this problem was indicated as the most important by 51 respondents. The respondents over 65 years of age find the number of green areas too small in 27 responses. The group of representatives of the young generation, in the second place, indicated disorder (20 responses) and then problems with access roads (16 responses). All representatives of different age groups notice socio-environmental problems in cities. Improving conditions in this area will bring many benefits to urban space in the future. By creating socio-environmental initiatives supporting the protection of biodiversity, applied individually and collectively, the chances for positive changes in the natural environment increase.

The respondents taking part in the survey also indicated other ways in which they care for the natural environment and climate (Tab. 3).

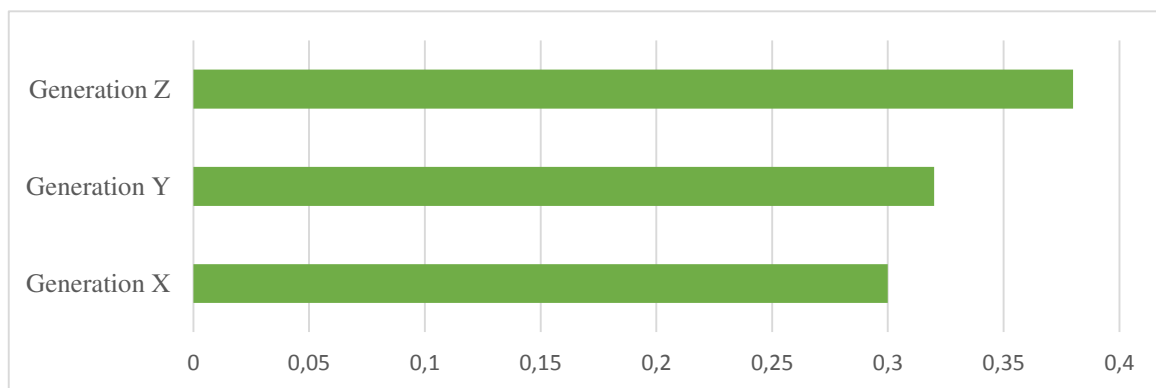
**Table 3.***Characteristics of activities aimed at protecting the natural environment and climate*

Type	Number of responses
Reducing consumption (e.g. limiting the purchase of products and services)	233
Eco-friendly driving (e.g. driving steadily, maintaining optimal engine RPM, etc.)	207
Limiting driving (e.g. using public transport, taking a neighbor to work, etc.)	213
Reducing meat consumption	113
Shopping for sustainable products (e.g. organic food, products made from recycled materials, etc.)	111

Source: Own study, N = 605.

The presented results of own research conducted in 2022 confirm the level of social awareness related to the need to take measures to protect the natural environment and rational use of natural resources in various age groups. All changes in everyday life implemented for the sake of the natural environment bring results in the long run, therefore it is important to promote and implement them.

Among the survey questions regarding elements of social responsibility in local activities, the respondents considered raising the environmental awareness of residents to be the most important (Fig. 4).

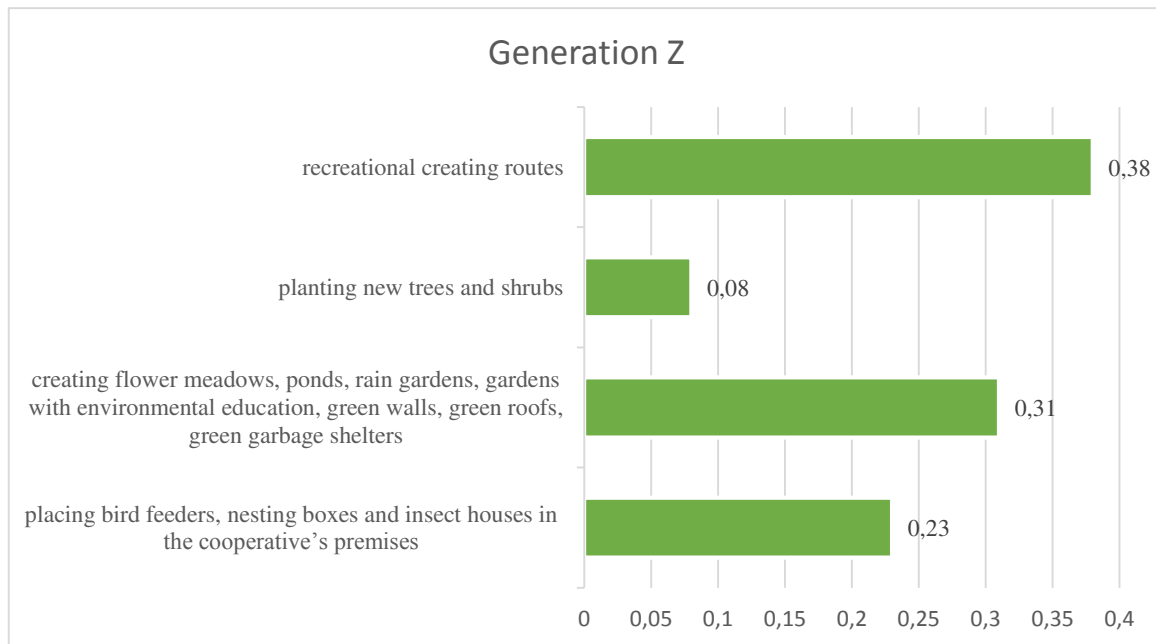
**Figure 4.** Sample structure broken down by the generation group.

Source: Own study, N = 362.

The data presented in Fig. 4 indicate that the respondents from all the generation groups equally considered it to be important to raise the environmental awareness of residents. Knowledge always allows for making informed choices. All the initiatives that increase environmental awareness among city dwellers bring social benefits.

Among the representatives of Generation Z, the most important activities in raising environmental awareness are the following (Fig. 5).





**Figure 5.** The structure of responses provided by Generation Z representatives concerning pro-environmental activities.

Source: Own study, N = 362.

Figure 5 indicates that for Generation Z, recreational routes constitute the largest percentage of responses (38%). However, in the second place they indicate the creation of flower meadows, ponds, rain gardens, gardens with environmental education, green walls, green roofs, and green garbage shelters (31% of responses). All the activities are particularly important for representatives of the young generation.

Based on the research carried out, the following pro-environmental activities were specified:

- placing bird feeders, nesting boxes, insect houses in the cooperative's premises,
- creating flower meadows, ponds, rain gardens, gardens with environmental education, green walls, green roofs, green garbage shelters,
- planting new trees and shrubs,
- creating recreational routes,
- installing rainwater tanks, photovoltaic panels on roofs, heat pumps for buildings, anti-smog ventilators, LED lighting,
- creating white roofs.

Generation Z residents are always willing to engage in pro-environmental initiatives in their immediate surroundings, regarding these activities as a chance to improve their immediate living space. The research indicates that the representatives of all generation groups are highly aware of the need to adapt urban space to ensure closer contact with the natural environment. Therefore, many changes need to be made to take care of the environment as much as possible and not lead to its degradation.

## Conclusions

Summarizing the information presented in the article, it can be clearly stated that modern society is aware of the threats and benefits resulting from the assumptions of environmental social responsibility. All the activities undertaken in the field of environmental protection and reasonable management of resources allow for a better life for future generations. Representatives of the young generation, who want to take care of their own and their children's future, must focus on introducing the necessary changes now so that these actions can pay off in the future. It takes many years to develop urban space in accordance with the principles of environmental social responsibility. The article presents the implemented changes that improve the comfort of social life and closer contact with nature. This affects not only the physical, but also mental aspects of life, which is now very dynamic. Creating new environmental spaces and places for relaxation does not always require large financial outlays. By recommending the implementation of the following actions: waste minimization, care for energy and water consumption, encouraging the implementation of environmental initiatives in the immediate surroundings, digitization of documents, etc., one can minimize the adverse impact on the environment. Socio-environmental behavior in urban spaces influences building awareness in this area. The article analyzes and assesses social behavior in the field of ecology and in accordance with environmental social responsibility. This research proves the hypotheses and objectives of the article, indicating that representatives of the young generation are focused on implementing environmental initiatives in cities to obtain future benefits. The pro-environmental activities indicated in the surveys contribute to improving life in the city and building awareness of consumer behavior in terms of environmental responsibility. All possible actions implemented locally will allow for global changes.

## References

1. Ali, H.Y., Danish, R.Q., Asrar-ul-Haq, M. (2019). How corporate social responsibility boosts firm financial performance: The mediating role of corporate image and customer satisfaction. *Corporate Social Responsibility and Environmental Management*, 1-12. <https://doi.org/10.1002/csr.1781>.
2. Alonso-Almeida, M.D.M., Llach, J. (2019). Socially responsible companies: Are they the best workplace for millennials? A cross-national analysis. *Corporate Social Responsibility and Environmental Management*. *John Wiley & Sons*, vol. 26(1), pp. 238-247. DOI: 10.1002/csr.1675.

3. Arruda Filho, N.D.P. (2017). The agenda 2030 for responsible management education: An applied methodology. *The International Journal of Management Education*, 15(2, Part B), 183-191. doi: <https://doi.org/10.1016/j.ijme.2017.02.010>.
4. Böcker, L., Meelen, T. (2017). Sharing for people, planet or profit? Analysing motivations for intended sharing economy participation. *Environmental Innovation and Societal Transitions*. Elsevier, 23, 28-39. <https://doi.org/10.1016/J.EIST.2016.09.004>.
5. Borda, A., Morales, O., Teegen, H., Rees, G., Gonzalez-Perez, M.A. (2021). Addressing Sustainable Rural Development with Shared Value: A Peruvian Model from the Cacao Industry. *Sustainability*, 13, 8028.
6. Butler, T., Hackney, R. (2021). The role of informational mechanisms in the adoption of Green IS to achieve eco-sustainability in municipalities. *Information & Management*, Vol. 58, Iss. 3, April, p. 103320.
7. Chi-Shiun Lai, Chih-Jen Chiu, Chin-Fang Yang, Da-Chang Pai (2010). The effect of corporate social responsibility on Brand performance: The mediating effect of industrial Brand equity and corporate reputation. *Journal of Business Ethics*; 95(3), 457-469.
8. Cubilla-Montilla, M., Nieto-Librero, A.-B., Galindo-Villardón, M. P., Vicente Galindo, M.P., Garcia-Sanchez, I.-M. (2019). Are cultural values sufficient to improve stakeholder engagement human and labour rights issues? *Corporate Social Responsibility and Environmental Management*, 26(4), 938-955. <https://doi.org/10.1002/csr.1733>.
9. Fazlagić, J. (2010). Szczególne zjawisko. Pokolenie Y wyzwaniem dla pracodawców. *Personel i Zarządzanie*, 3.
10. Gast, J., Gundolf, K., Cesinger, B. (2017). Doing business in a green way: A systematic review of the ecological sustainability entrepreneurship literature and future research directions. *Journal of Cleaner Production*, 147, 44-56. <https://doi.org/10.1016/j.jclepro.2017.01.065>.
11. Giuliano, R., Mahy, B., Rycx, F., Vermeulen, G. (2017). Does corporate social responsibility make over-educated workers more productive? *Applied Economics*, 49(6), 587-605. <https://doi.org/10.1080/00036846.2016.1203061>.
12. Gonzalez-Perez, M.A. (2016). Climate Change and the 2030 Corporate Agenda for Sustainable Development, Climate Change and the 2030 Corporate Agenda for Sustainable Development. *Advances in Sustainability and Environmental Justice*, Vol. 19. Emerald Group Publishing Limited, pp. 1-6. <https://doi.org/10.1108/S2051-503020160000019005>.
13. 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), 399-420. <https://doi.org/10.1007/s11135-014-0155-z>.
14. Hur, W.-M., Kim, H., Kim, H.K. (2018). 'Does customer engagement in corporate social responsibility initiatives lead to customer citizenship behaviour? The mediating roles of customer-company identification and affective commitment'. *Corporate Social*

- Responsibility and Environmental Management*, November 2017, pp. 1-12. <https://doi.org/10.1002/csr.1636>.
15. Kim, S.-S., Baek, W.-Y., Byon, K.K., Ju, S.-B. (2021). Creating Shared Value to Enhance Customer Loyalty: A Case of a Sporting Goods Company in Korean Athletic Shoe Market. *Sustainability*, 13, 7031.
  16. Kureshi, S., Thomas, S. (2020). Testing the influence of message framing, donation magnitude, and product category in a cause-related marketing context. *Journal of Marketing Communications*, Vol. 26, No. 3.
  17. Kurz, C.J., Li, G., Vine, D.J. (2019). Are millennials different? In: *Handbook of US Consumer Economics*. Academic Press Cambridge.
  18. Lamarche, T., Bodet, C. (2018). Does CSR contribute to sustainable development? What a regulation approach can tell us. *Review of Radical Political Economics*, 50(1), 154-172.
  19. Luten, S., Ryan, E., Wakefield, J. (2021). *Born into the Climate Crisis: Why we must act now to secure children's rights*.
  20. Lyon, T.P., Maxwell, J.W. (2008). Corporate social responsibility and the environment: A theoretical perspective. *Review of Environmental Economics and Policy*, 2(2), 240-260.
  21. Nureen, N., Liu, D., Irfan, M., Işık, C. (2023). Nexus between corporate social responsibility and firm performance: a green innovation and environmental sustainability paradigm. *Environmental Science and Pollution Research*, 30, 21, 10.1007/s11356-023-26675-1 (59349-59365).
  22. Pencarelli, T., Ali Taha, V., Škerháková, V., Valentiny, T., Fedorko, R., (2020). Luxury Products and Sustainability Issues from the Perspective of Young Italian Consumers. *Sustainability*, 12.
  23. *Raport z badania przeprowadzonego przez PBS Sp. z o.o. na zlecenie Ministerstwa Klimatu i Środowiska* (2023). Warszawa: Ministerstwo Klimatu i Środowiska, [www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej](http://www.gov.pl/web/klimat/badania-swiadomosci-ekologicznej)
  24. Ren, S., Huang, M., Liu, D., Yan, J. (2022). Understanding the impact of mandatory CSR disclosure on green innovation: Evidence from Chinese listed firms. *British Journal of Management*. doi:10.1111/1467-8551.12609.
  25. Salehi-Amiri, A., Zahedi, A., Hajiaghahi-Keshteli, M., Akbapour, N. (2021). Designing a sustainable closed-loop supply chain network for walnut industry. *Renew. Sustain. Energy Rev.*, 141, 110821.
  26. Schembera, S. (2018). Implementing corporate social responsibility: empirical insights on the impact of the UN global compact on its business participants. *Business & Society*, 57(5), 783-825.
  27. Shams, G., Rehman, M., Samad, S., Oikarinen, E. (2020). Exploring customer's mobile banking experiences and expectations among generations X, Y and Z. *Journal of Financial Services Marketing*, 25.

28. Shiu, Y.M., Yang, S.L. (2017). Does engagement in corporate social responsibility provide strategic insurance-like effects? *Strategic Management Journal*, 38(2), 455-470.
29. Stranieri, S., Orsi, L., Banterle, A., Ricci, E.C. (2019). Sustainable development and supply chain coordination: The impact of corporate social responsibility rules in the European Union food industry. *Corporate Social Responsibility and Environmental Management*, 26(2), 481-491. <https://doi.org/10.1002/csr.1698>.
30. Sullivan, K., Thomas, S., Rosano, M. (2018). Using industrial ecology and strategic management concepts to pursue the Sustainable Development Goals. *Journal of Cleaner Production*, 174, 237-246. <https://doi.org/10.1016/j.jclepro.2017.10.201>.
31. Tewari, S., Bhattacharya, B. (2022). Financial resources, corporate social responsibility, and ownership type: Evidence from India. *Asia Pacific Journal of Management*. doi:10.1007/s10490-022-09810-3.
32. Tliche, Y., Taghipour, A., Canel-Depitre, B. (2020). An improved forecasting approach to reduce inventory levels in decentralized supply chains. *European Journal Operational Research*, 287, 511-527.
33. Wenbing Jiang, Xuejun Wang, Lei Du (2023). Intergenerational externalities and corporate innovation. *Sustainable Development*, 31, 4, 10.1002/sd.2501 (2212-2221).
34. Wright, C., Nyberg, D. (2017). An inconvenient truth: how organizations translate climate change into business as usual. *The Academy of Management Journal*, 60(5), 1633-1661.
35. [www.stat.gov.pl](http://www.stat.gov.pl)



## RECOMMENDATIONS FOR MINIMISING EMPLOYEE ABSENCES BASED ON THE ANALYSIS OF ABSENTEEISM IN A GIVEN ENTERPRISE

Anna SZOŁKIEWICZ<sup>1</sup>, Małgorzata KOWALSKA<sup>2</sup>

<sup>1</sup> Valeo Lighting Systems, Chrzanów; anna.szolkiewicz04@icloud.com, ORCID: 0009-0001-3650-6551

<sup>2</sup> Faculty of Applied Chemistry, Casimir Pulaski Radom University; m.kowalska@uthrad.pl,  
ORCID: 0000-0001-8947-2861

\* Correspondence author

**Purpose:** The aim of this paper is to analyse employee absences in a selected enterprise and suggest methods or solutions helping to determine the causes of absenteeism.

**Design/methodology/approach:** Some actions intended to minimize the problem of employee absences are described. The methods of interviews, observations, and data and document reviews are applied. The impact of frequent employee absenteeism on social relations in a selected production enterprise is examined.

**Findings:** The results confirm the levels of sudden absences are minimum in social groups characterized by strong cooperation and transparent communication among colleagues and direct supervisors.

**Research limitations/implications:** The topic of absenteeism is a very sensitive topic. Statistical data was easy to obtain. However, during direct interviews with employees, there were people who did not want to talk and did not want to fill out surveys, which constituted minor limitations.

**Practical implications:** The tools and methods suggested in this study provide some exceptionally useful knowledge to employers, helpful with identifying the existence and background of employee absenteeism in their organizations.

**Originality/value:** Some selected practical and optimum methods of examining employee absences are presented that help to identify the causes of employee absenteeism.

**Keywords:** human capital management, absence management, employee absenteeism, employee.

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

## 1. Introduction

Human capital management has now become a strategic part of every organization's policy (Juchnowicz, 2010). The dynamic job market, shortages of specialist and production personnel, and heavy competition have compelled employers to contend with one another at creating progressive, modern, as well as more productive work environments (Zajac, 2014). In this context, they implement the processes of employee monitoring to take particular care of their workers and to improve the productivity of their organizations (Kozioł, Wojtowicz, 2016). Following trends in the job market is essential as well in order to continue updating strategies and manage enterprises in up-to-date and innovative ways (Arendt, Fraczyńska, 2019).

The growing rank of the personnel management process has naturally given rise to indicators assessing its effectiveness (Lachiewicz, 2010). A continuous monitoring helps managers track progress on the realization of business objectives, promptly respond to any major deviations from assumed standards, and introduce streamlining efforts (Wilczyński, 2014). All such actions are ultimately expected to allow enterprises to reach their overarching objective of becoming profitable (Łochnicka, 2015). The monitoring of employee absences is a key indicator of personnel management (Farrell, 2005). It has recently become very important to employers, since high employee absenteeism generates considerable costs both to enterprises and the state (Pecillo, 2013). The insufficient numbers of workers, absent for a variety of reasons, results in the unplanned costs of extra pay to those working overtime (Gajdzik, 2015) and greater spending on the recruitment of temporary staff (Przywojska, 2014).

From the viewpoint of employees, high overtime initially has the positive effect of boosting their domestic budgets. In the longer run, however, those constantly working in excess of monthly time standards become fatigued and frustrated, which may impair their productivity and social working conditions (Kroik, Malara). A chronic fatigue and greater responsibilities may produce demotivation and high personnel dissatisfaction. It may also result in unexpected conflicts among employees and between employees and their bosses. According to the author (Walentek, 2019) claims a reduced work satisfaction and motivation, or the lack of work and private life balance, can be expressed with more unplanned absences. Firms have recently become worried by the trend of employees becoming less loyal to their employers as attractive job offers are readily available in the market (Lewicka, 2017). A clear division emerges between those identifying with and highly committed to their workplace regardless of their firm's position and those who find it easy to switch jobs and are indifferent to the fates of their firms (Świątek-Barylska, 2013).

When exploring the sources of absenteeism, good working time management and effective reporting models are important. Employers who tend to downplay the issue of absences experience grave interferences with the operation of their businesses. Excessive absenteeism in a single period, both scheduled (e.g., holidays) and not (e.g., sickness leaves), may halt



production processes. To prevent such situations, employers must prepare appropriate action plans for emergencies (Sierpińska, 2013). It is reasonable to compare and analyze most cases of absenteeism to accurately diagnose their causes or factors affecting them. Some records of this information will become starting points for identifying and implementing actions designed to safeguard processes and minimize the additional costs of absenteeism (Badubi, 2017).

The ratio of absent days (or hours) to the nominal working days (or hours) of all employees is the most common method of measuring absences in manufacturing firms (Goetzl, 2004). It can be computed in different ways in various countries and corporations subject to diverse regulations and other conditions, of course (Egan, 2011). Regardless of the method of calculation, however, minimizing absenteeism is a key objective of organizations (Work, 1996). Examining absences on the basis of available data seems relatively easy, yet the great variety of their causes can hinder it substantially (Striker, 2013). Basic monthly data as numbers or percentages related to absence indicators give but a rough overview of a firm's situation. Employers should monitor the indicator to respond promptly to any adverse trends and introduce corrective actions (Carraro, 2021).

Therefore, the aim of this paper is to analyse employee absences in a selected enterprise and suggest methods or solutions helping to determine the causes of absenteeism. Employers are aware a regular monitoring of absenteeism levels is of paramount importance to a proper operation of their organizations (Walton, 1985). A pragmatic approach to the issue is a major part of management. In this work, the hypothesis was put forward that a high percentage of absences is directly related to the situation and relations in a given area. This is a new approach to the topic, because employers mainly focused on finding the causes among absent employees and rarely examined this problem in a broader aspect of management.

The article provides an original perspective and suggestions on the topic of absence in a very modern, specific and simple way.

## **2. Material and Methods**

### **Description of the enterprise**

Employee absenteeism was studied in 2022 in a motor enterprise in south Poland, with a staff of more than 200. The firm is part of an international corporation where Human Resources Management and employee development are key parts of the strategy.

All the employees are on long-term contracts and belong to two chief groups: direct production workers, 80% of the entire population, and office staff (20%). Direct production employees work in 4 teams as part of a 3-shift system (the 1<sup>st</sup> shift: 06:00-

14:00 hours; 2<sup>nd</sup> shift: 14:00-22:00 hrs; 3<sup>rd</sup> shift: 22:00-06:00), while office staff works a single daytime shift from 8 to 4 pm. Women account for 54% and men for 46% of the workforce.

Daily absence reporting is the fundamental method of controlling working time, expressed as percentages or numbers according to need. A SAP working time system is implemented and managers are able to check the staffing of their teams on an ongoing basis.

The absence data presented and analysed here are the enterprise's proprietary material. Around 700 employees were reviewed. Employee interviews, statistical analysis, documents including correspondence with the National Insurance Company, post-absence surveys, and observations constituted the research materials.

The interviews were conducted by direct managers in cooperation with Human Resources on the first day following absences. A dedicated questionnaire was prepared to this end, so that the dialogue was professional and in compliance with Polish law. The questions to employees are listed below:

- Was your absence related to work?
- Could it be caused by factors present at work?
- Can absences be in any way prevented in future?
- What actions do you suggest to prevent absences?
- How can the employer help prevent the reasons for absences?
- How can sickness absenteeism be reduced in the company?

This paper focuses on 4 types of absences with maximum impacts on the company operation:

- ordinary sickness (affecting a given employee),
- benefits (e.g., to care for children or other family members),
- accidents (at work and on the way to work)
- sudden absences (certified or not).

Rest leaves are excluded as employers and employees normally work to schedule their dates, so that they can be planned for well in advance.

Data derived from the working time system were used in the statistical analysis. Correlations were sought between such factors affecting absenteeism as gender, age, and work experience. In search for their specific and direct causes, factors characteristic of the enterprise were analysed in depth from the perspective of employee and organisation structure. To this end, 175 anonymous surveys completed by employees after absences were reviewed and 146 individual interviews were conducted. 35 written responses from the National Insurance Company checking the reasons for employees' sickness benefits were verified in addition. Based on observations and dialogue with employees, the effectiveness of preventive campaigns organised by the employer was examined to determine their impact on the firm perception by employees and their motivation to work.

### 3. Results and discussion

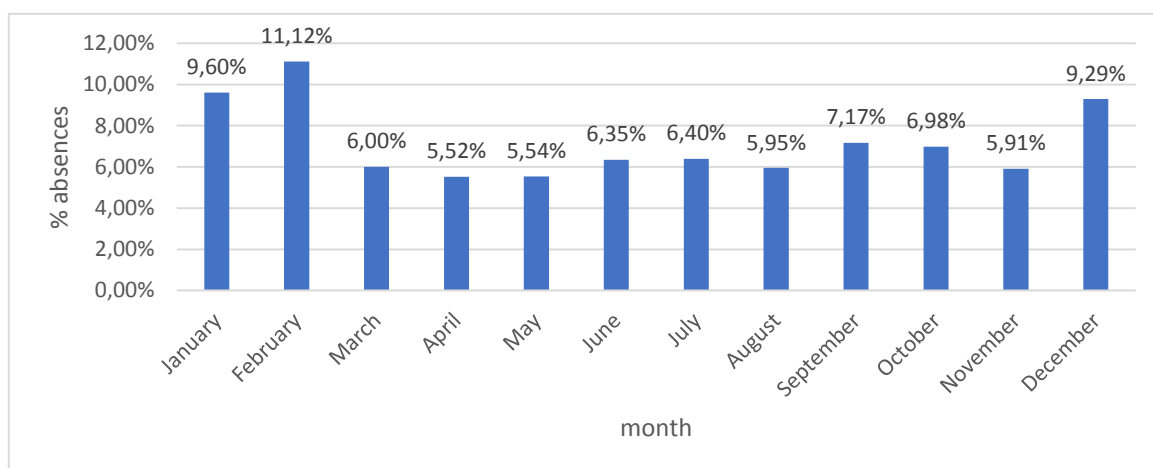
A list of employee absences by duration in 2022 is included in Table 1. Most arise from causes named ‘ordinary own sicknesses’ (85.88%). These may be described as sensitive due to the employee’s right to the protection of sensitive health data (Nerka, 2010). Ordinary sicknesses are the source of most problems and controversies among employers, since they pay sickness benefits until the 33<sup>rd</sup> calendar day (Article 92 of the Labour Code). The obligation is assumed by the National Insurance Company only from the 34<sup>th</sup> calendar day (Striker, 2016).

**Table 1.**

*Days of employee absences by type*

Absence type	Days
Sickness	28971
Benefits	4291
Accidents	171
Non-certified absences	300

A comparative analysis of absences in the particular months was carried out (Fig. 1). They soared substantially in winter months: February – 11.12%, January – 9.60%, and December – 9.29%. The increased absenteeism during that period has been corroborated by other research (Jurek, 2021; Groenewold, 2019). Winter, with its low temperatures and adverse weather conditions, has an adverse effect on health and boosts the risk of viral and bacterial development (Lindner-Cendrowska, 2021). Prevention of cross-infections in both the work environment and private life seems difficult to control (Luyten, 2013). This has an unfortunate influence on absenteeism.



**Figure 1.** The percentage of employee absences in 2022.

The data in Table 2 clearly show more women than men were absent during the year. There were 33733 days of absences including 21922 days taken by females. There is a range of studies showing women are absent more than men (Jurek, 2021). The absences identified in this study can be approached from another angle, though. Namely, females represent a larger share

of employees in the firm under discussion. The results imply absences taken to care for children or family members were far more frequent than in the case of males. This ties in with the prevailing behaviour and choices. Pungello says women shoulder the bulk of caring for children or other people needing support. Females were absent a monthly average of 1768 days (65%) and males 971 days (35%).

**Table 2.**

*The distribution of men's and women's absences in the particular months of 2022*

Gender	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Female	2398	2507	1769	1388	1363	1631	1633	1495	1993	1816	1457	2472
Male	1155	1787	883	714	847	891	865	949	922	920	745	1133
<b>Total days</b>	<b>3553</b>	<b>4294</b>	<b>2652</b>	<b>2102</b>	<b>2210</b>	<b>2522</b>	<b>2498</b>	<b>2444</b>	<b>2915</b>	<b>2736</b>	<b>2202</b>	<b>3605</b>

Legend: I-XII months in a year.

Another determinant addressed was the employees' age. It is a major factor when studying employee absences as there is a sequence of stages in life that differentiate not only motivation and commitment to work but also the determination to appear at work. In addition, there are some stereotypes at work, not always fair. (Jurek, 2021) notes one of them is the belief older people take sickness leaves more often. This study denies this claim. The results suggest those aged 56-59 and above 60 seldom took sickness leaves (Fig. 2). This is aligned with the findings of (Gilga, Jurek 2022), who report similar results in this population.

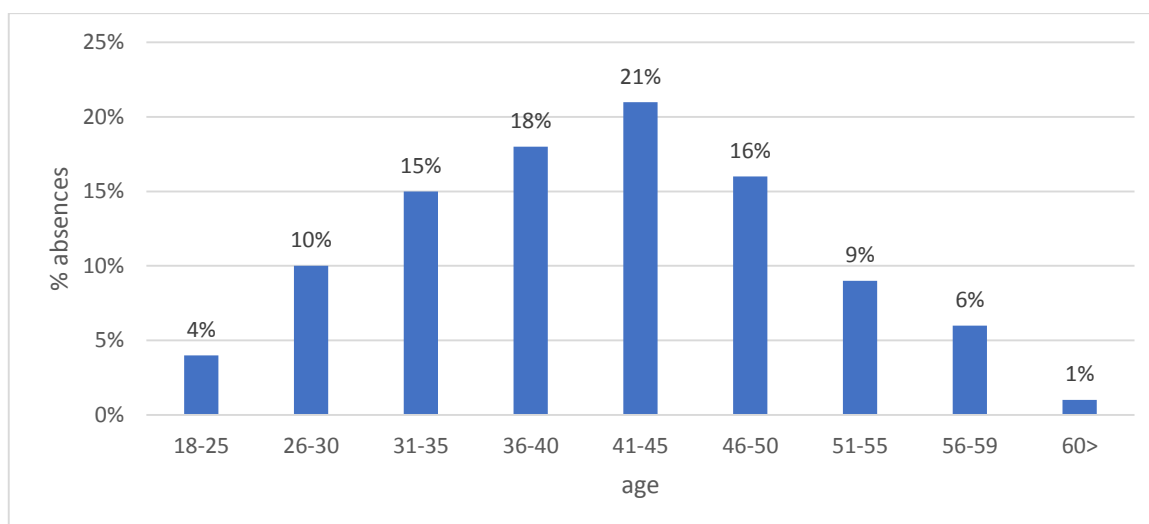
**Table 3.**

*The distribution of employees' absences in the particular months of 2022 depending on age*

Age	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
18-25	175	200	37	60	68	106	65	161	94	129	101	181
26-30	400	489	257	218	245	177	219	240	267	232	180	352
31-35	567	649	317	370	279	352	399	405	520	514	366	418
36-40	612	760	530	323	396	522	535	376	530	412	373	638
41-45	726	781	686	478	469	493	404	469	667	649	509	774
46-50	551	681	392	311	417	411	399	397	463	352	417	620
51-55	335	426	294	248	156	230	298	221	249	262	117	284
56-59	176	252	128	55	145	203	156	160	102	140	116	299
60>	11	56	11	39	35	28	23	15	23	46	23	39
<b>Total days</b>	<b>3553</b>	<b>4294</b>	<b>2652</b>	<b>2102</b>	<b>2210</b>	<b>2522</b>	<b>2498</b>	<b>2444</b>	<b>2915</b>	<b>2736</b>	<b>2202</b>	<b>3605</b>

Legend: I-XII months in a year.

Similarly rare absences were recorded for employees aged up to 25. The study has shown they seldom take sickness leaves. This diverges from the prevailing view of 'Generation Z'. An overwhelming majority of employers believe those born after 1995 are irresponsible and take advantage of medical leaves even for mild infections (Muster, 2020). Our research has demonstrated employees aged about 40 take ordinary medical leaves most frequently. The absence results in the diagram below correspond to the Gaussian curve, with middle age as the median. This is also due to the relatively smaller numbers of those aged below 25 and over 56 in the organization.



**Figure 2.** The percentages of employee absences depending on their age.

Years of service, closely related to productivity, were another major determinant of work absences (Batóg et al., 2002). Employees with a long work experience are convinced they are not about to suffer disciplinary consequences if they often take unreasonable and non-certified absences as employers accept more absenteeism from employees with more years of service (Borgogni et al. 2013).

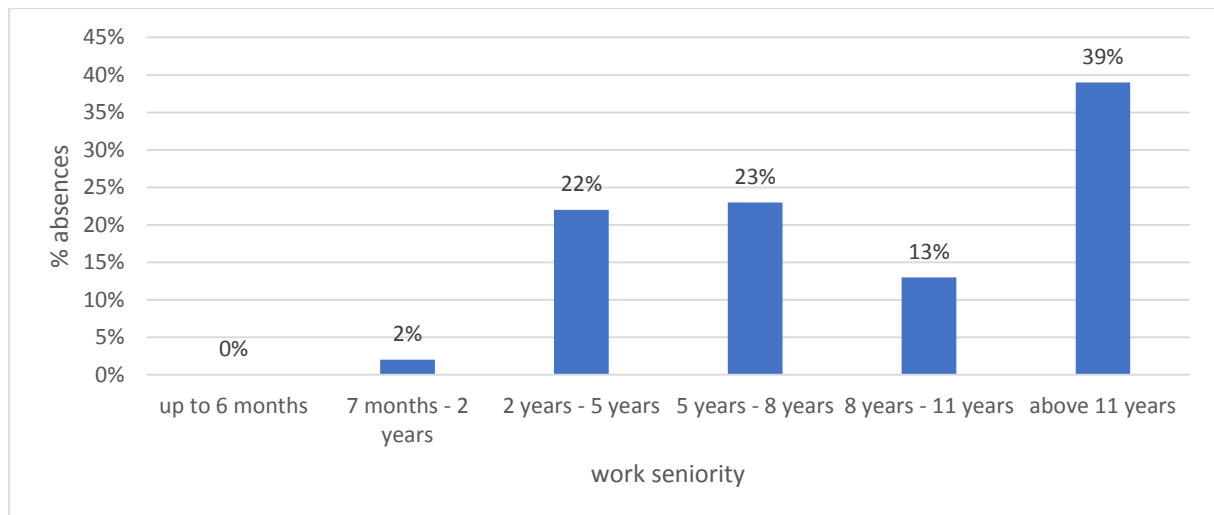
The comparative analysis of statistics (Table. 4, Figure 3) upholds a strong correlation between absences and work experience. This means individuals with more than 11 years of service are more often absent (as much as 39% annually), whereas employees with less than 2 years in work account for merely 2% of the absences. The results are comparable in the age groups 'above 2-5 years' and 'above 5-8 years' (Figure 3) and total 22% and 23%, respectively.

**Table 4.**

*The distribution of employees' absences in 2022 depending on work experience*

Work experience	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Up to 6 months	0	0	0	0	0	0	0	0	0	0	0	0
7 months - 2 years	12	51	59	33	44	75	74	101	70	58	66	132
2-5 years	995	1119	528	447	447	495	562	612	607	547	443	705
5-8 years	770	991	678	489	469	575	577	590	648	656	476	792
8-11 years	423	547	345	254	279	290	239	268	452	489	354	588
11 years	1353	1586	1042	879	971	1087	1046	873	1138	986	863	1388
Total	3553	4294	2652	2102	2210	2522	2498	2444	2915	2736	2202	3605

Legend: I-XII months in a year.



**Figure 3.** The percentages of employee absences depending on their work experience.

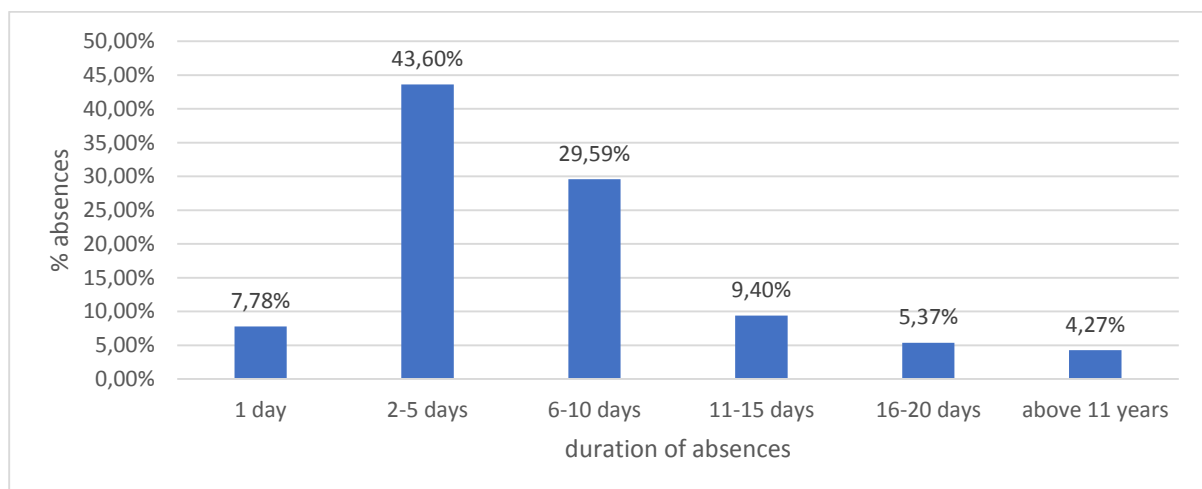
The duration of work absences is another key aspect to be examined, since frequent and brief absences greatly disturb the realization of production plans (Kłos, Nalewa, 2021). Medical leaves between 2 and 5 days were most commonly recorded in the enterprise studied (Fig. 4). This result suggests which absences should be analysed and addressed by management in the first place. In this case, the employer ought to focus on leaves taking up to 5 days (Fig. 4). It's difficult to look for their causes as they are short, therefore, the employer must react quickly.

**Table 5.**

*The distribution of employees' absences in the particular months of 2022 depending on their duration*

Absences [days]	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	51	46	21	30	28	19	50	30	28	25	20	20
2-5	264	231	168	127	123	149	112	169	201	170	156	193
6-10	173	225	96	83	69	90	95	88	118	116	101	146
11-15	46	66	35	24	34	28	29	31	33	35	21	63
16-20	35	34	12	32	15	20	12	13	19	7	29	26
Above 21	1	1	24	1	25	25	32	21	22	27	1	22

Legend: I-XII months in a year.



**Figure 4.** The percentages of employee absences depending on the duration of absences.

Some absences related to organization and management structure in the enterprise have been detected as well. Exploring the particular elements of work organization helps to define the foci of absenteeism.

To limit the scope of research and concentrate on the groups with maximum absenteeism, the results for direct production and office employees were compared (Table 6). Significant shortages of production personnel cause grave consequences to employers, such as more quality complaints, failure to produce orders or even retain clients (Kłos, Nalewa, 2021). The data for the enterprise under discussion suggest 91.25%, or 2565 days a month on average (Table 6), of all the absences are noted for production employees. The low level of absences among office staff was a result of the extensive opportunities for remote working, among other things. This solution allowed these employees to work from home even when they were not fully available or when those in their direct care required assistance. They didn't take medical leaves and remained in employment even when their availability was restricted.

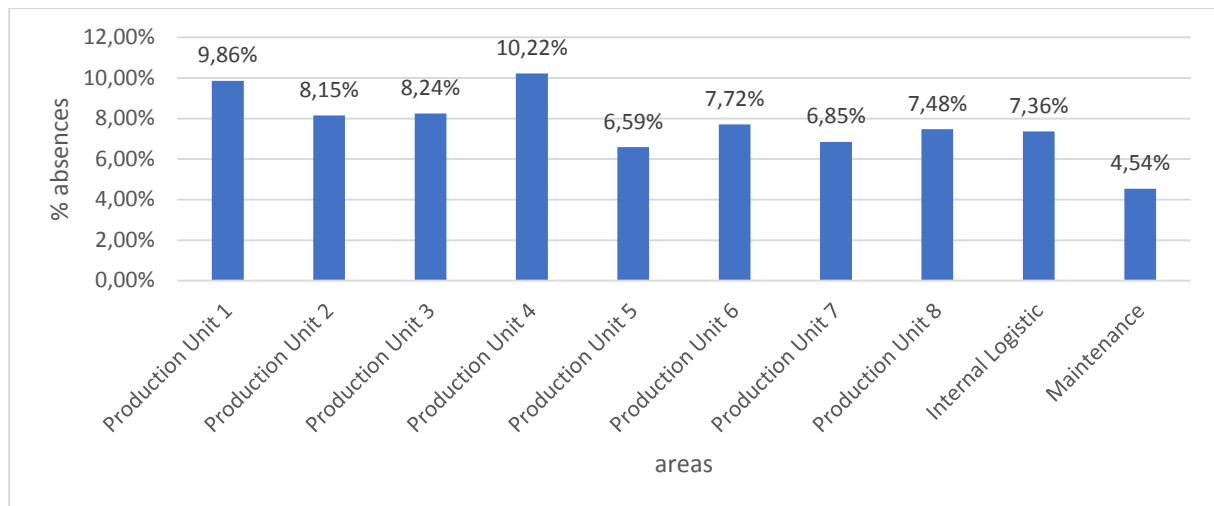
**Table 6.**

*The distribution of employees' absences in the particular months of 2022 depending on employee status*

<b>Employee status</b>	<b>I</b>	<b>II</b>	<b>III</b>	<b>IV</b>	<b>V</b>	<b>VI</b>	<b>VII</b>	<b>VIII</b>	<b>IX</b>	<b>X</b>	<b>XI</b>	<b>XII</b>
<b>BPP</b>	3231	4004	2435	1976	2026	2355	2273	2182	2572	2425	1994	3307
<b>BP</b>	322	290	217	126	184	167	225	262	343	311	208	298
Total days of absences	3553	4294	2652	2102	2210	2522	2498	2444	2915	2736	2202	3605

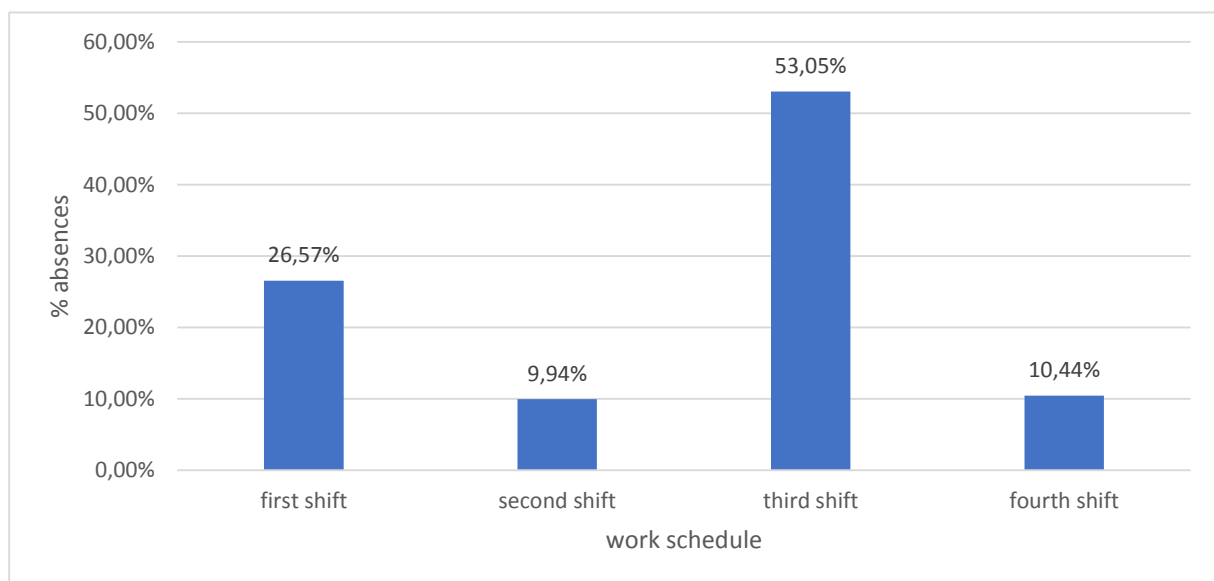
Legend: I-XII months in a year. BPP – direct production employees. BP – office employees.

As the percentage of absences was highest in the population of direct production employees, the analysis continued to focus on the areas where only such employees work, in order to determine the locations of maximum occurrence. The production part of the enterprise studied is divided into 8 units which form distinct organizations. Direct production employees also work in Internal Logistics and Maintenance, which are added to the analysis. The results in Figure 5 indicate two production areas of maximum absences, namely, 'Production Unit 4' and 'Production Unit 1'.



**Figure 5.** The percentages of employee absences divided into the areas of direct production.

Employee absences were also divided as per work schedules in the particular settlement periods. This information enables to take actions restricted to employees of specific shifts (Figure 6). The schedules include the days and hours an employee must work in a given settlement period, too.



**Figure 6.** The percentages of employee absences versus the work schedule (shifts).

This analysis shows the third shift experienced the most absences (53%). Actions were therefore taken to determine the causes of these absences and to reduce them.

All the employees with absences were interviewed and asked to complete anonymous surveys in order to have a most realistic view of the situation. The employees identified several causes of their absences from work. They complained about high temperatures in the production area, inter alia. They pointed to bad working conditions, unacceptable from the EH&S perspective, namely, inadequate ventilation and air-conditioning. They reported their work was too hard and they suffered from back pains as a result. They additionally mentioned terms of payment, complaining against the lack of bonuses, low pay allowances, inadequate tools,



and excessive duties. They also signaled a lack of respect in their managers' treatment (Badubi, 2017).

The surveys were supplemented with direct conversations with employees, on the one hand intended to make them aware their frequent absences adversely affect the organization and their teams and to bring information about the actual causes of their absences, on the other hand. Employees were quite open about the causes persuading them to take advantage of benefits. They complained about the poor spirit in their teams and relations with managers. The following most common reasons for sudden absences were cited:

- Lack of understanding by managers, who didn't follow the principles of compromise.
- Lack of teamwork and bad relations with managers - intimidation and threats of consequences.
- Lack of an adequate and open dialogue with employees that could let them feel the necessary parts of work.
- Inadequate working conditions – overwork and risks to health.

The dialogue between the employer and employees has affirmed the relations in the organizations experiencing most absences, both within teams and with immediate supervisors, were not optimal. The employees stressed bitterly managers failed to treat them with due respect or solve day-to-day problems, managing their teams badly. Managers vented their frustration on employees, who rebel, resort to medical leaves or even quit as a result.

The interviews with employees in teams with low absence ratios suggested partner relations with managers. Mindful of letting their colleagues and supervisors down, employees minimize their absences, because they know that might affect their whole team, the realization of goals or bonus levels. This tallies with what (Mazur, 2013) has to say about well-motivated, appreciated and respected employees, who do not consciously take steps harmful to their organizations. Belonging to a group and supervisors' appreciation, just after the satisfaction of basic needs, are some key factors influencing work satisfaction (Maslow, 1998).

Conversations with direct managers and with employees from the areas of high absence percentages led to the suggestion of additionally verifying reasons for some medical certificates issued. In the circumstances, the employer requested the National Insurance Company in writing to check whether the insured used their benefits according to purpose. The responses gave no reason to find any formally unfair usage of sickness benefits in 2022. According to (Mędrala, 2021), such a procedure remains very popular and used by employers as an official path.

Preventive campaigns staged by the employer were the final element to be addressed. A range of studies affirm such actions have beneficial impacts on employees' health, which in turn translates into their reduced absences (Kukawska, 2022). Such an action has been introduced to the business in question as well. In 2022, the employer organized two major campaigns promoting health prevention, called 'Pink October' and 'Movember'. The former involved breast cancer prevention in women, the latter, prostate cancer prevention in men.

Employees were happy to take part in various competitions relating to health, great numbers attended seminars with physicians, and have their pictures taken in special balloon frames. Our findings are in line with those reported by Namysłow et al. (2012), who state the promotion of a healthy lifestyle and preventive medical testing improves work satisfaction and productivity, thus helping to cut the costs of absenteeism. Similar issues are addressed by Hildt (2013), who reports prevention promoted by enterprises will in the long run have a positive influence on absence levels, commitment to work, and employees' productivity.

#### **4. Conclusion**

Our results show the issue of absences should be approached from a broader perspective of the entire management system, not mere numbers and statistics. An effective monitoring and control of absence frequency may assist with identifying all factors that affect absenteeism. A clear conclusion is the existence of a very strong correlation between the level of absences and relations between employees and their supervisors in an enterprise.

Any negative levels of the indicators, thus of absenteeism, are closely related to HR policies in an enterprise. It is reasonable, therefore, to introduce actions that might help to reduce the percentages of employee absences. Actions with impact on a whole organization are recommended, since disciplinary actions targeted at individual employees abusing leaves don't have any significant effect on absenteeism in an entire undertaking. Determining the causes of absences allows employers to prepare strategies to cut personnel absenteeism and thus improve a firm's performance.

The authors believe absences in enterprises should be studied over 5 main stages:

1. Defining the chief absence types with crucial impacts on enterprise operation.
2. The collection and monitoring of monthly data classified by gender, age, work experience, and duration of employee absences to arrive at the main sources of the problem.
3. Focus on factors connected to work organization itself to find and determine specific areas and employee groups showing maximum absence levels.
4. In-depth observations and detailed interviews with employees after they return to work.
5. Requesting employees to complete anonymous surveys that would imply the causes of their absences.

Founding corporate culture on strong values should be a major part of human resources policy. Mutual respect, genuine care for employees, team work, and cooperation should be promoted at all the levels of an organization. This will substantially improve employee loyalty and commitment to their firm, thus minimizing their negative behavior in the enterprise. To counter the high levels of absenteeism, therefore, employers should monitor and foster a good atmosphere and relations among employees.

It should also be added that while investigating the problem, certain limitations were observed that should be taken into account. Limitations may include looking for the sources of the problem, that employees who are often absent are not entirely open to talking about the real reasons. They are afraid to openly speak not good of their superiors or what is really happening in the team. Employers also have boundaries in checking the accuracy of information provided anonymously by employees. That's why employers should analyze them wisely and approach negative opinions carefully. Therefore, it is important to build relationships with employees on transparent and honest rules from the beginning. This helps in solving most problems in the company.

This study has demonstrated employers spend a lot of time analyzing the issue of absences, focusing on statistics, and adopting a variety of perspectives. These analyses and the diverse methods cannot be questioned as they are highly reasonable in some cases. The question should be posed, however, are not the fundamentals of management and motivation forgotten among all that activity? Where enterprises take a sufficiently good care of their employees in different dimensions, the commitment to business grows and employees are not compelled to make extreme decisions like escaping into absenteeism or even quitting their jobs.

The article complements the existing literature and can be an excellent guide in finding the causes of absenteeism in any company.

## References

1. Arendt, Ł., Flaszewska, E. (2019). *Zmiany na rynku pracy i na świecie*, 88.
2. Badubi, R.M. (2017). A critical risk analysis of absenteeism in the work place. *Marketing*, 2(6), 32-36.
3. Batóg, J., Gazińska, M., Mojsiewicz, M. (2002). Ekonometryczne normowanie indywidualnej wydajności pracy. *Przegląd Statystyczny*, 49(1), 79-89.
4. Borgogni, L., Dello Russo, S., Miraglia, M., Vecchione, M. (2013). The Role of Self-Efficacy and Job Satisfaction on Absences from Work. *Revue Européenne de Psychologie Appliquée*, 63, pp. 129-136.
5. Carraro, F. (2021). *Monitoring, controlling and reducing absenteeism cost—a Luxottica case analysis during the Covid-19 Pandemic*.
6. Egan, G. (2011). *An Investigation into the Causes of Absenteeism in 'Company X'*. Doctoral dissertation. Dublin: National College of Ireland.
7. Farrell, T. (2005). *Absenteeism and the Effectiveness of Absence Management Strategies - A Study within Bausch and Lomb*. Doctoral dissertation. National College of Ireland.
8. Gajdzik, B., Zwolińska, D., Szyszczak, J. (2015). Behavioural determinants of work accidents and absenteeism in a metallurgical enterprise. *Metalurgija*, 54(4), 741-744.

9. Gilga, K., Jurek, Ł. (2022). Absentyzm chorobowy w Polsce: przejawy i uwarunkowania. *Polityka Społeczna*, 583(10).
10. Goetzel, R.Z., Long, S.R., Ozminowski, R.J., Hawkins, K., Wang, S., Lynch, W. (2004). Health, absence, disability, and presenteeism cost estimates of certain physical and mental health conditions affecting US employers. *Journal of occupational and environmental medicine*, 398-412.
11. Groenewold, M.R., Burrer, S.L., Ahmed, F., Uzicanin, A., Luckhaupt, S.E. (2019). Health-related workplace absenteeism among full-time workers—United States, 2017–18 influenza season. *Morbidity and Mortality Weekly Report*, 68(26), 577.
12. Hildt-Ciupińska, K., Bugajska, J. (2011). Rola zachowań prozdrowotnych w promocji zdrowia pracowników. *Bezpieczeństwo Pracy: nauka i praktyka*, 10-13.
13. Juchnowicz, M. (2010). Zarządzanie kapitałem ludzkim a poziom zaangażowania pracowników. *Zarządzanie Zasobami Ludzkimi*, 1(3-4), 57-66.
14. Jurek, Ł. (2021). Sytuacja na rynku pracy a absencja chorobowa: ujęcie koniunkturalne i sezonowe. *Studia Prawno-Ekonomiczne*, 120, 197-219.
15. Jurek, Ł. (2021). Wiek a absencja chorobowa pracowników. *Ruch Prawniczy, Ekonomiczny i Socjologiczny*, 83(4), 225-238.
16. Kłos, S., Nalewa, T. (2021). Analiza czynników wpływających na efektywność procesów w zakładach produkcyjnych o niskim stopniu automatyzacji-studium przypadku. *Zarządzanie Przedsiębiorstwem*, 24(3-4).
17. Kozioł, L., Wojtowicz, A. (2016). Wybrane praktyki zarządcze a dobrostan pracowniczy. *Zeszyty Naukowe Politechniki Poznańskiej. Organizacja i Zarządzanie*.
18. Kroik, J., Malara, Z. *Ocena otwartości menedżerów KGHM na innowacyjne działania w rozmowach postabsencyjnych*.
19. Kukawska, K. (2022). Raport z akcji prozdrowotnej pracodawcy dbający o zdrowie pracowników—ocena zaangażowania pracodawców. *Studia Prawa Publicznego*, 38(2), 145-168.
20. Lachiewicz, S., Walecka, A., Błaszczuk, W., Czekaj, J., Jędrych, E. (2010). *Współczesne problemy zarządzania zasobami ludzkimi*. Wydawnictwo Politechniki Łódzkiej.
21. Lewicka, D. (2017). Przywiązanie organizacyjne w zróżnicowanych pokoleniowo grupach pracowników. *Zarządzanie Zasobami Ludzkimi*, 3-4(116-117), „Zarządzanie różnorodnością w świetle wyzwań współczesnego rynku pracy” (*Managing Diversity in Light of the Challenges of the Contemporary Labor Market*), 67-86.
22. Lindner-Cendrowska, K. (2021). Wpływ warunków meteorologicznych na zachorowalność na grypę w wybranych polskich miastach (Impact of meteorological conditions on influenza morbidity in the selected Polish cities). *Prz. Geogr.*, 93, 103-122.
23. Luyten, J. (2013). Mutual moral obligations in the prevention of infectious diseases. *Justice, Luck & Responsibility in Health Care: Philosophical Background and Ethical Implications for End-of-Life Care*, 85-100.

24. Łochnicka, D. (2015). Zaangażowanie pracownika jako determinanta rozwoju organizacji. *Studia Prawno-Ekonomiczne*, 94, 317-334.
25. Maslow, A.H. (1998). *Maslow on management*. John Wiley & Sons.
26. Mazur, M. (2013). Motywowanie pracowników jako istotny element zarządzania organizacją. *Nauki Społeczne*, 2(8), 156-182.
27. Mędrala, M. (2021). Incydentalne wykonywanie czynności zarobkowych w trakcie pobierania zasiłku chorobowego. *Zeszyty Prawnicze BAS*, 70(2), 11-32.
28. Muster, R. (2020). *Pokolenie „Z” na współczesnym rynku pracy w opiniach pracodawców*.
29. Namysł, A., Kazenas, A., Bugajska, J. (2012). Promocja zdrowia w miejscu pracy-inwestycja w zdrowie pracownika i w kapitał firmy (1). *Bezpieczeństwo Pracy: nauka i praktyka*, 8-11.
30. Nerka, A. (2010). Etyczne problemy ochrony danych osobowych pracownika w stosunkach pracy. *Annales. Etyka w życiu gospodarczym*, 13(1), 107-121.
31. Pęciłło, M. (2013). Szacowanie ukrytych kosztów absencji chorobowej. *Bezpieczeństwo Pracy: nauka i praktyka*, 10, 13-15.
32. Przywojska, J. (2014). Pracownicy tymczasowi w firmie w perspektywie pracodawców-agencji pracy tymczasowej. In: B. Urbaniak, P. Oleksiak (ed.), *Praca tymczasowa. Droga do kariery czy ślepy zaułek?* Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
33. Pungello, E.P., Kurtz-Costes, B. (1999). Why and how working women choose child care: A review with a focus on infancy. *Developmental review*, 19(1), 31-96.
34. Sierpińska, M. (2013). Zarządzanie czasem jako umiejętność wpływająca na skuteczność organizacji pracy menadżera. *Zeszyty Naukowe Politechniki Częstochowskiej, s. Zarządzanie*, 9, 16-28.
35. Striker, M. (2013). Pomiar i analiza absencji pracowniczej. *Edukacja Ekonomistów i Menedżerów*, 29(3), 99-112.
36. Striker, M. (2016). *Absencja chorobowa pracowników*. Uwarunkowania–kształtowanie–pomiar. Wydawnictwo Uniwersytetu Łódzkiego.
37. Świątek-Barylska, I. (2013). *Lojalność pracowników współczesnych organizacji. Istota i elementy składowe*. Wydawnictwo Uniwersytetu Łódzkiego.
38. Walentek, D. (2019). Koncepcja Work Life Balance a efektywność pracy. *Archiwum wiedzy inżynierskiej*, 4(1), 19-21.
39. Walton, R.E. (1985). *From Control to Commitment in the Workplace: In factory after factory, there is a revolution under way in the management of work*. US Department of Labor, Bureau of Labor-Management Relations and Cooperative Programs.
40. Wilczyński, R. (2014). Pomiar efektywności, a cele przedsiębiorstw. *Zeszyty Naukowe Uniwersytetu Szczecińskiego*, 803, 547-558.
41. Work, A.F. (1996). ABC of Work Related Disorders. *BMJ*, 313, 5.
42. Zajac, C. (2014). Skuteczne zarządzanie kapitałem ludzkim jako czynnik sukcesu przedsiębiorstwa. *Zarządzanie i Finanse*, 1, 195-207.



## CYBERSECURITY IN POLISH SECURITY SYSTEM

Małgorzata TERLECKA-MACIEJEWSKA

SZPZLO Warsaw – Wawer; lek.mterlecka@gmail.com, ORCID: 0009-0009-7589-9237

**Purpose:** the aim of the article is to provide a broader context for the discussion on the significance and role of cybersecurity system in Poland. Cybersecurity is extremely significant for individual users, enterprises and entire countries. Cyberthreats might lead to serious consequences, for example data theft, loss of reputation, financial losses. They can be even dangerous for national security. Therefore, cybersecurity is an intrinsic element of the security system which needs to be constantly enhanced and adapted to the dynamically changing environment of threats.

**Design/methodology/approach:** the article is cross-sectional. The implementation of the goal is based on a critical analysis of literature.

**Findings:** the cross-sectional approach and literature review employed in this study have contributed to a comprehensive understanding of cybersecurity system in Poland.

**Practical implications:** effective cybersecurity has a fundamental meaning for the stability and national security of Poland. Providing protection against cyberthreats is crucial for maintaining the continuity of essential services, securing data protection and citizens' privacy, as well as for preventing potential disruptions in the functioning of economy and critical infrastructure.

**Social implications:** an effective cybersecurity system builds public trust and strengthens the position of Poland on the international area as a country capable of protecting its interests in the digital world. In the face of dynamically changing threats, continuous improvement and adaptation of the cybersecurity system remains necessary to tackle contemporary challenges and ensure long-lasting stability and national security.

**Originality/value:** this paper has provided an in-depth exploration of cybersecurity system in Poland the context of management.

**Keywords:** cybersecurity, security system, threats, cyberthreat, management.

**Category of the paper:** literature review.

### Introduction

Cybersecurity has become a crucial element in the modern system of national security. In the era of dynamically developing information and communication technologies, an increasing number of cyberthreats and increasingly advanced cyberattacks, it is necessary to ensure protection against cybercrime both on the national and international level. Similarly to

other countries, Poland is undertaking a number of legal, organisational and operational actions aiming at enhancing cybersecurity. The present paper presents crucial legal, institutional and operational aspects connected with cybersecurity in the Republic of Poland, as well as a role of international cooperation, education and public or private partnerships in this area. Moreover, it draws attention to challenges and future paths of development for the cybersecurity system, which are essential for maintaining stability and national security in the face of dynamically changing cyberthreats.

”In 2023, the level of threats in cyberspace on a global scale continued to be high, which also resulted in a significant level of cyberthreats in Poland. The activity of various groups acting illegally in the digital world was on the rise, including hacktivists, cybercriminal groups of a gainful character and groups connected with other countries or even operating directly within the APT system. The proliferation of cyberattacks also resulted from new types of threats which had emerged thanks to the development of new technologies and their increasing availability. The rising level of cyberthreats in contemporary digital environment exerts an influence on everyday functioning of citizens, enterprises and state institutions, which is why the effective functioning of the National Cybersecurity System needs to be constantly improved” (Report, 2024).

## **Cybersecurity in a theoretical approach**

In order to understand what cybersecurity means, it is necessary to present its definition. Cybersecurity is a complex of practices, technologies, processes and actions aiming at the protection of computer systems, networks, devices, programmes and data against attacks, damages or unauthorised access. In the era of digitalisation and global communication, cybersecurity plays a critical role in ensuring integrity, confidentiality and availability of information.

Addressing the issue of security, one should begin with paying attention to the following aspects: Data Protection, Risk Management, Threat Prevention, Incident Response, and Awareness and Education.

A key element in the area of cybersecurity is connected especially with Data Protection, i.e. with ensuring that data are stored, processed and transferred in a safe way which prevents them from being stolen, damaged or lost. Data Protection involves data encryption, employing access policies and regular security audits. Encryption secures the data in transmission and storage, access policies indicate who can gain access to the data, whereas security audits regularly check the systems in terms of potential gaps or infringements (<https://ikmj.com>, 2024). In turn, Risk Management consists in identifying, assessing and prioritising threats related to information security. It involves the implementation of relevant control measures



aiming at minimalizing the risk of cybernetic incidents. Threat Prevention consists in employing preventive measures such as firewalls, systems of detecting and preventing intrusions (IDS/IPS) and antivirus software. It is also important to update the systems and applications regularly in order to fill security gaps and provide protection against new threats. Incident Response means developing and implementing response procedures. It involves detecting, analysing and reducing the effects as well as restoring the normal functioning of the systems after an attack (Pilarski, 2022). Furthermore, it is important to create special teams responding to computer security incidents (CERT/CSIRT), which are responsible for quick and effective management of various incidents. In turn, Awareness and Education comes down to organising trainings and campaigns the aim of which is to raise users' awareness of cyberthreats and useful practices in the area of security. It is also supposed to promote safe habits such as using strong passwords, avoiding suspicious links or phishing e-mails.

Cybersecurity is extremely significant for individual users, enterprises and entire countries. Cyberthreats might lead to serious consequences, for example data theft, loss of reputation, financial losses. They can be even dangerous for national security. Therefore, cybersecurity is an intrinsic element of the security system which needs to be constantly enhanced and adapted to the dynamically changing environment of threats.

Cybersecurity plays an essential role in protection against the threats of the modern world, which are becoming increasingly advanced and common. At the time of digital transformation, when almost each and every aspect of social, economic and political life is dependent on information and communication technologies, cyberthreats can have serious and long-term consequences.

## **Present-day cyberthreats**

Among present-day threats of cybersecurity one should mention the following ones: ransomware, phishing, DDoS attacks, data theft, information leakage, or threats connected with the Internet of Things (IoT).

Ransomware attacks are based on malicious software which blocks access to a victim's systems or data, demanding ransom for unblocking them. The examples of such attacks are WannaCry and NotPetya. They are extremely dangerous since they can paralyse functioning of companies, hospitals, government institutions and critical infrastructure, leading to huge financial losses and disruption in providing crucial services. In turn, phishing is a form of social engineering which consists in obtaining confidential information (e.g. logins, passwords) by posing as trustworthy entities, and in manipulating people in order to gain unauthorised access to systems or information (<https://www.netia.pl>, 2024). The importance of these techniques results from their effectiveness in breaking security, which may lead to identity thefts, financial

frauds or data compromising. DDoS attacks (Distributed Denial of Service) consist in sending a vast number of enquiries in order to overload servers or networks and, consequently, make them unavailable (<https://blog.az.pl>, 2024). Such attacks are dangerous since they can block access to online services, causing discontinuity in business operations, financial losses and collapse of confidence among clients. Data theft and leakage of information consist in unauthorised obtaining of confidential information such as personal, financial or commercial data. Such incidents could result in collapse of confidence among clients, financial penalties, and the stolen information can be used in further cyberattacks. Finally, threats connected with the Internet of Things (IoT) result from the fact that IoT devices are often not properly secured, which makes them vulnerable to attacks. Such threats should not be overlooked since taking control over IoT devices can lead to disruptions in the functioning of smart homes, cities or even industrial systems.

In the face of rising and increasingly more complex cyberthreats, cybersecurity is becoming fundamental for national security, economic stability and privacy protection. Its importance is going to grow with further technological advancements and global digitalisation.

## **Legal aspects of cybersecurity in Poland**

A fundamental legal act in the field of cybersecurity in Poland is the National Cybersecurity System Act of 5 July 2018 (National Cybersecurity System Act, 2018). The act specifies the following aspects: organisation of the national cybersecurity system as well as tasks and duties of all entities included in the system; ways of exercising supervision and control regarding the application of the provisions of the act and a scope of the Cybersecurity Strategy for the Republic of Poland. The act also implements the regulations of the European Union NIS (Network and Information Security) Directive (Directive EU, 2016), issued in 2016 as the first EU legal act which was aimed at increasing the level of network and IT systems safety in the entire European Union. The directive obliged member countries to introduce legal and organisational measures in order to improve the ability to prevent, detect and respond to cybernetic incidents. The crucial elements of the NIS Directive involve:

- identifying operators of essential services: sectors such as energy, transport, banking, healthcare, as well as providers of digital infrastructure must be considered crucial for the functioning of society and economy;
- security requirements and reporting incidents: operators of essential services and providers of digital services must implement proper security measures and report serious cybernetic incidents to relevant state authorities;

- national and EU cooperation: each member state must establish the Computer Security Incidence Response Team (CSIRT) and National Cybersecurity Office, as well as be involved in a special Cooperation Group which facilitates the exchange of information and most effective practices on the European Union level.

The NIS Directive is a foundation for building a consistent and integrated cybersecurity system in Europe. It enhances protection against the rising threats in cyberspace.

The National Cybersecurity System Act defines the national cybersecurity system which is expected to ensure cybersecurity on the national level, including uninterrupted provision of essential services and digital services, by means of achieving a proper level of security of information systems responsible for providing the above mentioned services and by ensuring the management of incidents (National Cybersecurity Act, 2018). The national cybersecurity system involves numerous entities, including: operators of essential services; providers of digital services; Computer Security Incidence Response Teams operating on the national level and led by the Head of the Internal Security Agency, the Minister of National Defence, and Scientific and Academic Computer Network – National Research Institute; cybersecurity teams operating in particular sectors; public finances institutions, research institutes; entities providing services in the field of cybersecurity; institutions relevant for cybersecurity issues.

At this point it is necessary to mention Resolution no. 125 of the Council of Ministers of 22 October 2019 on the Cybersecurity Strategy of the Republic of Poland for years 2019-2024 (Resolution no. 125, 2019), adopting the Cybersecurity Strategy of the Republic of Poland for years 2019-2024 appended to the aforementioned resolution. This document replaced the National Framework of Cybersecurity Policy of the Republic of Poland for years 2017-2022, established by virtue of Resolution no. 52 of the Council of Ministers of 27 April 2017 on the National Framework of Cybersecurity Policy of the Republic of Poland for years 2017-2022.

## **Institutions responsible for cybersecurity issues**

Institutions responsible for cybersecurity issues include:

- for the energy sector – the minister responsible for energy issues;
- for the transport sector, excluding the subsector of water transport – the minister responsible for transport issues;
- for the sector of banking and financial markets infrastructure – Polish Financial Supervision Authority;
- for healthcare sector – the minister responsible for healthcare issues;
- for the digital infrastructure sector – the minister responsible for computerisation (National Cybersecurity Act, 2018).

A crucial role in coordinating actions in the field of cybersecurity in Poland is played by the Ministry of Digital Affairs, which consequently builds and develops the national cybersecurity system in order to ensure the protection of Polish cyberspace on a proper level. The Ministry in cooperation with its partners prepares documents and legal acts which are supposed to enhance and foster the national cybersecurity system. The Ministry of Digital Affairs also devised the above mentioned Cybersecurity Strategy of the Republic Poland for years 2019-2024. Moreover, due to the efforts of the Ministry, the provisions of the National Security Strategy and the Cybersecurity Strategy of the Republic of Poland for years 2019-2024 have been considerably harmonised. A special role among the organisational units of the Ministry is played by the Department of Cybersecurity which undertakes various actions, for example:

- determines quality goals for the cybersecurity of the Republic of Poland,
- shapes policies regarding the cyberspace of the Republic of Poland in cooperation with central government administration authorities and local self-government units;
- cooperates with state authorities and relevant Computer Security Incidence Response Teams (CSIRT) in terms of developing the ability to monitor and prevent incidents concerning the security of ICT systems, and fulfils tasks connected with the cooperation with CSIRT teams on the European level,
- monitors the process of implementing the provisions of strategic documents;
- devises, implements and reviews strategic documents with regard to cyberspace security issues,
- coordinates projects connected with preparing and updating the national cybersecurity strategy,
- prepares drafts of legal acts concerning the national cybersecurity system, suggests amendments to these acts and to other legal regulations regarding the protection of Polish cyberspace,
- represents Poland in international organisations, i.a. the Horizontal Working Party on Cyber Issues in the European Council, Cooperation Group established in the NIS Directive, Central European Cyber Security Platform.

The actions of the Ministry of Digital Affairs are aimed at ensuring effective protection of Polish cyberspace and increasing its resistance to present-day threats in the area of cybersecurity (Bógdał-Brzezińska, Gawrycki, 2003).

When it comes to institutions dealing with cybersecurity issues, it is also important to mention Computer Security Incidence Response Teams operating on the national level and led by the Head of the Internal Security Agency, the Minister of National Defence, and Scientific and Academic Computer Network – National Research Institute. These Teams cooperate with each other, with institutions dealing with cybersecurity issues and the minister responsible for computerisation, providing a consistent and complete risk management system on the national level, performing tasks in favour of preventing cyberthreats of a cross-sectoral and cross-border

character, and also ensuring the coordination of reported incidents (National Cybersecurity Act, 2018). The tasks of the Teams include:

- monitoring cyberthreats and incidents on the national level; estimating risk connected with a revealed cyberthreat and occurrent incidents, incl. conducting a dynamic risk analysis;
- conveying information about incidents and risks to the entities of the national cybersecurity system;
- issuing statements concerning identified cyberthreats;
- reacting to reported incidents.

Coordinating actions and enacting the government policy in terms of ensuring cybersecurity in the Republic of Poland are one of the responsibilities of the Government Representative for Cybersecurity who is appointed and recalled by the Prime Minister. The main duties of the Representative include:

- analysing and evaluating the national cybersecurity system on the basis of the aggregate data and indicators devised in cooperation with public administration institutions and institutions dealing with cybersecurity issues;
- controlling the process of risk management of the national cybersecurity system by the use of the aggregate data and indicators devised in cooperation with institutions responsible for cybersecurity issues;
- giving opinions about government documents, incl. drafts of legal acts which have an influence on the fulfilment of tasks in the cybersecurity area;
- implementing new solutions and initiating actions with regard to ensuring cybersecurity on the national level (National Cybersecurity Act, 2018).

One should also point out that the Council of Ministers' actions are supported by a special Board of Experts which is an opinion-giving and advisory body in cybersecurity issues.

An important role in the Polish cybersecurity system is also fulfilled by the Government Centre for Security which takes part in crisis management and cross-ministerial coordination in the area of cybersecurity in Poland. Its main task is to monitor, analyse and react to cyberthreats on the national level. The Government Centre for Security is a central contact point for different institutions and government bodies. It coordinates their activities in case cybernetic incidents occur. By means of information exchange and cooperation with different ministries, the Government Centre for Security guarantees an effective reaction to threats and minimalizes negative effects of cybernetic incidents for the country and its citizens (Trubalska, Wojciechowski, 2019) It also plays a crucial role in creating and maintaining safety in Polish cyberspace.

Finally, it is also worth paying attention to CERT Poland (Computer Emergency Response Team) which fulfils a central role in responding to cybernetic incidents in Poland. Its main task is to respond quickly and effectively to all incidents related to the security of information and

cybernetic infrastructure. CERT Poland collects, analyses and circulates information concerning threats. In addition, it provides technical and advisory support in case of cyberattacks. One of the key areas of CERT Poland's functioning is cooperation with a private sector. By working together with companies and organisations from the private sector, CERT Poland facilitates the exchange of information about threats, provides tools and clues regarding security and assists in responding to incidents. Thanks to such cooperation, the private sector can more effectively protect its resources and data against cyberattacks, which contributes to the overall enhancement of cybersecurity in Poland.

## Summary

Summarising the topic of cybersecurity in the security system of the Republic of Poland, one should emphasise key legal, institutional and operational aspects, which overall form a complex system of protection from cyberthreats. The principal legal aspect is the *National Cybersecurity Act* of 2018 which can be considered as a foundation for the Polish system of cyberspace protection. The act implements the provisions of the NIS Directive and assigns duties to operators of essential services, providers of digital services and public sector entities. These regulations are aimed to ensure a high level of network and IT systems security by the use of risk management, responding to incidents and ensuring the continuity of operation.

The cybersecurity system in Poland is based on the cooperation between numerous institutions, among which the essential role is played by the Ministry of Digital Affairs and the Government Centre for Security. Another important element is the cross-ministerial cooperation that involves both public and private sector, which allows more effective threat prevention (Terlikowski, 2019).

As for the operational level, a crucial role is performed by actions connected with monitoring and analysing threats, designing and developing the National Cybersecurity System, and implementing systems of early warning and responding to incidents. Training courses and educational campaigns are an indispensable element of raising the awareness and competences in the cybersecurity area.

In order to successfully face cybersecurity challenges, it is necessary to constantly develop and adapt the system. The crucial directions and strategies which need to be taken into consideration are:

- investing in new security technologies such as advanced detection and reaction systems, artificial intelligence used to analyse threats;
- increasing the competences of specialists in cybersecurity by means of trainings, certifications and educational programs, as well as educating end users on basic safety rules;

- enhancing cross-sectoral cooperation, tightening public and private cooperation in the exchange of information about threats, establishing public and private partnerships, and participating in international initiatives and cooperation networks;
- updating legal regulations in order to adapt the rules to the changing environment of threats, incl. implementing new regulations concerning data protection, liability for security infringements and requirements for reporting incidents;
- developing and improving the National Cybersecurity System (Report, 2024).

Effective cybersecurity has a fundamental meaning for the stability and national security of Poland. Providing protection against cyberthreats is crucial for maintaining the continuity of essential services, securing data protection and citizens' privacy, as well as for preventing potential disruptions in the functioning of economy and critical infrastructure. An effective cybersecurity system builds public trust and strengthens the position of Poland on the international area as a country capable of protecting its interests in the digital world. In the face of dynamically changing threats, continuous improvement and adaptation of the cybersecurity system remains necessary to tackle contemporary challenges and ensure long-lasting stability and national security.

## References

1. Bógdał-Brzezińska, A., Gawrycki, M.F. (2003). *Cyberterrorizm i problemy bezpieczeństwa informacyjnego we współczesnym świecie*. Warszawa, p. 64.
2. Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union (Official Journal of the European Union 19.7.2016, L 194).
3. [https://blog.az.pl/co-to-jest-atak-ddos-i-jak-sie-przed-nim-chronic/?gad\\_source=1&gclid=CjwKCAjwgdAyBhBQEiwAXhMxtjQO6KXZXNvLmGFYetXKDDsx6kXbxu3Eog-6t84cX6J-512vclkCXBoC\\_OoQAvD\\_BwE&gclsrc=aw.ds](https://blog.az.pl/co-to-jest-atak-ddos-i-jak-sie-przed-nim-chronic/?gad_source=1&gclid=CjwKCAjwgdAyBhBQEiwAXhMxtjQO6KXZXNvLmGFYetXKDDsx6kXbxu3Eog-6t84cX6J-512vclkCXBoC_OoQAvD_BwE&gclsrc=aw.ds), 9.04.2024.
4. <https://ikmj.com/jakie-sa-cele-cyberbezpieczenstwa/>, 9.04.2024.
5. <https://www.netia.pl/pl/blog/phishing-co-to-jest-jakie-sprawia-zagrozenie>, 9.04.2024.
6. National Cybersecurity System Act of 5 July 2018 (Journal of Laws from 2023, item 913), art. 3, 36, 41, chapter 8.
7. Pilarski, G. (2022). Wybrane aspekty cyberbezpieczeństwa w organizacji w zakresie analizy ruchu sieciowego. *Zeszyty Naukowe Pro Publico Bono, No. 1(1)*, pp. 120-122.
8. Report of the Government Representative for Cybersecurity for the year 2023 (2024). Warsaw, pp. 7, 93-96.

9. Resolution no. 125 of the Council of Ministers of 22 October 2019 on the Cybersecurity Strategy of the Republic of Poland for years 2019-2024 (Monitor Polski from 30 October 2019, item 1037).
10. Terlikowski, T. (2019). Bezpieczeństwo cyberprzestrzeni wyzwaniem naszych czasów. System cyberbezpieczeństwa w Polsce (w świetle obowiązującego prawa). *Zeszyty Naukowe SGSP, No. 71/3*, p. 16.
11. Trubalska, J., Wojciechowski, Ł. (2019). *Cyberbezpieczeństwo jako element bezpieczeństwa państwa i ochrony prywatności obywateli*. Lubin: Innovatio Press, p. 38.



## POST-CLOUD SOLUTIONS IN THE HIGH-DEFINITION DIAGNOSTICS OF SOLAR FARMS

Ireneusz TOMECKI

Silesian University of Technology, Faculty of Organization and Management; ireneusz.tomecki@polsl.pl,  
ORCID: 0000-0003-1816-767X

**Purpose:** The aim of this article is to demonstrate the benefits of using post-cloud solutions in the monitoring and servicing of large photovoltaic farms.

**Design/methodology/approach:** This article analyzes current problems with maintaining high generation of large photovoltaic farms, discusses the limitations of current service methods and indicates the direction of development and possible applications of new IT tools in the field of the Internet of Things to solve these problems and limitations.

**Findings:** This article presents a revolutionary fog computing method and as a tool for building IT infrastructure for monitoring large photovoltaic farms.

**Originality/value:** The information contained in the article concerns the operation of large photovoltaic farms and the next step in the development of monitoring and service tools in terms of maintaining production efficiency at a high level thanks to the use of the latest IT technologies. The author indicates the possible direction of development of IT architecture based on the latest revolutionary methods of collecting and processing data as a solution to the limitations of currently used methods.

**Category of the paper:** General review, Technical paper.

**Keywords:** high resolution monitoring, cloud computing; fog computing; resource management, Solar Power Plants, Large-scale Photovoltaic, private blockchain.

### 1. Introduction

Will the operation of solar farms take advantage of the opportunities offered by the fourth industrial revolution? The new accelerating industrial revolution is primarily about the exponential increase in the amount of data processed and analyzed, allowing us to make business decisions faster and in a more reasonable way. This data will be the main component of modern monitoring solutions for power grid systems. They include large solar farms, sometimes called photovoltaic power plants. Procedures related to processing, storing, transmitting and securing the data should be the basic determinant supporting the decision-making process for choosing specific technologies or the architectural model of such systems.

It is of paramount importance to choose the right basic technology to digitalize the sector. The result of the digitalization will make it impossible for many years to change the adopted solution and introduce a new one. This will have a significant impact on the pace of changes, local market simulations and, first of all, on the performance and security of IT infrastructure, and will also make a starting point for creating a new paradigm for building IT systems for the infrastructure of large-scale photovoltaic power stations.

## 2. Current state



**Figure 1.** Decrease in efficiency due to degradation of photovoltaic panels.

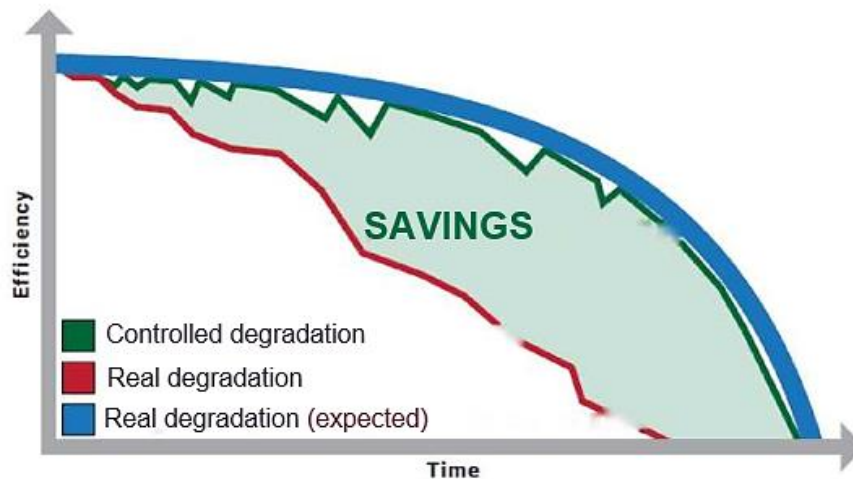
Source: Own elaboration.

Solar farms degrade over time – it’s natural. But, if poorly managed, they degrade at a much faster pace than expected (Figure 1). Investors do not achieve the expected ROI. As a result, they incur O&M costs or have to accept lower power generation performance and reduced revenues. There are several phenomena described in the literature (Garcia et al., 2014) that affect it. It results from the superimposition of the following phenomena:

1. Production mismatch: differences in solar module performance resulting from generation variations.
2. Thermal gradients: differences in temperature between solar modules within a system.
3. Uneven soiling: environmental contamination of solar modules.
4. Cloud shading and refraction: power surges (both power increase and power drops) resulting from clouds passing over the panel.
5. Defected bypass diodes: solar modules delivered from factory with defected bypass diodes.
6. Voltage drops: voltage mismatch in chain, resulting from voltage drop on home run lines leading to inverters.

7. Variable degradation: silicon solar cells age at different rates; their mismatch increases over time.
8. Cumulative wear: serious problems with the system that increase over time, e.g. mechanical or electrical faults.

Detecting these phenomena and their effects in large-scale solar farms with a power of 1 MWp or bigger is costly and time-consuming. A significant limitation of the study is the fact that the life cycle of a photovoltaic farm is 10-25 years. In the currently rapidly changing financial and technological environment, accurate observation of the installation's behavior in such a period is also devoid of research and financial sense. The observed cascading degradation phenomena are a problem in the long-term operation of photovoltaic farms, however, a precise presentation of the scale of this problem requires further observations. At the current stage of research, the phenomenon shown in Figure 2 occurs in every installation, but its scale depends on many factors such as: geographical location, age of the installation, generations of photovoltaic panels used, and service quality. In the long term (10-25 years) achieving a reasonable level of profitability of the photovoltaic business will largely depend on the introduction to the market of a new O&M service mode based on a remote high-definition/resolution diagnostics and monitoring (according to the International Energy Agency, the progress in the efficiency of photovoltaic generation depends on the rapid introduction of the so-called High Resolution Monitoring Systems (Figure 2).



**Figure 2.** The scope of savings that can be achieved in the new monitoring and service model.

Source: Own elaboration.

Currently, due to rising labor costs and limited availability of technicians, monitoring of each solar panel in real time or near real time will allow the utility-scale (with a power over 5 MWp) farms to be maintained.

### **3. High-definition monitoring**

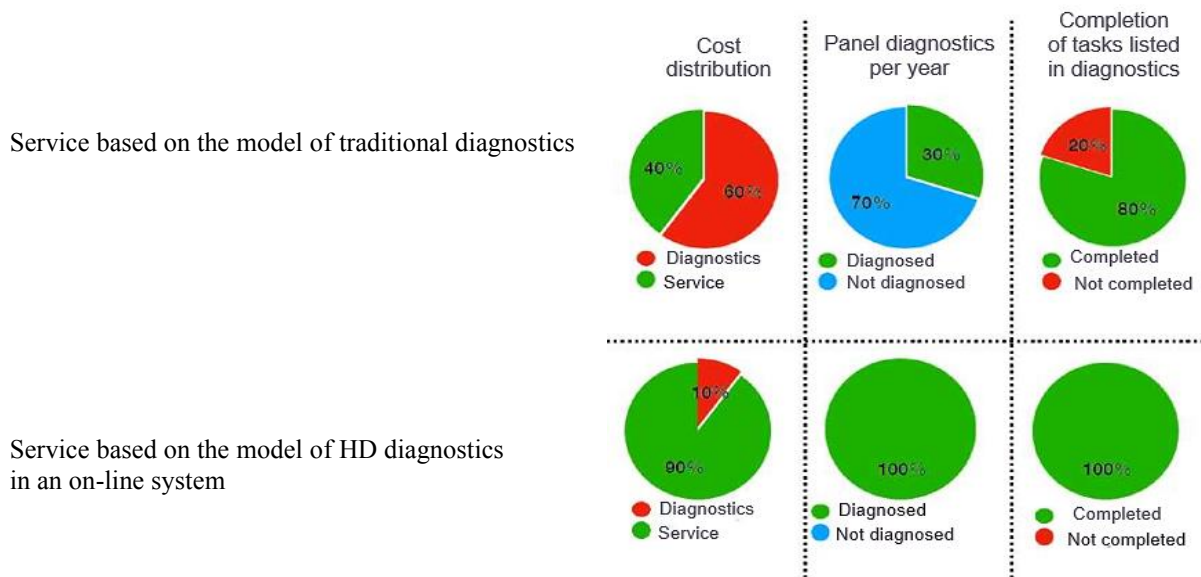
Network monitoring is a critical IT process to discover, map, and monitor photovoltaic panels and other photovoltaic farm components.

The high-definition (HD) monitoring adopts the principle of monitoring in real time basic operating parameters, including voltage, current, power, temperature of all farm components, i.e. panels, inverters and power output systems. Such a significant amount of data requires a highly efficient data collection system and an intelligent processing system using AI elements (Benadale et al., 2023).

The solution should also be scalable, i.e. enabling to build higher-level monitoring stations, common to many sites.

### **4. Business aspect of high-definition diagnostics.**

The basic trend is moving away from string-based monitoring systems. They are replaced with data acquired from inverters, offering the same diagnostic value without requiring additional expenses. However, data from inverters, similarly to string systems, does not solve the basic problem: the lack of indication of places and reasons for generation losses. This does not eliminate the need to conduct expensive field diagnostics by competent technicians using specialized measuring instruments. The costs of such diagnostics constitute 60% of the costs in the traditional O&M model (Figure 3). The main problems of the traditional O&M model include the growing labor costs and a shortage of qualified electrical technicians on the market. This has led to a widespread trend of not providing the required scope of services for utility-scale farms. The average percentage of panels covered by diagnostics does not exceed 30% (Figure 3) of the objectively required quantity and, in addition, the percentage of not completed scheduled service work is about 20% (Figure 3). All these adverse factors collectively result in structural losses of electricity generation (saw problem), practically impossible to make up for, and their removal requires stopping the farm's operation and involves additional large financial outlays. This fact also results in losses of electricity generation, which could be avoided by increasing the density of diagnostic measurements and optimizing the operation of service teams.



**Figure 3.** Comparison of the current service model based on manual diagnostics and the proposed model based on online diagnostics.

Source: Own elaboration.

Research in recent years has focused on the use of UAV-based thermal monitoring (Akai et al., 2024). This is significant progress, but it does not solve all problems and limitations and does not allow for the introduction of online monitoring.

The problem can be solved only by introducing to the market a service based on new technologies, enabling to detect failures and defects online with an accuracy of a single solar panel, automatically define and prioritize the service tasks and assign tasks to service teams, as well as introduce automatic verification of their implementation. However, this requires introducing a change in monitoring systems and the use of new – but also increasingly refined – IT technologies, the basis of which will be high-definition monitoring working online.

## 5. Fog computing as an alternative to cloud-based solutions in the diagnostics of solar farms

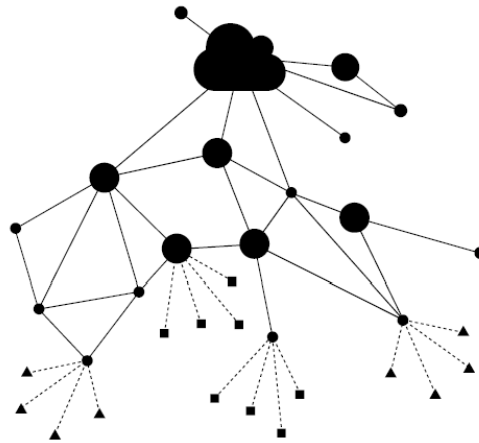
Moving to the next, lower level, i.e. to the level of a single panel, exponentially increases the number of measurement points. The use of instantaneous measurements of voltage, current and power obtained from sensors at all or most of the grid points, and collected by the system operating in real time will result in an exponential increase in the demand for IT systems and will not be possible without the use of emerging technologies. Currently, existing control and measurement, as well as automation solutions perform a specific task in a precisely defined location and only for the largest photovoltaic power stations. In most cases, they consist of a control and measurement or sensory layer, and a local data aggregation system. A natural

development step is to transfer data aggregation to cloud-based solutions. With the current state of infrastructure and security systems, using measurement data from two or more farms of an operator is very difficult, even only for security reasons (Ferrag et al., 2020). In this situation, the existing model of IT architecture has been preserved and the current state of information technology has not yielded any good solution.

Taking into account the already available technologies, if we know that there will be a change in monitoring architecture trends, we should answer the following question: what should an IT system based on the IoT and AI look like and what challenges does it face? Universal access to the Internet, widespread technology and growing automation tend to have a significant impact on the development of the new generation. Thanks to this, the operation of IT systems becomes the basis of education, while the number of specialists in fields other than power engineering is decreasing. This trend will inevitably force the digitization of all industrial sectors on a scale, that we have not witnessed so far. Not out of a desire for progress, but out of the need to improve the quality of services provided, improve efficiency and with shrinking expert resources. This means that aforementioned IT systems will become the basic working tool for the next generation. So, now is the right time to make directional decisions and prepare to enter the next level. The fourth industrial revolution and the introduction of 5G technology translates into millions of connected devices, PCs and smartphones and, above all, machines and sensory devices, that emit the data sets, based on which decisions are made. The same will also apply to the monitoring and servicing of solar farms. The main problem of IT systems will be not so much the collection of information, as its transmission and processing. This is also visible in the case of introducing HD monitoring in large solar farms. The role of the next generation of employees will be reduced to that of the system operator and decision maker, approving the scenarios created by the IT systems. It will allow us to maintain the increase in service levels, at least in the renewable energy industry. The support of artificial intelligence (AI) will also play an increasingly important role in developing optimum scenarios, especially service scenarios. For this purpose, it is necessary to consider collecting historical data now, which will serve as the basis for developing optimum decision-making models in the future. This approach will provide an advantage, due to the possessed database, that serves as a base for artificial intelligence. Even if the data will not be fully used immediately, it should already be collected now.

By observing market trends and cycles, we can expect a rapid growth and an increase in the sensory layer (Alba et al., 2020), followed by the amount of stored data and the need for computing power capable of processing these resources. The current decentralized architecture is highly inadequate, considering the impending large scale of the problem, and keeping this direction will exponentially increase the challenges associated with maintaining data integrity and security. Introducing superior units in the form of central operators for both information and maintenance will be sufficient, at least temporarily, but in the long run it will involve a significant risk of inhibiting the development of the O&M market. Scenarios for introducing

a centralized system based on building and maintaining own infrastructure in the form of large server rooms or implementing computing clouds are also being considered. There is a strong temptation to introduce centralized solutions, but this may create a vendor lock-in in a newly emerging market. We should, therefore, ask ourselves whether these systems meet the basic goals set by the energy industry, including renewable energy sector, for the coming years, if we treat renewable energy industry as a sector subject to special supervision? It can be assumed, that large computing centers can, at least to some point in time, be sufficient for operation, considering the digital wave. However, with the current performance level of the communication infrastructure, they will not be able to perform an efficient and quick analysis, due to the inability to deliver data from a large number of sensors within the time required for analysis. Therefore, they will not meet the above-mentioned requirement, that a modern smart grid system should support the operating process, and not only the analytical process performed afterwards. Another important aspect is data security, which raises considerable doubts, especially when stored on servers outside the country. The introduction of the central system will result in failure to meet the condition of local autonomy. Thus, the centralized architecture does not meet the basic goals of security, scalability and interoperability a modern infrastructure should feature in the era of the fourth industrial revolution. Currently, we are witnessing a stormy process of adopting distributed blockchain-based systems, rapidly conquering the financial market, posing a real threat to the long-standing status quo. The year 2017 saw the birth of the blockchain-based distributed data storage market, whose aim was to completely abolish the monopoly of large data centers in favor of small local infrastructure providers. Currently, large financial institutions, including the largest Polish banks, have already introduced this technology into their transaction systems, which additionally confirms their usefulness and guarantees further development. Such decentralization, thanks to post-cloud technologies, also opens the market of local services, enabling local providers to compete openly for local customers, while being part of a global system. Their major advantages will be flexibility and quick access to data for local users. The concept of the so-called fog computing goes exactly in the same direction. It aims at eliminating the need to build wide-area networks (WANs) and large computing centers for local infrastructure providers. Fog computing is a horizontal, physical or virtual layer, located between intelligent devices and traditional data centers (Figure 4). Its task The conceptual model of the fog computing was already described by the National Institute of Standards and Technology (NIST) (Iorga et al., 2020). It defines a new architectural model, an important part of which is the distributed infrastructure layer, operating on local computing power, distributed data storage and network connections edge computers. Its task is to aggregate and process data swiftly, using data centers and available, dynamically-allocated resources.



**Figure 4.** Fog computing model.

Source: Own elaboration.

The concept of fog computing fits perfectly into the requirements and directions for the development of intelligent monitoring systems. It introduces a unified infrastructure management mechanism and eliminates operational problems typical for the centralized system. It does not have a central unit, thus meeting the goals of local autonomy. The concept of fog computing described by NIST precisely defines the direction, in which the market will go, and what expectations should be met by IT systems in the era of total digitization. Smart grid is a technological challenge, which goal is to combine coherently operating IT systems and the entire infrastructure of both the modern automated, as well as the older one, in order to optimize electricity generation. That is why distributed systems are a breakthrough for Industry 4.0. Their most important features include location awareness and real-time or near-real-time data delivery. Computing nodes belong to an extensive p2p-class network, that can locate the nearest computing resources and data warehouses. The fog computing systems will process data much faster, more efficiently and ultimately cheaper than current cloud systems.

The local allocation of resources results in a drastic reduction of costs related to data storage and an equally drastic reduction of the load on telecommunication links. Fog computing uses distributed networks (p2p) making up primarily a different model of communication based on connections, where nodes can connect with many other nodes in the network and establish communication with one another, even using other nodes as intermediaries. If they cannot establish a direct connection, it is also possible to connect distributed networks operating even without Internet access.

Another significant feature is the dynamic allocation of resources (Foukalas, 2020). The main challenge of fog computing is quick adaptation to current computing requirements and releasing resources when they are no longer needed. The distributed processing system contains a mechanism that allocates resources in the nearest server room, and just in time when they are needed. Thanks to a specific data addressing system, fog computing provides the data set with a unique identifier, with which we query the whole network and the knowledge of the network node, to which the set belongs, is not required.



If we generate a redundancy mechanism by deploying selected sets not in one, but in several nodes, we will be able to automatically receive them when reading from several sources. This approach allows us to introduce the previously described local autonomy, with which the system works properly, even without Internet access, and provides the data on a continuous basis.

The implementation of the private blockchain concept is considered exceptionally useful. The blockchain is used as a control and management mechanism for distributed fog computing. Thanks to this, one can fully safely control all resources, without the need to install a central control unit.

The listed functionalities are only some of those, that a well-designed fog computing solution should have (Moura, Hutchison, 2020). Introducing this consistent environment into the renewable energy industry, especially for large solar farms, will make it possible to build a scalable IT system and a structure independent of external providers. The solutions already available on the market should be used as a basis for building new monitoring systems in large grids, including the solar farms.

## **6. Summary and Conclusions**

Large photovoltaic farms are complicated organizationally and financially. The technologies used so far did not allow for effective monitoring and servicing of these facilities. Numerous sources indicate that it is necessary to introduce online HD monitoring. There are more and more new solutions, but none of them allows for full online monitoring down to the level of a single element of the installation. The author focuses on the latest and revolutionary methods of collecting and processing large data sets and their possible application in monitoring large photovoltaic farms. The analysis of the possibilities of these technologies allows us to draw the conclusion that using post-cloud solutions it is possible to meet all expectations regarding modern HD monitoring of photovoltaic farms and indicates the direction of their development without current technical limitations.

## References

1. Akai, S.S., Özcan, O., Özcan, O., Yetemen, Ö. (2024). Efficiency analysis of solar farms by UAV-based thermal monitoring. *Engineering Science and Technology, an International Journal*, Vol. 53, 101688.
2. Alba, A., Maitheli, M.N., Yitzi, S., Olindo, I., Hesan, Z. (2022). Photovoltaic system monitoring and fault detection using peer systems. *Prog. Photovolt. Res. Appl.*, 237. Article 117806.
3. Al-Noman, A., Anmin Fu, P., Battula, K.S., Naha, R.K., Garg, S., Mahanti, A. (2020). FogAuthChain: A secure location-based authentication scheme in fog computing environments using Blockchain. *Computer Communications*, 162, 212-224.
4. Bendale, H., Aswar, H., Bamb, H., Desai, P., Aher, C.N. (2023). *Deep Learning for Solar Panel Maintenance: Detecting Faults and Improving Performance*. 14th International Conference on Computing Communication and Networking Technologies (ICCCNT).
5. Bhuvaneshwari, A.G., Selvakumar, S. (2020). Anomaly detection framework for Internet of things traffic using vector convolutional deep learning approach in fog environment. *Future Generation Computer Systems*, 113, 255-265.
6. Bilen, K., Erdogan, I. (2023). Effects of cooling on performance of photovoltaic/thermal (PV/T) solar panels: A comprehensive review. *Solar Energy*, Vol. 262, 111829.
7. Evans, D. (2011). *The Internet of Things How the Next Evolution of the Internet Is Changing Everything*. CISCO.
8. Ferrag, M.A., Babaghayou, M., Yazici, M.A. (2020). Cyber security for fog-based smart grid SCADA systems: Solutions and challenges. *Journal of Information Security and Applications*, 52, 102500.
9. Forcan, M., Maksimović, M. (2020). Cloud-Fog-based approach for Smart Grid monitoring. *Simulation Modelling Practice and Theory*, 101, 101988.
10. Foukalas, F. (2020). Cognitive IoT platform for fog computing industrial applications. *Computers & Electrical Engineering*, 87, 106770.
11. García, M., Marroyo, L., Lorenzo, E., Marcos, J., Pérez, M. (2014). Observed degradation in photovoltaic plants affected by hot-spots. *Prog. Photovolt. Res. Appl.*, 22, 1292-1301.
12. Guevara, J.C., Torres, R., Fonseca, N. (2020). On the classification of fog computing applications: A machine learning perspective. *Journal of Network and Computer Applications*, 159, 102596.
13. Iorga, M., Feldman, L., Barton, R., Martin, M.J., Goren, N., Mahmoud, C. (2020). *Fog Computing Conceptual Model*. NIST Special Publication, 500-325.
14. Losavio, M. (2020). Fog Computing, Edge Computing and a return to privacy and personal autonomy. *Procedia Computer Science*, 171, 1750-1759.

15. Moura, J., Hutchison, D. (2020). Fog computing systems: State of the art, research issues and future trends, with a focus on resilience. *Journal of Network and Computer Applications*, 169, 102784.
16. Tigo Energy Inc. (may 2012). *Sources of mismatch in unshaded photovoltaic commercial arrays*.
17. Wang, T., Zhang, Z., Bhuiyan, M.D.Z.A., Liu, A., Jia, W., Xie, M. (2020). A novel trust mechanism based on Fog Computing in Sensor–Cloud System. *Future Generation Computer Systems*, 109, 573-582.



## INTEGRATION OF RPA INTO PROCESS MANAGEMENT IN A LARGE RETAIL NETWORK ORGANIZATION

Anna UKLAŃSKA

Politechnika Warszawska, Wydział Zarządzania; anna.uklanska.dokt@pw.edu.pl,  
ORCID: 0000-0002-6577-0669

**Purpose:** The paper aims to present implementation of RPA (Robotic Process Automation) into the BPM (Business Process Management) Lifecycle to systematize the application of robotic solutions in process management.

**Design/methodology/approach:** By exploring BPM lifecycle principles and components, RPA methods, and the APQC® framework, an integrated BPM-RPA model was developed. The components of the BPM-RPA model were defined along with the necessary documentation.

**Findings:** The proposed model presents a systematic approach to RPA implementation by integrating it into the business process management model. A case study was conducted in a large network organization, and the results are presented.

**Research limitations/implications:** The model was designed for large network organizations and their branches and functional directorates.

**Practical implications:** The BPM-RPA model can be adapted to various supportive/back-office processes and applied across multiple industries.

**Originality/value:** This paper emphasizes the importance of linking RPA with the foundational process management model within an organization.

**Keywords:** process management, BPM lifecycle, Robotic Process Automation (RPA), process automation.

**Category of the paper:** case study, research paper.

### 1. Introduction

Robotic Process Automation (RPA) stands out as a tool for business process automation, with an impressive adoption rate. According to a survey by Deloitte in 2022, RPA solutions have been implemented in 80% of enterprises, often chosen as the primary subject for profitability case studies. The rapid growth of the RPA market is evident from recent research, revealing a global market value surge from USD 849 million in 2018 to USD 1.3 billion in 2019 and a substantial leap to USD 2.9 billion in 2021 (Deloitte, 2022). In 2020, a remarkable

73% of companies expressed their readiness to embrace intelligent automation processes (Deloitte, 2022).

At its core, RPA relies on specific software to map out processes. In the realm of RPA, the term "robot" refers to a license (Willcocks, 2015). Gartner offers a concise definition: "Robotic Process Automation is a tool enabling users to configure one or more scripts, often referred to as 'bots,' to automatically execute specific keystrokes, mimicking human actions. This allows bots to replicate selected tasks (transaction steps) across entire business or IT processes". RPA utilizes a combination of user interface interactions and descriptor technology, enabling scripts to span multiple applications (Gartner, 2022).

On the other side, it's noteworthy to recognize that RPA, often characterized as a programmatic tool, is a subject discussed in numerous articles (Table 1). These discussions typically shed light on the details of RPA method, emphasizing the necessity for specific phases in its implementation (like: technical documentation, programming, testing and maintenance).

**Table 1.**

*RPA models available in the literature*

<b>Publication</b>	<b>RPA model description</b>
Syed, 2020, p. 115	RPA is relatively easier and cheaper to implement, configure and maintain, compared to large enterprise systems and other forms of automation, and typically provides a simple and intuitive interface to users. Also, RPA can be implemented in a short timeframe.
Hofmann, 2020, pp. 99-106	It is key to focus not only on the short-term benefits of applying software robots, but also to concentrate on software robots' long-term influences on the complexity of IS ecosystems and on the organization as a whole. Thus, decision-making in the context of RPA must have a strategical focus.
Cooper, 2019, pp. 15-35	RPA was described a method to improve efficiency in taxation, assurance, and advisory professional services processes.
Leshob, 2018, pp. 46-53	Four step model of RPA was proposed in the article: validate the process eligibility for RPA, evaluate the RPA potential of the process, Evaluate the RPA relevance for the process, classify the process for RPA.
Enriquez, 2020, pp. 39113-39129	Proposal od RPA model: analysis, design, construction, deployment, control and monitoring and evaluation and performance phases.
Siderska, 2020, pp. 21-31	RPA was described as a technology for digitalization.

Source: own's elaboration.

The systematic combination of BPM lifecycle and RPA is not applicable in available literature. In author's article (Ukłańska, 2023b) review of accessible literature was made. And the provided cluster analysis state that while numerous publications delve into the definition and conduct cost-benefit analyses of Robotic Process Automation (RPA), there's a notable gap when it comes to practical implementation guidelines. Despite the abundance of RPA vendors and products in the market, a clear lack of well-defined implementation models persists. Additionally, many available rules may be misleading, and the number of presented case studies tends to be limited, further highlighting the need for a more detailed implementation framework.

This article aims to introduce RPA into BPM Lifecycle in the systematic way – by creating the BPM-RPA model. Creating this model is a worthy initiative, especially if there is a recognized gap in the existing literature.

The article consists of methodology chapter, where review of BPM lifecycle and available RPA implementation models were presented. As well as new approach to the BPM-RPA model. In results components of the model were presented with documentation required and outcomes, basing on the large network organization. Discussion part shows pros and cons of BPM lifecycle and RPA orientation. In conclusion, further steps are shown and approach to transformation procedure.

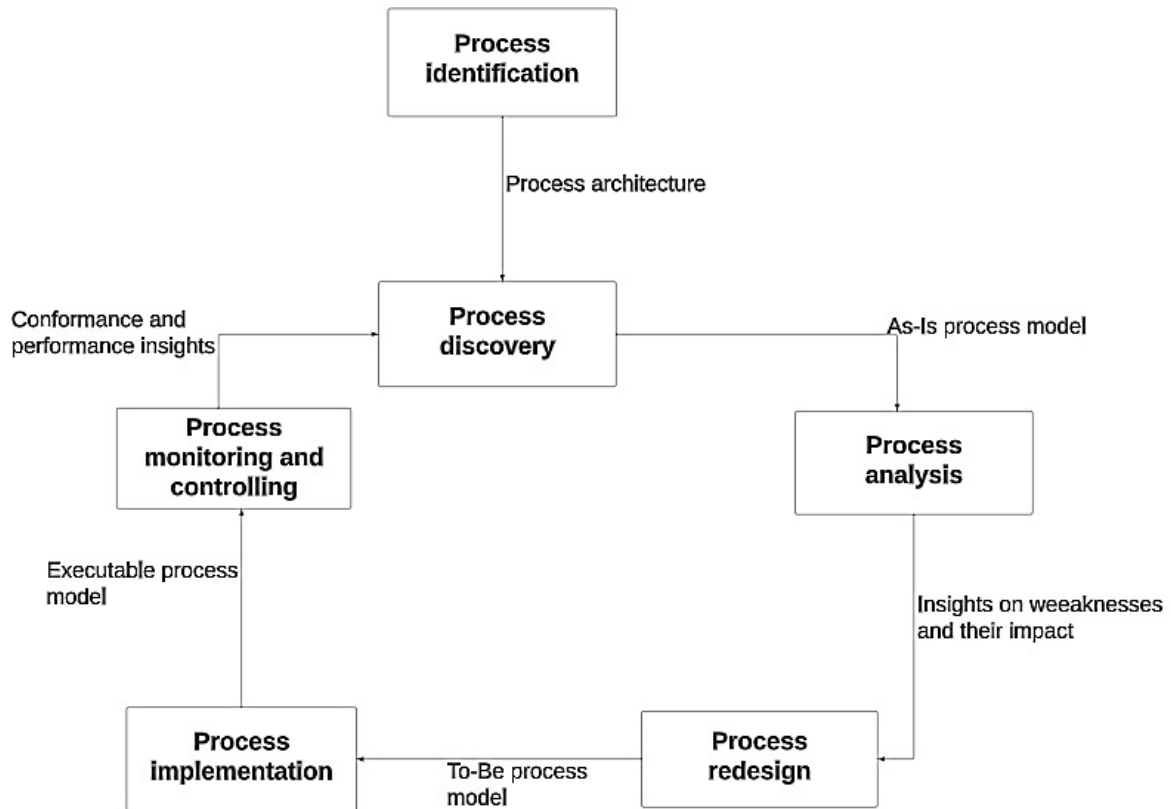
## 2. Material and methods

The BPM lifecycle is associated with the work of Marlon Dumas, Marcello La Rosa, Jan Mendling, and Hajo A. Reijers. The BPM lifecycle proposed by these authors is a widely recognized framework in the field of Business Process Management. It typically consists of six phases (Dumas et al., 2017, Weske, 2007, Mendling et al., 2017, Mohapatra, 2009, van der Aalst et al., 2010):

1. Process identification: identify and recognize processes within the organization. Capture and document existing processes, understand their purpose, and define their boundaries.
2. Discovery and analysis: describe the identified processes in detail. Use various techniques such as interviews, observations, and analysis tools to discover and comprehend the current state of processes.
3. Redesign: design improved or reengineered processes based on analysis. Develop new process models, incorporate best practices, and redesign processes to achieve organizational goals more effectively.
4. Implementation: put the redesigned processes into action. Deploy the redesigned processes, train employees, and implement any necessary technological changes.
5. Execution: objective: execute and manage the day-to-day operations of the implemented processes. Monitor, control, and execute the optimized processes, ensuring they align with organizational objectives.
6. Monitoring and evaluation: continuously monitor and evaluate the performance of the executed processes. Collect data on process performance, measure key performance indicators (KPIs), and use feedback mechanisms to assess the effectiveness of the implemented processes.

Process management execution is widely described in the literature. Mainly by phases of identification, modelling, implementation, control (review available in Olkiewicz, 2018).

This BPM lifecycle provides a structured and iterative approach to managing and improving business processes over time. Each phase contributes to the overall goal of achieving organizational efficiency, effectiveness, and adaptability. The iterative nature of the lifecycle allows for continuous improvement, ensuring that processes remain aligned with organizational objectives in a dynamic business environment (Figure 1).



**Figure 1.** BPM Lifecycle model.

Source: Dumas et al., 2018, p. 23.

The components considered in the model should be comprehensively integrated across the entire organization. A good tool for this purpose is the APQC® PCF® (Process Classification Framework). It defines five level of processes. For the retail the level 1 is as follows (APQC®, 2024):

1. Operating processes:
  - a. Develop Vision and Strategy.
  - b. Develop and Manage Customer Experience.
  - c. Market Products and Services.
  - d. Merchandise Products and Services.
  - e. Deliver Products.
  - f. Deliver Services.

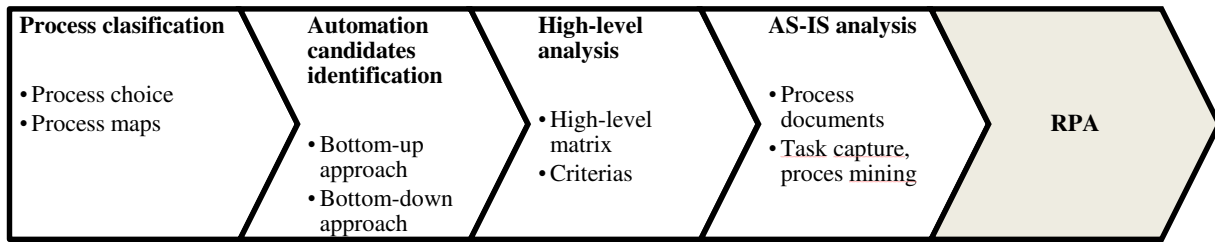


2. Management and support services:
  - a. Develop and Manage Human Capital.
  - b. Manage Information Technology (IT).
  - c. Manage Financial Resources.
  - d. Acquire, Construct, and Manage Assets.
  - e. Manage Enterprise Risk, Compliance, Remediation, and Resiliency.
  - f. Manage External Relationships.
  - g. Develop and Manage Business Capabilities.

### 3. Results

#### 3.1. Description of the BPM-RPA model

As mentioned before the main research question is how can Robotic Process Automation (RPA) and Business Process Management (BPM) be effectively integrated into a unified model to optimize organizational processes and enhance efficiency and productivity? In the research conducted by (Ukłańska, 2023a), a model (Figure 2) for process classification within the realm of Robotic Process Automation (RPA) was introduced. The model comprises several distinct phases. The initial phase involves process classification, where an examination and categorization of existing processes take place. This serves as the foundational step in identifying potential areas for automation, laying the groundwork for subsequent stages. Following the process classification stage, the model progresses to the automation candidates review phase. Here, potential processes that exhibit compatibility with RPA are carefully scrutinized, ensuring a targeted and strategic approach to automation implementation. Subsequently, the model incorporates a high-level analysis phase, providing a comprehensive overview of the selected automation candidates. This stage delves into the broader implications and potential impacts of automating identified processes, offering a strategic perspective to guide decision-making. Moving forward, the model includes a detailed process analysis phase, wherein an examination of the chosen processes is conducted, encompassing details. This in-depth analysis is essential for crafting a precise and effective RPA implementation strategy tailored to the unique requirements of each process. The final stage of the model is the RPA implementation, where insights gathered from the preceding phases are translated into actionable steps. This phase involves the actual deployment of RPA solutions, leveraging the analysed data to optimize and streamline automated processes.



**Figure 2.** Business Process Classification Model for RPA Purposes.

Source: own's elaboration.

The Business Process Management (BPM) lifecycle and Robotic Process Automation (RPA) are complementary concepts, and organizations often influence both to enhance their operational efficiency. Basing on the review presented previously they can be interconnected in the phases of BPM Lifecycle as presented in Table 2.

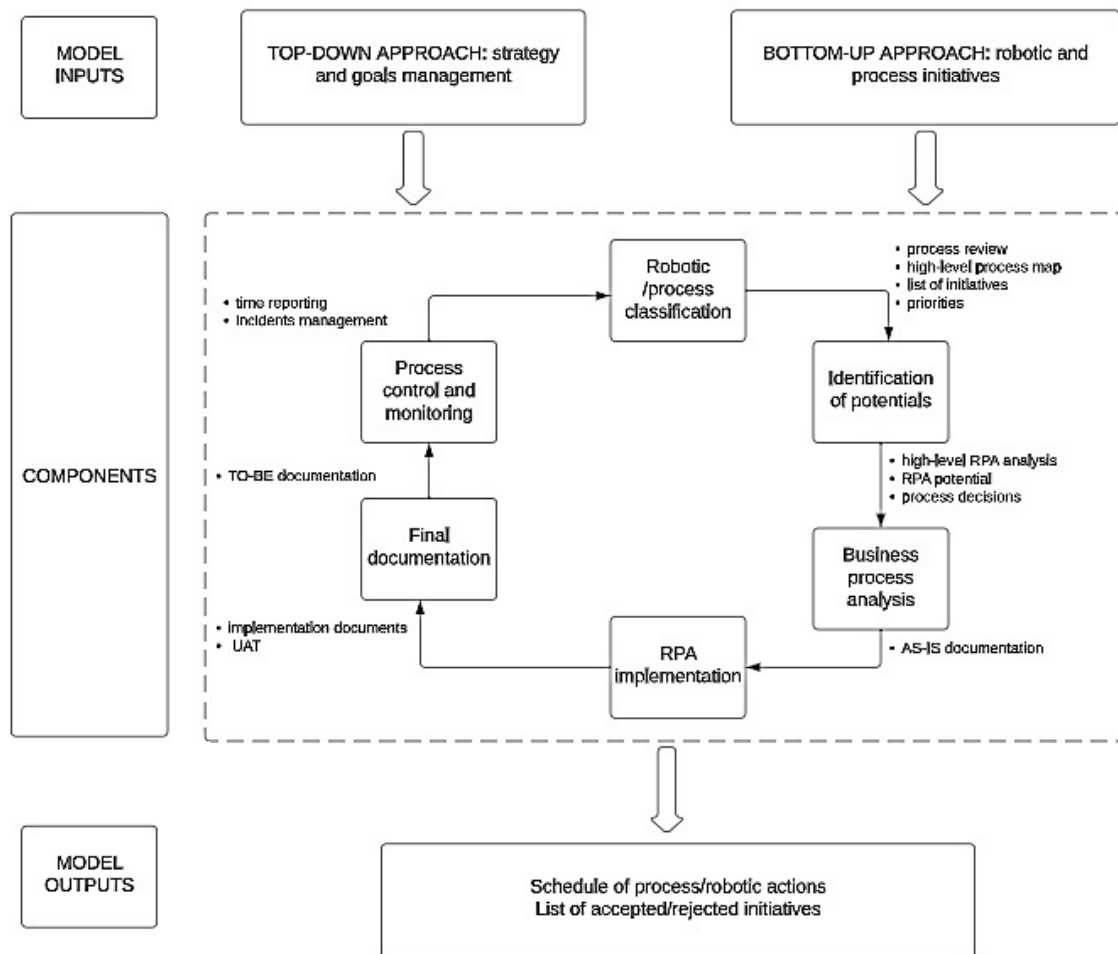
**Table 2.**

*Interconnections between BPM Lifecycle components and RPA*

BPM Lifecycle Phase	BPM role	RPA role
Process identification	Identify and design business processes to optimize workflow.	During the design phase, identify routine and rule-based tasks suitable for RPA automation.
Process discovery	Create visual representations of processes for better understanding.	Use process models to identify specific tasks that RPA bots can perform, improving clarity on automation opportunities
Process analysis	Analyse process performance and optimize for efficiency.	Analyse RPA performance data to identify bottlenecks or areas for improvement. Optimize automated tasks for better efficiency.
Process redesign	Align RPA implementation with BPM strategies to automate repetitive and rule-based tasks identified during the BPM lifecycle.	Implement automation for specific tasks within a process.
Process implementation	Deploy processes within the organization.	Implement RPA bots to automate specific tasks within the larger process, reducing manual effort.
Process monitoring and controlling	Monitor ongoing performance, track key performance indicators (KPIs).	Monitor RPA bots' performance, ensuring they execute tasks accurately and efficiently. Capture data for analysis.

Source: own's elaboration

By integrating RPA into the BPM lifecycle, organizations can achieve a more comprehensive approach to process improvement. While BPM provides the overall strategy and framework for managing and optimizing processes, RPA serves as a tactical tool to automate specific tasks within those processes, contributing to increased efficiency and reduced manual workload.



**Figure 3.** BPM-RPA model.

Source: own's elaboration basing on Dumas et al., 2018, p. 23.

The components of this model are as following:

1. Model inputs:

- Top-Down Approach: focuses on strategic assumptions and goal management.
- Bottom-Up Approach: involves initiatives from business users, particularly in the realm of robotics and process enhancements.

2. Robotic/process classification:

- Compilation of a comprehensive list of initiatives.
- Development of a primary process map.
- Process review detailing all organizational processes.
- Initiative categorization into process-related and robotic aspects, with priorities aligning strategically.

3. Identification of potentials:

- Determine a list of processes with associated decisions and priorities.
- Conduct a high-level analysis for processes.
- Assess and determine the potential for Robotic Process Automation (RPA).

#### 4. Business process analysis:

- Analyse processes comprehensively.
- Prepare process documentation.
- Develop AS-IS process documentation, encompassing mandatory process cards and optional process maps.
- For RPA solutions, a Process Definition Document (PDD) becomes imperative.

#### 5. Implementation of RPA:

- Take actionable steps based on prior decisions.
- Document the implementation process, summarizing the executed improvements.
- For RPA solutions, a Solution Design Document (SDD) is a requisite.
- If necessary, document the User Acceptance Testing (UAT) phase.

#### 6. Final Documentation:

- Prepare documentation for the TO-BE state.
- Develop TO-BE process documentation, including mandatory process cards and optional process maps.

#### 7. Process control and monitoring:

- Verify the sustainability of implemented solutions over time.
- Generate reports.
- Document and address any incidents that may arise.

#### 8. Model outputs:

- Develop a comprehensive schedule for both process and robotic work, considering organizational resources.
- Compile a detailed list of accepted and rejected initiatives, providing valuable insights into the success and feasibility of each proposed change.

Drawing from the analysis outlined in the previous chapters, Figure 3 illustrates the RPA-oriented BPM Lifecycle model. This model is predicated on the assumption that the company isn't required to have an existing process management system in place. The described model is designed to guide each stage of implementation by visually representing the requisite documents and processes.

### **3.2. Case study in a large network organization**

The case study was made in a large network organization. This organization is a retail company with a network of stores spread across Poland and a central office.

The case study was done in a:

1. Assignment of documents to the BPM-RPA model components.
2. Analysis of the model components and documentation available.
3. Preparation of results.

The analysis results are summarized in Table 3, offering insights into strengths, weaknesses, and areas for improvement. This concise presentation serves as a valuable tool for strategic decision-making and guiding interventions to optimize the existing model towards the target model.

**Table 3.**

*As-is BPM-RPA model diagnosis in the large network company*

Model component	Documents required according to the model	Results
Model inputs	Strategy	Document is available and properly defined
	Goals management	Goals are defined per each area of the organization, then up-bottom approach is used
Robotic/process classification	Robotic and process initiatives	Not available
	Process review	Not available
	High-level process map	Not available
	List of initiatives with priorities	Project Management Office is introduced in the organization, so the list of IT projects is available. No connection to process management is made
Identification of potentials	High-level RPA analysis	Not available
	RPA potential	Not available
	Process decisions	Not available
Business process analysis	AS-IS documentation	Available in specific areas, when required
Implementation of RPA	Implementation documentation	Available in specific areas, when required
Final Documentation	TO-BE documentation	Available in specific areas, when required
Process control and monitoring	Time reports	Data can be extracted, no report prepared
	Incidents management	Available, the organization is using tool for incidents management, needs adapting to RPA
Model outputs	Schedule of process/robotic acts	Not available
	List of accepted/rejected initiatives	Not available

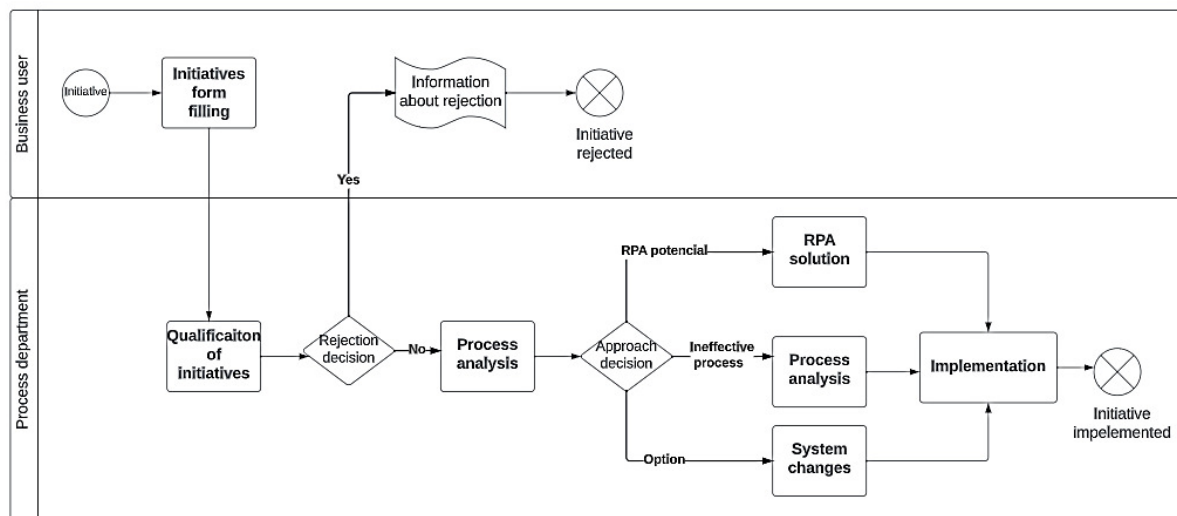
Source: own's elaboration.

### 3.3. Case study results

In summary of the analysis of Table 3, while certain aspects such as strategy and goals management are well-established, there are notable gaps in information related to robotic and process initiatives, RPA potential, process decisions, and certain documentation. Addressing these gaps could enhance the effectiveness and integration of the model within the organization's processes. The three most important of them are: high-level process map, initiatives process and high-level RPA analysis matrix. In the context of the proposed implementation of the discussed model, the subsequent section outlines proposals for the best approach to these areas.

If we take into account process map for large network organizations, the APQC® PCF® (Process Classification Framework) could be used. For each of the group of processes the decision-making process should take place to establish list of initiatives and priorities.

BPM-RPA model in the large network organization needs to be supported by initiatives management process. This process empowers stakeholders at all levels to navigate the changes with confidence. From conceptualization to execution, each step is designed, fostering a sense of clarity and purpose throughout the transformative journey. Initiation begins with the submission of an initiatives form, providing a platform for users to articulate their ideas. Following this, a comprehensive review of the ideas takes place, culminating in a decision-making phase to determine whether the proposed concept should proceed to Robotic Process Automation (RPA) or undergo a thorough process analysis. Furthermore, the evaluation considers whether systemic changes are necessary for successful implementation (Figure 4).



**Figure 4.** Initiatives management process.

Source: own's elaboration.

Furthermore, as part of the comprehensive strategy to implement the BPM-RPA model processes should be assessed by Robotic Process Automation (RPA) potential in a high-level matrix. This matrix served as a tool for evaluating each process, where those exhibiting substantial RPA potential were expected to demonstrate a positive alignment with all specified activators. This methodical approach aimed to not only identify processes ripe for RPA implementation but also to ensure a thorough understanding of the various activators contributing to their automation suitability.

## 4. Discussion

The synergy between Business Process Management (BPM) Lifecycle and Robotic Process Automation (RPA) represents a new approach to organizational processes. However, it's crucial to recognize that the inherent characteristics of each tool may leave certain aspects unaddressed when considered in isolation. BPM, with its focus on the human element, prioritizes process

optimization, collaboration, and agility. On the other hand, RPA is inherently automation-centric, concentrating on the streamlined execution of specific tasks through software robots.

One notable disparity arises in the adaptability of these methodologies to changing business needs. BPM inherently emphasizes the flexibility to evolve processes over time, catering to the dynamic nature of business requirements. Conversely, RPA is conventionally designed for stable and repetitive processes, showcasing its strength in ensuring efficiency but potentially falling short in scenarios demanding frequent adaptation.

The potential misalignment becomes more evident when considering the integration points between BPM and RPA. Seamless transitions between human-driven and automated tasks may pose challenges, especially in processes requiring dynamic decision-making or intricate judgment calls. The need for a harmonious blend that seamlessly combines the strengths of both BPM and RPA becomes apparent to bridge these transitional gaps effectively.

The insights from Cebuc's (Cebuc, 2023) research underscore the need to address these nuanced gaps in the BPM-RPA integration. It becomes imperative to explore solutions that enhance dynamic adaptability, visibility, governance, scalability, and overall process agility. Achieving a comprehensive and efficient approach to process management and automation might involve a strategic fusion of BPM and RPA with additional technologies or methodologies. This strategic combination would serve as a blueprint for organizations aiming to navigate the intricate landscape of process optimization and automation with maximum efficacy.

## 5. Conclusion

The primary objective of this paper is to show how the integration of Robotic Process Automation (RPA) into the Business Process Management (BPM) Lifecycle is aiming to systematize the utilization of robotic solutions in process management. This integration is crucial for enhancing operational efficiency and streamlining organizational processes.

To achieve this objective, a comprehensive exploration of BPM lifecycle principles, components, and RPA methodologies was undertaken, supplemented by insights from the APQC® framework. Through this rigorous examination, an integrated BPM-RPA model was meticulously developed, encompassing all essential components and accompanied by the requisite documentation.

The resulting BPM-RPA model offers a systematic approach to RPA implementation, effectively embedding it within the overarching business process management framework. To validate its worth, a case study was conducted within a large network organization, providing tangible evidence of the model's practical applicability and benefits.

It is worth noting that while the model was tailored for large network organizations and their various branches and functional directorates, its adaptability extends across diverse industries and organizational contexts. This versatility underscores its potential to revolutionize not only supportive and back-office processes but also core operational functions across multiple sectors.

Moreover, research conducted by (Brajer-Marczak, 2023) state that organizations need specific resources to enact dynamic process changes. Additionally, they require particular capabilities to ensure these resources yield the intended results.

However, it's essential to acknowledge certain considerations in the adoption of this model. The limitations of RPA, such as challenges in adapting to dynamic changes and the need for robust governance and compliance measures, should be carefully addressed. Successful implementation requires a holistic strategy that encompasses not only RPA tools but also a comprehensive understanding of the end-to-end business processes. Analysed case study in the large network organization can give an overall perspective, but is not sufficient. For further applications is needed to verify the model of broader scope of organizations and processes (to follow the Table 3). This table provides practical guidance on how to apply the model. It makes the integration process clearer and ensures that organizations get the most out of the model for their specific back-office needs.

The aforementioned case study underscores the importance of recognizing that mere analysis and recommendations may fall short in achieving comprehensive results. It highlights the necessity for a transformation procedure that navigates through distinct phases, meticulous steps, obligatory actions, and well-defined documentation frameworks. It is evident that supplementing the analysis with a structured model encompassing a comprehensive approach to BPM-RPA is essential for attaining optimal outcomes. While implementing RPA-oriented BPM Lifecycle model the organizations would need a dedicated roadmap presenting phases, responsibilities, steps and specific documentation. Without this kind of transformation procedure the model itself is not sufficient.

## References

1. APQC® (2024). *Retail process classification framework*. Available at: [https://www.apqc.org/system/files/resource-file/2023-04/K09368\\_Retail%20Process\\_v721\\_011519\\_April%202023.pdf](https://www.apqc.org/system/files/resource-file/2023-04/K09368_Retail%20Process_v721_011519_April%202023.pdf)
2. Brajer-Marczak, R., Marciszewska, A. (2023). Dynamic process improvement – theoretical and empirical perspectives. *Scientific Papers of Silesian University of Technology Organization and Management Series*, 172. 10.29119/1641-3466.2023.172.3.



3. Cebuc, C.N., Rus, R.V. (2023). The Use of Robotic Process Automation for Business Process Improvement. In: A.L. Negruşa, M.M. Coroş (eds.), *Remodelling Businesses for Sustainable Development*. ICMTBHT 2022. Springer Proceedings in Business and Economics. Springer.
4. Cooper, L.A., Holderness, D.K., Sorensen, T.L., Wood, D.A. (2019). Robotic process automation in public accounting. *Accounting Horizons*, 33(4), pp. 15-35.
5. Deloitte (2022). *Robots are coming*. Available at: <https://www2.deloitte.com/uk/en/pages/finance/articles/robots-coming-global-business-services.html>, 5 December 2022.
6. Dumas, M., La Rosa, M., Mendling, J., Reijers, H.A. (2017). *Fundamentals of Business Process Management*. Springer.
7. Enriquez, J.G., Jimenez-Ramirez, A., Dominguez-Mayo, F.J., Garcia-Garcia, J.A. (2020). *Robotic Process Automation: A Scientific and Industrial Systematic Mapping Study*. IEEE Access, pp. 39113-39129.
8. Gartner (2022). *Magic Quadrant for Robotic Process Automation*. <https://www.gartner.com/doc/reprints?id=1-26YSZ6WZ&ct=210729&st=sb>, 11.01.2022.
9. Hofmann, P., Samp, C., Urbach, N. (2020). Robotic process automation. *Electronic Markets*, 30(1), pp. 99-106.
10. Lazareva, N., Karasevskis, K., Girjatovcs, A., Kuznecova, O. (2022). *Business Process Automation in Retail*. 63rd International Scientific Conference On Information Technology And Management Science Of Riga Technical University (ITMS).
11. Leshob, A., Bourgouin, A., Renard, L. (2018). *Towards a Process Analysis Approach to Adopt Robotic Process Automation*. IEEE 15th International Conference on e-Business Engineering, ICEBE 2018, 8592629, pp. 46-53.
12. Mendling, J., vom Brocke, J. (2017). *Business Process Management Cases: Digital Innovation and Business Transformation in Practice*. Springer International Publishing.
13. Mohapatra, S. (2009). *Business process automation*. PHI Learning.
14. Olkiewicz, M. (2018). Zarządzanie procesowe w ramach funkcjonowania podmiotów sieciowych. *Scientific Papers of Silesian University of Technology, Organization and Management Series*, 117, 369-388. 10.29119/1641-3466.2018.117.24.
15. Siderska, J. (2020). Robotic Process Automation-a driver of digital transformation? *Engineering Management in Production and Services*, 12(2), pp. 21-31.
16. Syed, R., Suriadi, S., Reijers, HA. (2020). *Robotic Process Automation: Contemporary themes and challenges*. Computers in industry.
17. Uklańska, A. (2023). *Robotic Process Automation jako nowoczesna technologia automatyzacji procesów biznesowych*. In: A. Bitkowska (ed.), *Przyszłość zarządzania procesowego* (pp. 314-317). Strategie – Ludzie – Technologie. Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.
18. Uklańska, A. (2023). Robotic Process Automation (RPA) – Bibliometric Analysis and Literature Review. *Foundations of Management*, 15, pp. 129-140.

19. van der Aalst, W.M.P., Hofstede, A., Adams, A., Russell, N. (2010). *Modern Business Process Automation: YAWL and Its Support Environment*. New York.
20. Weske, M. (2007). *Business Process Management: Concepts, Languages, Architectures*. Berlin/Heidelberg: Springer.
21. Willcocks, L.P., Lacity, M.C., Craig, A. (2015). *The IT Function and Robotic Process Automation*. The Outsourcing Unit.
22. Willcocks, L., Lacity, M. (2016). Robotic process automation at telefónica O2. *MIS Q. Executive*, 15, 21-35.
23. Willcocks, L., Lacity, M. (2016). *Service Automation: Robots and the Future of Work*. Warwickshire: Steeve Brokes Publishing.
24. Willcocks, L.P., Lacity, M. (2016). A new approach for automating services. *MIT Sloan Manag. Rev.*, 58, 40-49.

## CONDITIONS OF CULTURAL CYCLE OF CONTINUATION AND ORGANISATIONAL CHANGE ON THE EXAMPLE OF NGOs

Piotr WERYŃSKI<sup>1\*</sup>, Dorota DOLIŃSKA-WERYŃSKA<sup>2</sup>

<sup>1</sup> Politechnika Śląska, Wydział Organizacji i Zarządzania; piotr.werynski@polsl.pl,  
ORCID: 0000-0001-9334-5048

<sup>2</sup> Politechnika Śląska, Wydział Organizacji i Zarządzania; dorota.dolinska-werynska@polsl.pl,  
ORCID: 0000-0001-8466-5867

\* Correspondence author

**Purpose:** The authors will answer two research questions: (1) What endogenous parameters of the cultural cycle in a given non-governmental organization introducing social innovations ensure its systemic stability, i.e. group and organizational morphostasis? (2) What parameters of the cultural cycle in a given organisation bring about its systemic change, that is, group and organisational morphogenesis?

**Design/methodology/approach:** The research was based on assumptions of the morphogenetic theory of structure and agency, in particular types of reflexivity as a factor that conditioning social agency. They relate to the determination of endogenous conditions limiting the innovative activity of the surveyed nongovernmental organisations. Based on them and using the qualitative analysis of the data obtained during group interviews (FGI), a diagnosis of developmental limitations and barriers will be made.

**Findings:** Among the members of the nongovernmental organisations surveyed, the dominance of the components of communicative reflexivity over autonomous reflexivity was diagnosed. This key cultural condition, which constitutes its morphostatic nature, i.e. focus on maintaining the organisational status quo, has anti-innovation potential. Most of the organisations members of the surveyed focused on maintaining the contextual continuity of the group and organisations, that is, reluctance toward new collective entities of action in NGOs, who question the existing status quo, that is, structural and/or cultural continuity. Such a context petrifies the level of tensions and social distances, and limits the innovative potential.

**Originality/value:** The dominance of the components of communicative reflexivity over autonomous reflexivity is a key cultural condition that negatively shapes the functioning of Polish NGOs in the area of innovation.

**Keywords:** reflexivity, innovations, NGOs, cultural cycles, focus group interview.

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

## 1. Introduction

Analyses of cultural change processes in management sciences focus on the relationship between management and employees (Dziadkiewicz, Juchniewicz 2013; Lewandowski, 2021). A classic example of this type of change is the transition from autocratic to democratic management. The purpose of the change is to design an organisation based on continuous learning and the high performance of its members. This is only possible with fairly flat organisational structures and strong ties between employees and the organisation (Saran, Clark, Mendonca, 2019; Brillman, 2002). This statement represents the transformation of a hierarchical management model into a flat and flexible organisational model that fosters individual initiative, independence, and risk taking (Borja de Mozota, 2006).

When examining the continuation and change in an organization in the cultural aspect, attention should be paid to strategies that effectively hinder the introduction of change and innovation and the impact of the leader on the change process and colleagues (Grzybowska, 2021; Ingram, 2023; Flieger, 2020; Sienkiewicz-Małyjurek, 2020). Therefore, the issue of optimal leadership qualities in a given cultural context is addressed, which should, among other things, effectively motivate employees and effectively solve potential problems and conflicts (Gocła, 2023; Bukłaha, Cabala, 2022; Baum, Haveman, 2020; Iansiti, Lakhani, 2020; Lazarević, Lukić, 2018). Today, we are dealing with a style of action called adaptive leadership, which has been described using a mnemonic tool, the "four A's" (Harvard Business Review, 2021): anticipation, which is an attempt to predict probable future trends and options; articulation, which consists of building a common understanding and gaining acceptance for the actions taken; adaptation, i.e. adopting in a way that ensures continuous learning and, if necessary, adapting responses; accountability, based on maximum transparency of decision-making processes and openness to change and providing feedback.

In the literature on the cultural determinants of organisational change, the attitudes of employees toward change (from opponents of change to pioneers) are also analysed. Depending on the type of change, they can take appropriate attitudes towards it: accepting, neutral, or non-accepting. In people who feel an indifferent or negative attitude to change (e.g. reactance theory), a slow process occurs in the process of implementing change, a cycle (e.g. a transtheoretical model of intentional change in human behavior) that aims to come to terms with change (Wybrańczyk, Szromek, 2018; Brzezinski, 2020; ADP Research Institute, 2020). Shaping attitudes of openness to change makes it easier to identify problems and increases flexibility (Bogdanienko, 2022). Change management is influenced by psychological factors (e.g., denial, resistance, experimentation, and commitment), which are one of the main sources of attitudes. They determine the reactions of employees to change. Of great importance are the strategies adopted by employees and circumstances that burden relationships, which effectively hinder the implementation of the desired process (including lack of

understanding of the meaning and purpose of change, communication of changes unexpectedly, and blaming for the past).

The authors have not found conceptualisations and operationalisations concerning the types of reflexivity that accompany the processes of continuation and change in organisations and culturally conditioned, resentment barriers to agency. Especially when the above-mentioned types of reflexivity and resentment conditions are barriers to the introduction of social innovations.

A special type of change is social innovation. In the scientific literature, one can find conceptualisations concerning the endogenous determinants of the development of social innovations (Murray, Caulier-Grice, Mulgan 2010; Westley, 2013; Wronka-Pośpiech, 2015; Berrett 2022). The most significant are: organisational culture, the potential of human capital, i.e., the educational aspirations and needs of the community along with ensuring the possibility of their continuous satisfaction by the education system, the potential of cultural and social capital, i.e., trust between partners in social life, the quality of the network of connections between them and the shared community of norms and values, or the quality of civil society institutions (e.g. NGOs) that create a microenvironment institutional innovation.

Unfortunately the vast majority of Poles are culturally excluded from co-creating the public sphere, they lack socialisation patterns of participation in nongovernmental organisations. At the same time, they do not recognise the requirements of democratic institutions and procedures necessary for deliberation in public life. Low resources for bridging social capital and a limited level of trust on the part of state institutions are persistently noted (Feliński, 2022). In the above sociocultural realities, the authors have defined the scope of the research issues. They will undertake to examine, by means of morphogenetic analysis (Archer, 2019) and the focus group interview method, endogenous determinants shaping causative and innovative capabilities in the state of morphostasis (contextual continuity) and morphogenesis (contextual discontinuity) of the subjects of activity from selected Silesian NGOs.

This article attempts to answer the following, as yet unverified research questions. (1) What endogenous parameters of the cultural cycle in a given non-governmental organization introducing social innovations ensure its systemic stability, i.e. group and organizational morphostasis? (2) What parameters of the cultural cycle in a given organisation bring about its systemic change, that is, group and organisational morphogenesis?

An attempt will be made to verify the research hypothesis that among the members of the studied NGOs, the processes of organisational morphostasis (continuation) are accompanied by the dominance of communicative reflexivity, while morphogenesis (change) is accompanied by the predominance of elements of autonomic reflexivity.

## 2. Literature review: Cultural Cycles and Group Resentment

In the research problems being investigated, the key conceptual category is culture and the related research area of resentful cultural context. The authors support a broad concept of culture, derived from the tradition of the anthropological school of Bronisław Malinowski (Malinowski, 1958). The aforementioned conceptualization assumes that the domain of the concept is social patterns, assessments, norms implied by actions and products as their indicators, but also such actions and objects that have value and meaning for a specific community, are the goal and expression of its attitudes (Kłoskowska, 1999). The above theoretical approach corresponds to the culturalist concept of Florian Znaniecki (Znaniecki, 1936) and the concept of culture as an integral part of the social system of Talcot Parsons (Parsons, 1937), in which one can also see the inseparable connection between the social and cultural spheres of human reality. Culture understood in this way is created by sets of norms and values, patterns and ideas, and social activities in which these axionormative sets are expressed. Antonina Kłoskowska also considers the coexistence of various categories of culture and social interactions as necessary, "culture is constituted by people, i.e. it is genetically, actually or potentially social" (Kłoskowska, 1981; 1999). A similar position is taken by Margaret Archer, whose works appear interdependent, although separate categories of culture and agency (2003, 2013, 2015).

Both society and culture are realised in social activities. Despite the community of ownership defined in this way, researchers of the aforementioned theoretical trend postulate the analytical separation of both categories at the methodological level, and implemented research directives. Archer particularly strongly emphasises the need to separate the level of culture and sociocultural interactions (Archer, 1996).

In the objectivist-realist perspective, cultural values (ideas) exist by themselves; just as in Karl Popper's epistemological assumption about the third world, they do not have to be connected to any external cognizers. This is also how Archer conceptualises this concept: "culture as a whole is defined as concerning all intelligibles, that is, everything that someone can understand – regardless of whether it is actually understood at a given moment (Archer, 2015). He supplements the definition of the concept with further features: (...) a cultural system exists objectively, and there are specific relations between its component parts (doctrines, theories, beliefs, individual propositions). These relations of contradiction and complementarity are independent of any claim to know them, believe them, agree with them, because this knowledge is independent of the cognizer, like an unread book (Archer, 2015).

Within the framework of emerging cultural properties, Archer distinguishes two main levels at which different axionormative systems confront or cooperate, for example, oppositional socioeconomic ideologies, patterns of active citizenship, and sociocultural interactions between entities involved in their framework, e.g., interest groups, social classes. There is a cultural

system that includes ideas that are in logical relations of contradiction (opposition) or complementarity. The relations between them do not require a knowing entity. There are also sociocultural interactions that concern, depending on the configuration of the elements of the cultural system, conflictual or ordered relations between individuals and interest groups. The aforementioned interactions between agents are causal in nature, because, as Archer claims: causal agreement, not a pure logical relation, is a property of people and the interactions that take place between them. Within their framework, individual and group entities refer to ideas originating from the cultural system to legitimise and realise their material and ideal interests.

Existing and independent of the scope of individual cognition, emergent cultural properties, like structural ones, condition, but do not determine social interactions. Emergent cultural properties (sets of key ideas) dominant in a given structural-cultural system condition social processes (Archer, 1996). Both levels are analytically and empirically distinct and can change independently of each other. They should be studied in this way. Archer's ontological assumptions regarding the difference between a cultural system, characterised by a certain degree of logical coherence, and sociocultural interaction, which are characterised by causal consistency, i.e., the degree of social homogeneity generated by the ideological influence of one set of people on another (Archer, 2015), constitute one of the basic assumptions of the morphogenetic theory of the analytical dualism of culture and agency. It allows for the analysis of the interactions between them in causal-diachronic order. The relations between the cultural system and the socio-cultural level shape three phases of the analytical cycle, situated in time, consisting of cultural conditioning, socio-cultural interaction, and cultural working through. The effect of the working phase is the reproduction (morphostasis) of the system or its transformation (morphogenesis).

A complete picture of a specific morphostatic or morphogenetic cycle must necessarily take into account not only cultural and structural conditions, but also the role of interactions between them and the participation of social agents in these processes. Archer postulates that for specific stages of social development and given structural and cultural contexts, analyses of the connections between morphostatic and morphogenetic cycles in the sphere of social interactions should be undertaken in diachronic order. He presents four basic scenarios of such connections (Archer, 1995; 2013).

The first scenario concerns societies of traditional organisations. It is characterised by a combination of structural and cultural morphostasis. The cultural system is dominated by an integrated set of ideas. However, in the area of structural properties, coherent, or at least noncontradictory in their interests, numerically limited, collective actors of action dominate, elites of power and culture. They are interested in continuing the existing social system.

The second and third scenarios are related to modernising societies. They will be particularly useful for research on Polish macro-, meso-, and microsocial morphostatic and morphogenetic cycles. The second scenario describes a situation where a permanent and historically shaped cultural morphostasis is undermined by processes of structural

morphogenesis. The number of collective actors striving to realise their interests in the sphere of structural properties is growing. However, their actions are limited by the dominant cultural order. Therefore, members of new material interest groups seek ideas and values that will legitimise their economic social position, thus gradually contributing to the processes of cultural morphogenesis.

The third of the scenarios discussed emphasises the role of the discrepancy between accelerated cultural morphogenesis and structural morphostasis. In this scenario, the growing differentiation of the cultural system is accompanied by the reproduction of power and material interests in the sphere of structure. However, the availability of alternative ideas weakens structural morphostasis over time. The process of moving away from the status quo is accompanied by the emergence of new collective actors orientated toward the realisation of their own ideological interests in the sphere of culture.

The fourth scenario describes interactions in a post-modern society. They are characterised by the occurrence of dynamic and uncoordinated morphogenesis processes, both structural and cultural. These processes are characterised by the rapid disappearance of socially passive primary agents of action, the growth of diverse and organised interest groups, i.e. collective agents of action, and also by the pluralism of competing ideas.

In order to determine the conditions of the course and effects of selected Polish cultural cycles, both morphostatic and morphogenetic, and to examine how the structural and cultural contexts of resentment existing in given time-space dimensions determine the course of the aforementioned oppositional cultural cycles, it is necessary to return to the full assumptions of the morphogenetic theory of structure, culture, and agency. At the same time, the analysis should be supplemented with elements of Max Scheler's concept of the necessary conditions for the formation of group resentments (1997; 2021). The morphogenetic causal analysis of the formation of the cultural context of resentment and the effects of group resentments should take into account the conditions of all the above-mentioned elements of social reality. Referring to the morphogenetic scheme of explanation allows for a diachronic analysis of the operation of specific mechanisms of resentment, both in the structural and cultural context and in the morphostatic and morphogenetic cycle.

The analysis should begin with a diagnosis of the basic structural and cultural characteristics of a given society or organisations. In order for a resentment structural context to exist in a given social, legal, and economic environment, all rights (citizen, labour, social) should be formally guaranteed. At the same time, however, social life, organisational or business practices often conflict with official legislation and adopted organisational regulations. It is equally important to diagnose the key emerging cultural conditions, i.e., the relationships between sets of norms and values, ideologies, patterns of attitudes, forms of social capital, and appropriate social practices. Conflicts of economic interests, social inequalities that create tensions in the structure and then inconsistencies in the cultural system, i.e., tensions between prevailing norms



and values, patterns of behaviour and ideologies and undertaken practices (interactions), as well as low socio-cultural integration, create resentful contexts for individual and group interactions.

What is the source of cultural tensions of resentment nature? They are created by opposing or complementary ideas, norms and values, political programmes, ideologies, organisational cultures constituting cultural power, which justify inequalities in access to power, wealth, and claims to prestige (respect). The cultural system, i.e. binding a more or less coherent set of values and ideas, in conditions of high sociocultural integration inspires the creation of legal regulations and norms that contribute to the elimination of structural and cultural tensions in groups and between groups or socioprofessional categories. On the other hand, in conditions of low sociocultural integration (non-uniformity of social practices), the binding cultural system perpetuates these tensions. The greater the difference between the guaranteed law, formal status of a group or organisation, and the existing balance of power in society, in organisations, the greater the potential for resentful tensions in them. They constitute a resentful cultural context that confirms structural conditions while legitimising relationships that elevate some entities and denigrate others.

Contexts of resentment, often created in long-term processes and having the characteristics of fossilised structural and cultural conditions, condition the agency of individual and group agents. Agents act emotionally and reflexively through the mechanism of internal conversation, at the interface of the structural and cultural context, and individually configured concerns (motivations), group, or organisational conditions of resentment. Depending on the type of reflexivity undertaken (communicative, autonomous, meta-reflexivity, broken reflexivity) by agents in a group or organisation and the sense of continuity or discontinuity of the contexts of action, agents exercise their agency differently in relation to structural and cultural conditions (Archer, 2003; 2007).

Entities undertake more or less active morphostatic actions, i.e. actions aimed at maintaining the existing socio-cultural order or morphogenetic actions aimed at changing it. In social actions aimed at maintaining the existing state of the socio-cultural system, the dominance of the communicative type of reflexivity helps. Morphogenetic actions, which have innovations features, are supported by the autonomous type of reflexivity, characterised by criticism of the environment that leads to action. In these actions, the type of meta-reflexivity, manifesting itself in a critical attitude towards oneself, the environment, leading to systemic change, is also helpful, to some extent.

### 3. Research methodology

The basic research method was morphogenetic analysis, diachronically understood. It is derived from the three-phase model: conditioning, interaction, and processing (Archer, 2015). It will provide an interpretive framework (data systematisation template) for analysing the emergence and persistence of specific barriers to agency identified through literature searches, observations, focus group interviews, and theoretical deduction. They are the result of often socially unconscious mechanisms of conditioning (e.g. jealousy and group resentments). The model will be the basis for analyses of identified agency barriers in selected Silesian nongovernmental organisations. It is, firstly, an extension of the author's previous ideas (Weryński, 2010, 2022; Weryński, Dolińska-Weryńska, 2021), secondly, it is based on the theory of structure and agency and the conceptualization of organisations in a state of morphostasis and morphogenesis (Archer, 2003, 2007, 2015).

Below, the elements of the author's analytical model will be presented, which explains the course of two scenarios of working through the structural and cultural context and the scopes of agency of the surveyed members of nongovernmental organisations: morphostatic (durability) and morphogenetic (changes).

Morphostatic scenario:

- The distribution of structural, cultural, and causal forces contributes to organisational morphostasis when there is compliance of actors in terms of existing relationships between the structural context (group interests) and the cultural context (dominant ideas and values focused on the survival of a social group, nongovernmental organisations) or there is acceptance of tensions between structural and cultural contexts. This division blocks the development of new collective entities and changes in the continuity of organisational contexts.
- In the case of an organisation in a state of morphostasis, that is, the persistence of the basic interests and values of its members, the existing structural and cultural contexts limit the emergence of innovations (an indicator of the state of morphostasis are attitudes focused on maintaining the organisational status quo).
- Indication of the dominant type of reflexivity (Archer, 2007, 2010, 2012, 2014). The course and effects of potential innovative activities are also the result of the reflexivity of organisations members who make decisions in the context of an individual approach to their practical projects in relation to existing contexts.
- The morphostatic experience of contextual continuity is perpetuated by the dominance of the communicative type of reflexivity. An indicator of the existence of communicative reflexivity is that respondents emphasise the importance of structurally determined barriers more than the opportunities and possibilities of overcoming them by members of the organisations; lack of trust in the external environment, domination

of bonding elements of social capital, i.e., based on family, neighbourly and friendly ties (Coleman, 1988; Burt, 1997; Woolcock, 1998; Portes, 1998; Lin, 2001).

- Reconciling mutual relations between operating entities in the structural and cultural context blocks changes to the organisational status quo and innovation.

Morphogenetic scenario:

- The distribution of structural, cultural, and causal forces leads to organisational morphogenesis when conflict arises between the main actors regarding the distribution of structural and cultural resources and/or new collective actors emerge (new differences of interests, new ideas, and values) that challenge the existing structural context and culture of the organisations.
- In a state of contextual discontinuity, interpersonal tensions that arise in the past (emotional traumas and conflicts) activate new actors, thus facilitating organisational changes (positive function of conflict) and conditioning the course of innovation processes.
- The factor that dynamizes the organisational morphogenesis described above is a type of autonomous reflexivity that spreads in a state of context discontinuity. This manifests itself in an increasingly critical approach to individual aspects of organisational life. It develops at the expense of the previously dominant type of communicative reflexivity.
- In the morphogenetic scenario, in conditions of contextual discontinuity, associated with the predominance of autonomous reflexivity; surveyed organisation members (e.g. in the SWOT analysis) emphasise the opportunities and opportunities to overcome structurally determined barriers to a greater extent than the limitations and threats resulting from them; There are manifestations of bridging social capital among the members of the organisations, i.e., declarations of trust in colleagues, participation in the network of organisational connections, acceptance of the introduction of horizontal structures in management, declarations of openness and willingness to cooperate with the environment.

Mechanisms of resentment will be identified based on several interdisciplinary concepts explaining their origin. They will allow for the diagnosis of resentful (morphostatic) states in selected non-governmental organisations. We will talk about the following mechanisms that have been assigned specific interpretive indicators:

- a) transferred hatred (Scheler, 1997) - an indicator of morphostasis in the case of accepting the statement: the main tensions and conflicts in the organisations arise between the management staff and the rest of the members, a common language cannot be found,
- b) negative acceptance (Scheler, 1997), morphostasis index: although we are not in good relations with the current government, we have no choice but to somehow come to terms with it,

- c) double axiological consciousness (Scheler, 1997) - morphostasis index: One often says one thing to a superior, but also to a coworker, and thinks and does something else,
- d) bitter grapes (Scheler, 1997), morphostasis index: when ambitious goals cannot be achieved, it is better to set smaller ones and ignore the previous ones;
- e) escape from freedom (Fromm, 2011) - morphostasis indicator: during restructuring, crisis, conflicts in the organisation, it is better to give the initiative to others,
- f) normative overregulation (Skąpska, 1991) - morphostasis index: instructions, orders, regulations are necessary for the efficient functioning of the organisation, they protect against chaos,
- g) time perception disorders (Kemper, 1984) - morphostasis index: things were better under the previous management (president), and real development is already behind us,
- h) postcolonial effect (Thompson, 2002) - morphostasis index: we do not need foreign capital (e.g. German or Russian) or foreign orders in the company,
- i) social ostracism (Aristotle) - morphostasis index: no one likes tricksters who sometimes need to be shown their place, e.g. unnoticed, excluded from society and attractive offers of cooperation,
- j) individual and collective jealousy (Schoeck, 2012) - morphostasis index: If you failed to implement your own idea, there is no reason to help others to elevate themselves later.

The lack of indicators of resentimental mechanisms in the respondents' statements [from (a) to (j)] will allow for a more morphogenetic interpretation of intra-organisational relations. The model presented will be a reference point and a model for systematising data to analyse the emergence and duration of detailed identified resentment effects, which are the result of more or less hidden, often socially unconscious, mechanisms of determinants.

To examine structural continuity (distribution of group interests) and cultural continuity (determination of group norms and values, type of organisational culture), in addition to morphogenetic analysis, the interview method will be used, i.e., a more focused group interview with key members of the group of nongovernmental organisations and the analysis of SWOT questionnaires prepared by the respondents' management boards organisations. The Atlas.ti computer programme was used to analyse the collected empirical data, which allowed us to graphically present the frequency distributions of opinion categories appearing in FGI and the connections between them.

The selection of people for the research groups was purposeful. This means that obtaining fully representative statistically significant distributions of sociodemographic characteristics in the composition of individual focus groups was not as important as saturation with people with the most diverse and well-established attitudes, knowledge, judgments, and opinions on the scope of agency and innovative activities in the studied groups. Nongovernmental organisations, limitations in communication within the organisations, and building relationships with the environment. It was also assumed, in accordance with the principles of grounded theory, that the data collected in individual groups would be continuously compared with each

other to extract codes from the focus groups that organise and interpret the research material. Then more general categories were constructed (through grounding in similar cases) to show the connections between the categories (Konecki, Chomczyński, 2012; Hensel, Glinka, 2012).

Focus groups were held in 2022. They covered 48 Silesian NGOs. A total of 48 focus group interviews were conducted with representatives of each of the organisations surveyed separately. Purposive selection was applied to the research sample in such a way that in each focus group there were equal proportions of representatives of both the management board and the rank and file members. 192 people participated in the qualitative study of the FGI, including 96 leaders (presidents and board members of non-governmental organisations) and 96 members of non-governmental organisations. When selecting nongovernmental organisations for the research sample, an equal percentage of organisations from metropolitan (cities with more than 100,000 inhabitants), urban (from 30,000 to 100,000 inhabitants) and small-town and rural (less than 30,000 inhabitants) environments were taken into account. Respectively, rural environments and small town environments were represented by organisations from Poręba, Łazy, Wojkowice, Lubliniec and Mikołów, from medium-sized cities, organisations from Tarnowskie Góry, Mysłowice, Zawiercie, Piekary Śląskie, and as representatives of metropolitan environments, respondents came from Katowice, Sosnowiec, Gliwice, Bytom, Chorzów, Rybnik. Furthermore, the configuration of the research sample included a variable: the main area of activity of the organisations. Therefore, nongovernmental organisations were selected in equal proportions for the focus research, four organisations each from the six areas of activity most frequently represented among all Polish nongovernmental organisations, i.e., from the area of charity and health promotion activities, education and education, sports and recreation, religious organisations, and communities (incl. including parish), local governments (districts, housing estates, housing communities) and animal care (Feliksiak, 2022).

An additional criterion for selecting a given organisation for the research was its documented implementation of at least one social innovation in the last two years before the start of the research. Such innovation should be characterised by at least five of the nine parameters: cross-sectorality, openness and cooperation, presumption and coproduction, interdependence, creation of new social roles and relationships, bottom-up, more efficient use of means and resources, development of new resources and opportunities, use of ICT technologies and tools. A social innovation was granted the status of implemented when a given project underwent a final external evaluation, e.g., carried out by an intermediate body representing the European Union or national authorities, appointed to distribute funds for individual social programmes.

#### 4. A case study of the morphostatic cultural cycle in an organisations

The group of early medieval community reenactors has existed since 2015. A few years later, it obtained the formal status of a public benefit organisations. The organisations is headquartered in a 200,000-person city in Silesia with significant industrial and scientific potential. Currently, its area of activity covers all of Poland, and it also cooperates with similar nongovernmental organisations from neighbouring countries (Czech Republic, Slovakia, Germany). In the first years of the association's activity, the board and its active members focused on maintaining community ties among themselves, building integration among members and supporters of early medieval reconstructions. Their activities mainly came down to preparing and organising reconstructions of elements of old customs and knight tournaments, i.e., exclusive activities aimed at building ties that were more community-based than bridging and open to the social environment (inclusive). An internally integrated group of leaders was created, which then elected the association's board from among themselves. According to respondents, in this initial period, relations between members of the organisation and with entities from the social, business, and political environment were limited to a minimum. As the group of historical reconstruction enthusiasts grew in size and became more functionally diverse, there was a need to formalise and structurally diversify their activities. The association was established. One of the members of the association's board describes this period of the organisation's activity as follows.

*When we founded the association, we founded the group, there were a few of us, sometimes 10, and it was as if the communication in the team was completely different. We lived completely differently, so to speak. Because we had daily direct face-to-face contact, it was great. We talked, we spent a lot of time together, for ourselves. Now that there are more than 30 of us, well, we have to somehow formalise certain things, somehow arrange them, we create different kinds of subgroups, so that, for example, here are those who are interested in participating, here are those who are not interested. For example, here are the warriors, here are the craftsmen, and so on. It is as if the dynamics change, the integration of the group as a whole decreases.*

In the initial period of the organisation's formation, there were no collective entities questioning the existing status quo, i.e. the existence of contextual continuity (structural and/or cultural). During this period of organisation management by its founders, within the framework of statutory activities and in accordance with the adopted mission and strategy, board members declared a democratic (integrative) and participatory style of team management and consciously created horizontal organisational structures based on independent task groups of enthusiasts. However, the actual and practical style of team management was closer to the autocratic model, in which the board itself set the goals and tasks of the team leading to their implementation. It also divided into terms of setting goals between groups of members, volunteers,

and employees. The existing organisational culture was a reflection of the oligarchic management style (a group of warriors exercising power). It legitimised the relations of elevating those members who strictly and uncritically implemented the ideas and orders of the board and distancing themselves from independent and critical people (elements of the group ostracism mechanism were used). The democratic and participatory style of team management was maintained in official declarations, which in practice was expressed, for example, in the creation of façade advisory groups that did not have the authority to solve existing organisational problems. Over time, these declarations become increasingly contradictory with the actual method of management and motivation. This came down to implementing attitudes of lack of trust and attention to grassroots, innovative proposals. The existing contradictions between the declared and enforced style of management (power) and the related division of intraorganisational elements of prestige, implemented through equalisation, i.e. a system of hierarchising and promoting members, in subsequent years deepened inequalities and a sense of relative poverty among most members. This is how the current president of the NGO spoke about this issue:

*We have a levelling system, you could call it that. It was developed under previous management. When someone joins the team, they are the lowest-ranking person, a quasislave, and then they are promoted when they successfully develop their character, so in this historical world they have to prove themselves, gain new skills, get involved, and then, if they could, wear better and better clothes and become a richer and more important person. And, for example, we wanted to change the system of even counting these points for people. So it took months of convincing, mainly warriors, because the latter got used to it and did not touch this system. And the latter took part in its creation and this system is definitely the best and there will be no better...*

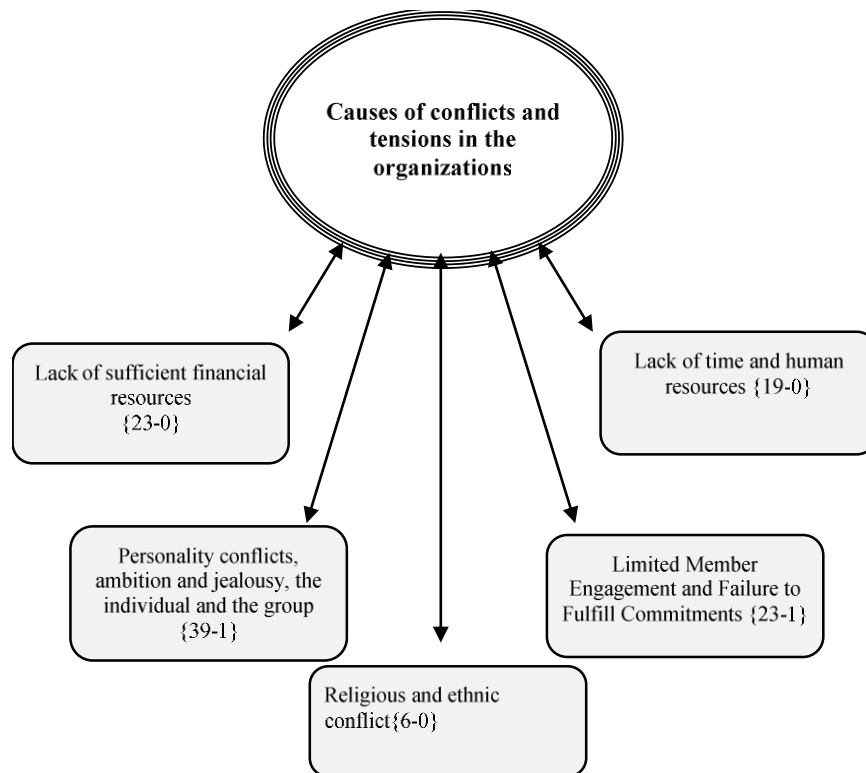
The co-occurrence of the above-mentioned conditions exacerbated the mechanism of double axiological consciousness of members and employees, who were forced to "play" in building an open, partner team of innovators. In this way, they increased the potential for traumatic tensions among the members of the organisation. The team members subjected to the impact of this mechanism were forced to work through the conditions mentioned above emotionally and at a reflective level. Members representing organisational roles different from the roles of warriors did not directly address their reservations to the board regarding the injustice in the way of equalising and hierarchising members during the first four years of the association's operation. Instead of focussing on personal changes in people holding managerial positions, attitudes that were characterised by the traumatic mechanism of transferring hatred (reluctance) were adopted, focussing on ways of modifying internal regulations regarding the hierarchy of members.

The indicated manifestations of the morphostatic state of the studied organisations did not favour the undertaking of externally orientated innovative activities. Group resentments encapsulated in the above structural and cultural context petrified the existing social and organisational continuity. The dominance of the components of binding social capital was diagnosed among the management staff, especially in the dimension of trust in the internal task and the social circle. This potential maintained the existing contextual continuity of the group and organisation and the level of tensions and resentment distances. The stage of organisational stagnation burdened with resentment diagnosed above was also stabilised by the dominance of the communicative type of reflexivity among a significant part of the members and employees. That is, conformist towards the management staff, reluctant to change, maintaining the status quo.

The growing contextual discrepancy between the formally guaranteed position of entities and the observed balance of power in the organisation increased the potential for resentment tensions. The greater the inconsistency between the formally and normatively assigned position (equalisation) and the observed one that deprives the balance of power in the organisation, the greater the barriers of resentment to agency. The indicator of the existence of the phenomenon was the respondents' emphasis on the importance of personal conflicts and tensions, injustice in rewarding for activity or in access to status factors, the accumulation of negative group emotions, mainly individual and group jealousy, as a barrier to innovation.

The observations of the members surveyed of the historical reenactors association on the causes of conflicts and tensions in their innovative activities correspond to the aggregated results of all the focus interviews conducted. The main categories of causes of conflicts that occur during the introduction of innovations indicated by the participants of the group interviews and the connections between them are presented in the following perception map, generated in the Atlas.ti programme (see: Fig. 1). This tool made it possible to generate codes and their families, presenting the main categories of responses from respondents obtained from group interviews. For example, the code that occurred most frequently in the analysis was the code called 'personality conflicts, ambitions, individual and group jealousy' 39-2 and consists of two elements: the first is the degree of grounding (39), that is, the number of connections of the code with quotations within the text document, the second (3) is coherence, that is, the connection of a given code with other codes. This code was included in the family of codes (CF): causes of conflicts and tensions in the organisations.

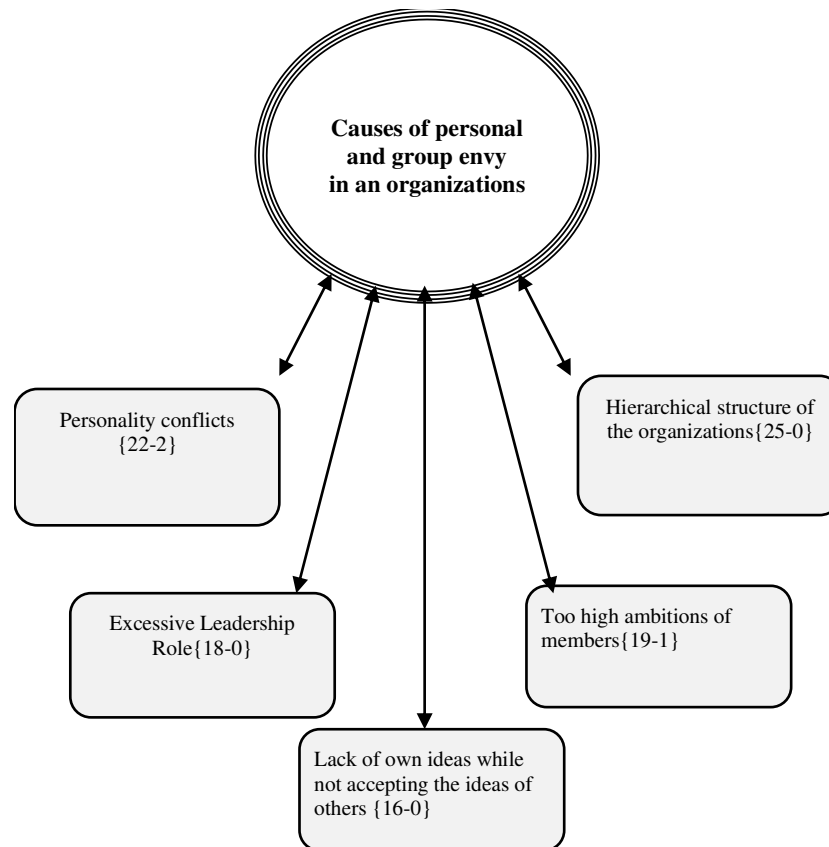




**Figure 1.** Perceptual map: Causes of conflicts and tensions in the organisations.

The key code: personality conflicts, ambitions, individual and group jealousy includes, for example, the following statements by members of the analysed nongovernmental organisation. According to the current president of the association, individual and group ambitions and jealousy related to the inability to hold management positions in nongovernmental organisations are expressed by those *who do not have the appropriate education, experience and social competences and aspire to hold them*. Another member of the current board adds that strong personalities and ambitions clash in the organisations, which block new activities. *"This is the specificity of historical groups, that there are personalities with very, very strong characters. A large part of these groups, even 100% of some, are warriors. These are people who are specifically directed to enter this military hierarchy.*

The observations of the board members on the causes of personal and group jealousy in the organisations presented above were included in the codified statements of all respondents obtained in the focus group interviews. They also correspond to them to a large extent (see Figure 2).



**Figure 2.** Perceptual map: Causes of personal and group jealousy in an organisations.

The toxic interactions between the majority of the board and the remaining members, as well as the everyday organisational behaviour of the members of the analysed team, revealed the existence of tensions. They were an expression of the action of group aversion. They also produced certain effects. Several founding members of the organisation left the association. Destabilisation resulting from the limitation of the development possibilities of the group of oppositional nonwarriors serving key institutional, business, and organisational stakeholders, and their subsequent resignation from membership, affected the overall functioning of the NGO. What conditions led to organisational morphogenesis? The mechanisms and effects of aversion that emerged in interaction with structural and cultural contexts found expression in social actions and also conditioned the processes of innovation in the organisations. These processes took place at three levels: structural (power and status of individual entities), cultural (preferred norms and values expressed through attitudes) and through intraorganisational formal regulations, e.g. equalisation of systems, scopes of responsibility, methods of document circulation and formal (vertical) communication, introduction of privileges for some and limitation of the possibilities of action of other members.

The emergence of contextual structural and cultural discontinuity occurred when differences of interest emerged between the majority part of the board and the elite group of warrior reenactors supporting them, and the minority part of the board, representing the majority of the organisation's members, who played less prestigious roles of farmers, craftsmen,

and servants. The board members associated with the warrior group were focused on the exclusive self-fulfilment of group knightly passions, at the expense of building broader relations with the socioeconomic and institutional environment. The system of member levelling they created was to legitimise and maintain the original contextual continuity of the NGO. On the other hand, the much larger group of reenactors (nonwarriors) wanted more openness to the micro-, meso- and macro-environment, to different levels of schools, academic and sports clubs, and other NGOs. They also postulated changing the rules for building the member levelling system, which they considered unfair.

Among the minority part of the board and the vast majority of members not performing combat roles, an autonomous reflection has developed over time on whether the people holding power in the organisation, i.e. the president and the members of the board, are trustworthy and deserve the positions entrusted to them, as well as on how to get beyond the circle of elitism maintained by the current authorities of the association.

The change of the organisation's management was preceded by a broad action of the opposition group towards the board, which began cooperation with the social and institutional environment of the organisation and prepared a modification of the positioning system. The opposition group (the new collective subject of action) preferred more communal and egalitarian norms and values (aims). They were supported by elements of a new inclusive organisational culture, in opposition to the previous culture characterised (according to the assessments of the majority of the surveyed participants of the organisation) by the elevation of some members and the deprecation of others. In conversations with newly elected members of the board, after the change of the structural status quo of the organisation, manifestations of the dominance of elements of autonomous reflexivity, i.e., focused on change, were noticed over the previously mentioned communicative reflexivity, i.e., maintaining the status quo. The processes of morphogenesis also began to be strengthened by the growing potential for inclusive bridging capital among the new collective subjects of action in the organisation. This potential increased with subsequent successful projects in the social, business, and institutional environment of the organisation.

## **5. A Case Study of the Morphogenetic Cultural Cycle in an Organisations**

In the following, a case study of the emergence of situational logics and practices related to competing contradictions of ideas in the local cultural system and related intergroup interactions will be presented. Empirical illustrations of the course of the morphogenetic cycle of culture will be provided by participant observation data and results collected during a focus group interview with leaders and members of a senior NGO.

In a medium-sized city in Upper Silesia, it operates as a nongovernmental organisation, the University of the Third Age at the Higher School of Pedagogy; since its establishment in 2004 as an independent, ideologically neutral organisation, open to diverse ideas, new paradigms. Within its framework, for the first years, the idea of an open university was implemented through a pluralistic, consensual, and grassroots selection of lecture topics and lecturers. The programme strategy of the UTW Board resulted in high attendance at lectures, courses, and integration events. Then one of the Catholic orders took over the care of the UTW and the entire infrastructure after the WSP. Since then, according to the respondents, a lot has changed at the university. The interviewees claim that currently a representative of the university authorities decides on behalf of seniors about the selection of lecturers and topics of classes. The number of participants and members of the UTW began to systematically decrease. Social tensions on ideological and cultural grounds between the two groups of seniors grew, both on the UTW board and among members. Both groups were divided according to their attitude towards the religious institution that cared for them.

There was ideological rivalry, then intragroup interactions, integration and institutional efforts within two opposing senior communities: increased ideological cohesion, internal reorganisation of structures, increased effectiveness of practices of both communities in the city. Social actions undertaken led to the creation of two competing collective entities of action. Within each of the groups, the assumptions of the programme were clarified and effective ideological offensives were organised in marketing. The co-occurring oppositional sets of ideas in the city were subject to gradual changes, introducing pluralism into the local cultural system and its institutional manifestations. At the same time, supporters of each side of the ideological conflict tried to convince undecided entities of action, e.g., in the City Council and the Seniors' Council, which resulted in a decrease in social cohesion in the studied senior community.

What were the effects (including the effects of resentment) of the course of the local morphogenetic cycle of culture presented above? The new ownership situation of the partner university and UTW began to legitimise the relations of elevation of some members of the organisation and marginalisation of others. A dissonance emerged between the formally equal status of all participants in the organisation and the actual balance of power in the environment and the organisations, which resulted in increased tensions of resentment. The fact that the studied organisation and the environment remained in the state of existing structural and cultural contexts of resentment limited the emergence of innovations in the organisations and blocked participation in broader innovative ecosystems. Therefore, the respondents, who represented the majority of recent UTW members, decided to create a second UTW, secular and more pluralistic, open in terms of worldview. The competitive contradiction led to systemic changes.

Among those who had not yet left the organisations in the initial phase of the conflict, the mechanism of double axiological consciousness, double thinking, and valuation – official and private – was at work. As a result, autonomous subjects of action emotionally and

reflectively worked through their interactions in the context of resentment. Then they made decisions to migrate to a new environment, open to introduce social innovations. The mechanism of accepting change as a negation of the previous state was at work.

Within the local community, the cultural system legitimised the existing sociocultural context through the emergence of competing sets of ideas and opposing values. Diversity encouraged systemic innovation because it “unpredictably broadens cultural horizons; coherence stays at home to systematically embellish and colour the cultural environment” (Archer, 2015).

Competing contradictions (diversity) in the area of ideas and worldviews had socio-cultural effects in the form of specialisation within the senior groups studied, which over time took the form of sectoral groups, i.e., differentiating themselves in relation to the social environment more horizontally than polarisation. In other words, initially competing groups stopped defining themselves through mutual opposition, but as differences in relation to the entire environment. A feedback mechanism was in operation: Specialisation provoked and reinforced further differentiation of ideas and horizontal sociocultural differentiation within autonomous and increasingly active local senior environments.

## 6. Results

Based on the adopted theoretical assumptions and the results of the presented qualitative research (FGI), it was concluded that organisational morphostasis occurs when the following endogenous conditions coexist, limiting innovative activities among members of the studied NGOs. The agency of members is based to a greater extent on communicative reflexivity, which favours organisational and group persistence, than on autonomous reflexivity, open to change. There are no new collective entities of action in NGOs questioning the existing status quo, i.e., there is contextual continuity (structural and/or cultural). The tensions and group resentments resulting from the above contexts petrify the structural and cultural continuity of NGOs. At the same time, the predominance of components of binding social capital maintains the existing contextual continuity and a relatively permanent level of tensions and resentment distances.

On the other hand, organisational morphogenesis occurs when the following conditions stimulating the activities of the studied NGOs coexist. Agency of the organisation members is based to a greater extent on autonomous reflexivity, which is conducive to innovation, than on stabilising communicative reflexivity. New collective subjects of action are formed, or more precisely, new interests (structural conditions) and group values (cultural conditions), i.e. there is a structural and/or cultural discontinuity. Group tensions and resentments inscribed in the structural and cultural contexts of the organisation dynamize the course of the

organisational morphogenesis process. The predominance of components of social capital that bridge social capital facilitates breaking the existing status quo in the organisation, introducing innovations. In the cultural morphogenetic cycle, the cultural context facilitates breaking potential resentful structural contexts, through the existence of competing ideas and values and sociocultural interactions realising them. In this way, it facilitates systemic innovations.

## **7. Conclusions and Discussion**

The authors have not found operational approaches to the types of reflexivity that accompany the processes of duration and change in organisations, nor the cultural determinants of the formation of resentment barriers to agency. Therefore, it was assumed that the analysis of organisational activities burdened with group resentments, in accordance with the Archer directives on the relationship between structure, culture, and agency and Scheler's assumptions on the occurrence of resentful tensions, should include the coconditioning of structural and cultural factors and the possibility of agency in their context of the organisation's members. On their basis, an original research procedure was created to diagnose the potentials of resentful structural and cultural contexts and to explain the operation of their effects in a situation of contextual continuity or discontinuity. A comparison of the FGI results gives grounds for the conclusion that morphostatic attitudes and the type of communicative reflexivity dominate among the respondents. Similar results were obtained by the behavioural economics team of the Polish Economic Institute. Fear of change and risk taking has been found to be the main variable that disrupts innovation activities for most members of Polish business organisations (Hryniewicz, 2021).

The challenge for the future remains the identification of further mechanisms that burden the processes of group, organisational, and institutional innovation with resentment. This will only be possible with the use of a multidisciplinary approach to the search for the sources of tensions and social traumas. It also seems necessary to use theoretical triangulations that will broaden cognitive perspectives on such a difficult issue.

## References

1. ADP Research Institute (2020). *People at Work 2021: A Global Workforce View*, <https://www.adp.pl/wszystko-o-kadrach/zaangazowanie-pracownikow-zarzadzanie-talentem/people-at-work-2021-a-global-workforce-view/>, 2.05.2021.
2. Archer, M. (1995). *Realist Social Theory: the Morphogenetic Approach*. Cambridge: Cambridge University Press, pp. 303-304, 309-323.
3. Archer, M. (1996). *Culture and Agency. The Place of Culture in Social Theory*. Cambridge: Cambridge University Press.
4. Archer, M. (2003). *Structure, Agency and the Internal Conversation*. Cambridge: Cambridge University Press, pp. 342-361.
5. Archer, M. (2005). Structure, Culture and Agency. In: M. Jacobs, N. Hanrahan, *The Blackwell Companion to the Sociology of Culture*. Oxford: Blackwell Publishing, pp. 17-34.
6. Archer, M. (2007). *Making our Way through the World. Human Reflexivity and Social Mobility*. Cambridge: Cambridge University Press.
7. Archer, M. (2007). Social Integration, System Integration and Global Governance. In: I. Rossi (Ed.), *Frontiers of Globalization Research* (pp. 221-224). New York, NY, USA: Springer.
8. Archer, M. (2010). Can Reflexivity and Habitus Work in Tandem? In: M. Archer, *Conversations About Reflexivity* (pp. 123-143). London/New York: Routledge.
9. Archer, M. (2010). *Conversations About Reflexivity*. London/New York: Routledge.
10. Archer, M. (2010). Morphogenesis versus structuration: On combining structure and action. *Br. J. Sociol.*, 61, pp. 225-252.
11. Archer, M. (2012). *The Reflexive Imperative in Late Modernity*. Cambridge, UK: Cambridge University Press.
12. Archer, M. (2013). *Człowieczeństwo. Problem sprawstwa*. Kraków: Zakład Wydawniczy NOMOS, pp. 270-283.
13. Archer, M. (2014). Structural Conditioning and Personal Reflexivity. In: D. Finn, *Distant Markets, Distant Harms: Economic Complicity and Christian Ethics*. Oxford: Oxford University Press.
14. Archer, M. (2015). How Agency is Transformed in the course of Social Transformation: Don't forget the double morphogenesis. In: M. Archer, *Generative Mechanisms Transforming the Social Order*. New York: Springer.
15. Archer, M. (2015). Morfogeneza: ramy wyjaśniające realizmu. *Uniwersyteckie Czasopismo Socjologiczne UKSW*, 10, pp. 16-46.
16. Archer, M. (2016). *Morphogenesis and the Crisis of Normativity In Introduction, Does Social Morphogenesis Threaten the Rule of Law?* New York, NY, USA: Springer.

17. Archer, M. (2019). *The Morphogenetic Approach; Critical Realism's Explanatory Approach. In Agency and Causal Explanations in Economics*. In: P. Róna, L. Zsolnai (Eds.), *series Virtues and Economics*. Berlin/Heidelberg, Germany: Springer.
18. Baum, J., Haveman, H. (2020). Editors' Comments: The Future of Organizational Theory. *Academy Management Review*, 45(2), pp. 268-272, <https://doi.org/10.5465/amr.2020.0030>.
19. Berrett, J.L. (2022). Linking overhead expenses and nonprofit effectiveness: Evidence from habitat for humanity. *Nonprofit Management and Leadership*, 32(4), pp. 509-530. <https://doi.org/10.1002/nml.21492>.
20. Bogdanienko, J. (2020), *Ryzyko i kryzys w procesie rozwoju organizacji*. Warszawa: CeDeWu.
21. Boguszewski, R. (2016). *Spółczesność obywatelska w Polsce A.D. 2012*, (cbos.pl).
22. Brillman, J. (2002). *Nowoczesne koncepcje i metody zarządzania*. Warszawa: PWE.
23. Brzeziński, M. (2020). Zdolności organizacyjne przedsiębiorstwa – ujęcie procesowe. In: S. Gregorczyk, G. Urbanek (Ed.), *Zarządzanie strategiczne w dobie cyfrowej gospodarki sieciowej* (pp. 367-383). Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
24. Bukłaha, E., Cabała, P. (2022). Przydatność wybranych koncepcji zarządzania zmianą w świecie VUCA. *Studia i Prace Kolegium Zarządzania i Finansów*, z. 185, pp. 119-131.
25. Burt, R.S. (1997). The contingent value of social capital. *Administrative Science Quarterly*, 42.
26. Coleman, J.S. (1988). Social Capital in the Creation of Human Capital. *The American Journal of Sociology*, 94, Supplement. Organizations and Institutions: Sociological and Economic Approaches to the Analysis of Social Structure. Chicago: The University of Chicago Press.
27. Czapiński, J., Panek, T. (2014). *Diagnoza Społeczna 2013. Warunki i jakość życia Polaków*. Warszawa.
28. de Mozota, B. (2006). The four powers of design: a value model in Design Management. *Design Management Review*, vol. 17, no. 2.
29. Dziadkiewicz, A., Juchniewicz, P. (2013). Koncepcja zarządzania zmianą w organizacji. *Research Papers of Wrocław University of Economics*, no. 227.
30. Feliksiak, M. (2022). Aktywność w organizacjach obywatelskich. CBOS. *Komunikat z badań*, nr 41.
31. Flieger, M. (2020). Współczesne kryzysy a elastyczność organizacyjna. *Przegląd Ekonomiczny*, 20, pp. 41-44.
32. Fromm, E. (2011). *Ucieczka od wolności*. Warszawa: Czytelnik.
33. Gocała, P. (2023). Lider, zespół i organizacja w procesie zmian. Zarządzanie innowacyjne w Gospodarce i Biznesie. *Czasopismo naukowe o problemach współczesnego zarządzania. Widok*, no. 2(37) (lodz.pl).
34. Grzybowska, W. (2021). Rola przywództwa w procesie zarządzania zmianą. *Akademia Zarządzania*, 5(2), pp. 70-86.



35. *Harvard Business Review*, <https://hbr.org/>, 20.05.2021.
36. Hensel, P., Glinka, B. (2012). Teoria ugruntowana. In: D. Jemielniak (ed.), *Badania jakościowe. Podejścia i teoria*. Warszawa: PWN.
37. Hryniewicz, J. (2021). The Sociocultural and Economic Premises of Quality of Governance and Bureaucratic Efficiency in Central East European Regions in the Context of the EU. *Pol. Soc. Rev.*, 214, pp.183-198.
38. Iansiti, M., Lakhani, K.R. (2020). *Competing in the Age of AI: Strategy and Leadership when Algorithms and Networks Run the World*. Harvard Business Review Press.
39. Ingram, T. (2023). *Odporność organizacyjna przedsiębiorstw rodzinnych*. Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach.
40. Kemper, T.D. (1984). Power, status, and emotions: A sociological approaches to the sociology of emotion. In: P. Ekman (ed.), *Approaches to emotions*. Hillsdale, New York: Lawrence Erlbaum.
41. Kłoskowska, A. (1981). *Socjologia kultury*, Warszawa: PWN, p. 286.
42. Kłoskowska, A. (1999). *Kultura. Encyklopedia socjologii, T. 2*. Warszawa: Oficyna Wydawnicza, pp. 103-104.
43. Konecki, K., Chomczyński, P. (2012). *Słownik socjologii jakościowej*. Warszawa: Difin.
44. Lazarević, S., Lukić, J. (2018). Team Learning Processes and Activities in Organization: A Case Study. *Economic Themes*, 56(3), pp. 301-319, doi: <https://doi.org/10.2478/ethemes-2018-0018>.
45. Lewandowski, M. (2021). *Organizacyjne zdolności kadrowania*. Warszawa: PWN.
46. Malinowski, B. (1958). Naukowa teoria kultury. In: *Szkice z teorii kultury*. Warszawa: Książka i Wiedza.
47. Murray, R., Caulier-Grice, J., Mulgan, G. (2010). *Open book of Social Innovation*. London: Young Foundation.
48. Parsons, T. (1937). *The Structure of Social Actions*. New York: McGraw Hill.
49. Portes, A. (1998). Social Capital: Its Origins and Applications in Modern Sociology. *Annual Review of Sociology*, 4, 15-18.
50. Sarran, H.P., Clark, D., Mendonca, K. (2019). *Change Management Toolkit, Tips, tools, and techniques for leading a successful change initiative*. Berkeley University of California, [hr.berkeley.edu](http://hr.berkeley.edu), 10.09.2023.
51. Scheler, M. (1997). *Resentment a Moralność*. Warszawa: Czytelnik.
52. Scheler, M. (2021). *Cognition and Work: A Study Concerning the Value and Limits of the Pragmatic Motifs in the Cognition of the World*. Evanston, IL: Northwestern University Press.
53. Schoeck, H. (2012). *Zawiść. Źródło agresji, destrukcji i biedy*. Warszawa: Wydawnictwo Fijorr Publishing.
54. Sienkiewicz-Małyjurek, K. (2020). Odporność i przedsiębiorczość w zarządzaniu kryzysowym. *Ekonomia Społeczna*, 2, pp. 22-36.

55. Skąpska, G. (1991). *Prawo i dynamika społecznych przemian*. Kraków: Wydawnictwo Uniwersytetu Jagiellońskiego.
56. Thompson, E. (2002). *Gombrowicz*. Katowice: Wydawnictwo Uniwersytetu Śląskiego.
57. Weryński, P. (2010). *Wzory uczestnictwa obywatelskiego Polaków*. Warszawa: IFiS PAN.
58. Weryński, P. (2022). Resentment barriers to innovation development of small and medium enterprises in Upper Silesia. *Sustainability*, 14(23), 1-30.
59. Weryński, P., Dolińska-Weryńska, D. (2021). Agency barriers of members of senior Silesian NGOs in the implementation of social innovation (Poland). *Sustainability*, 13, 3734.
60. Westley, F. (2013). *Social Innovation and Resilience: How One Enhances the Other*, [http://www.ssireview.org/articles/entry/social\\_innovation\\_and\\_resilience\\_how\\_one\\_enhances\\_the\\_other](http://www.ssireview.org/articles/entry/social_innovation_and_resilience_how_one_enhances_the_other), 26.11.2023.
61. Woolcock, M. (1998). Social capital and economic development: Toward a theoretical synthesis and policy framework. *Theory and Society*, 27(2), 172.
62. Wronka-Pośpiech, M. (2015). Innowacje społeczne – pojęcie i znaczenie. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, nr 212. Katowice.
63. Wybrańczyk, K., Szromek, A.R. (2018). Postawy pracownika wobec zmian oraz wybrane koncepcje wprowadzania zmian w postawach pracowniczych. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, z. 131, pp. 611-622.
64. Zarycki, T., Warczok, T. (2014). Hegemonia inteligentka: Kapitał kulturowy we współczesnym polskim polu władzy. In: *Kultura i społeczeństwo*, 58(4), pp. 39-42.
65. Znaniecki, F. (1936). *Social Actions*. New York: Farrar and Rinehart.

## CYBERSECURITY ANALYTICS: LEVERAGING BUSINESS ANALYTICS IN INDUSTRY 4.0 SETTINGS

Radosław WOLNIAK

Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; [rwolniak@polsl.pl](mailto:rwolniak@polsl.pl), ORCID: 0000-0003-0317-9811

**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in cybersecurity analytics.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** The integration of business analytics into cybersecurity practices within Industry 4.0 signifies a pivotal advancement in safeguarding organizational assets against the evolving cyber threat landscape. As industrial systems grow more complex and interconnected, traditional security methods focused on perimeter defenses are increasingly inadequate. Modern cybersecurity strategies must therefore incorporate advanced analytics to manage and mitigate risks effectively. Business analytics enhances cybersecurity through sophisticated machine learning algorithms, predictive capabilities for anticipating future threats, and improved incident response via real-time monitoring and automated alerts. These innovations foster a proactive and efficient security approach, enabling swift detection, response, and informed decision-making based on thorough risk assessments. Despite these advantages, challenges such as data overload, false positives, integration hurdles, and the need for specialized expertise persist. Additionally, concerns about data privacy, costs, and analytical complexity must be managed. Embracing business analytics while addressing these challenges will enable organizations to fortify their security posture, optimize resource use, and adapt to the demands of Industry 4.0, thereby shaping the future of cybersecurity in a rapidly evolving digital landscape.

**Originality/Value:** Detailed analysis of all subjects related to the problems connected with the usage of business analytics in the case of cybersecurity analytics.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; cybersecurity.

**Category of the paper:** literature review.

## 1. Introduction

As more devices and systems interact within complex industrial networks, the number of entry points for potential attacks increases. The traditional approach to security, which focused on protecting the perimeters of systems and networks, proves inadequate in the face of modern, distributed architectures. Cybercriminals exploit vulnerabilities not only in hardware and software but also within the dynamically evolving IT and operational technology (OT) environments.

In the context of Industry 4.0, cybersecurity analytics aims not only to identify threats but also to predict and prevent potential attacks. Modern analytical systems leverage advanced machine learning algorithms and artificial intelligence to process the vast amounts of data generated by devices and systems. This approach enables the detection of patterns and anomalies that may indicate security breaches. Such analytics not only allow for real-time monitoring and risk assessment but also facilitate the early detection of potential threats before they escalate into significant incidents.

The implementation of techniques like automated incident response has become indispensable. In the realm of Industry 4.0, where the speed of response can determine the extent of damage, automation enables swift and effective actions to mitigate the impact of incidents. Automated systems can isolate affected components, adjust network configurations, or initiate recovery procedures, thereby minimizing disruptions to industrial operations (Scappini, 2016).

In addition to technological aspects, understanding the human factor in managing security in the Industry 4.0 era is also crucial. Organizations must invest in training their personnel to ensure they are well-versed in the threats and defensive strategies. Effective management of risk and protection of resources requires collaboration between IT and OT teams, supported by appropriate policies and procedures. This holistic approach is essential for safeguarding the integrity and continuity of operations in an increasingly interconnected and complex industrial landscape.

The purpose of this publication is to present the applications of usage of business analytics in cybersecurity analytics.

## **2. The selected aspects of business analytics usage in cybersecurity analytics**

Business analytics has increasingly become a critical component in the field of cybersecurity, offering powerful tools and methodologies to enhance the effectiveness of security measures. In particular, several aspects of business analytics play a pivotal role in optimizing cybersecurity strategies and operations.

One of the primary aspects of business analytics in cybersecurity is predictive analytics. By leveraging historical data and advanced statistical models, organizations can anticipate potential security threats before they manifest. Predictive analytics utilizes machine learning algorithms to identify patterns and anomalies in network traffic, user behavior, and system performance. This proactive approach allows cybersecurity teams to implement preventive measures and bolster defenses against emerging threats, rather than reacting to incidents after they occur.

Another crucial aspect is the use of risk analytics, which helps organizations assess and prioritize security risks based on their potential impact and likelihood. Risk analytics involves quantifying and evaluating vulnerabilities in the context of business operations and objectives. By analyzing factors such as asset value, threat landscape, and existing controls, risk analytics enables organizations to make informed decisions about where to allocate resources and which security measures to prioritize. This strategic approach ensures that security efforts are aligned with the overall business strategy and effectively mitigate the most significant risks (Akundi et al., 2022).

Business analytics enhances incident response and management through real-time monitoring and analysis. Security information and event management (SIEM) systems, which are integral to modern cybersecurity frameworks, utilize business analytics to collect, correlate, and analyze data from various sources (Ghibakholl et al., 2022). This real-time visibility allows cybersecurity teams to detect and respond to incidents swiftly, minimizing the potential impact on the organization. Advanced analytics tools can sift through vast amounts of log data and identify indicators of compromise, enabling quicker identification of breaches and more effective containment strategies (Gajdzik, Wolniak, 2022; Gajdzik et al., 2023).

Also business analytics contributes to improving threat intelligence by aggregating and analyzing data from diverse sources, including external threat feeds, social media, and industry reports. This comprehensive view enhances the understanding of the threat landscape and helps organizations stay ahead of emerging threats and trends (Bakir, Dahlan, 2022). By incorporating threat intelligence into their security strategies, organizations can better anticipate and prepare for sophisticated cyber attacks, ensuring a more resilient defense posture (Cillo et al., 2022).

Business analytics supports continuous improvement in cybersecurity practices through performance measurement and benchmarking. By analyzing metrics such as incident response times, detection rates, and compliance levels, organizations can evaluate the effectiveness of their security measures and identify areas for enhancement. This data-driven approach facilitates ongoing optimization of cybersecurity processes and ensures that security investments deliver tangible benefits (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023).

Table 1 contains descriptions of how business analytics is used in the case of cybersecurity analytics.

**Table 1.**

*The usage of business analytics in cybersecurity analytics*

Aspect of cybersecurity analytics	Description of Usage of Business Analytics
Predictive Analytics	Business analytics utilize predictive models and machine learning algorithms to analyze historical data and identify patterns or anomalies that may indicate potential security threats. This approach allows organizations to anticipate and prepare for future cyber threats, improving their proactive defenses and reducing the likelihood of successful attacks.
Risk Analytics	Risk analytics involves assessing and quantifying vulnerabilities in the context of business operations. By analyzing asset values, threat landscapes, and existing controls, organizations can prioritize security measures based on the potential impact and likelihood of risks. This strategic approach ensures that resources are allocated effectively to mitigate the most significant risks.
Real-Time Monitoring	Business analytics are employed in real-time monitoring through Security Information and Event Management (SIEM) systems. These systems collect and analyze data from various sources to detect and respond to security incidents swiftly. Advanced analytics tools help identify indicators of compromise, enabling quicker responses and effective containment strategies.
Threat Intelligence	By aggregating and analyzing data from diverse sources such as external threat feeds, social media, and industry reports, business analytics enhance threat intelligence. This comprehensive analysis improves understanding of the threat landscape, helps anticipate emerging threats, and strengthens defensive measures against sophisticated cyber attacks.
Performance Measurement	Business analytics track and measure various cybersecurity metrics, including incident response times, detection rates, and compliance levels. Analyzing these metrics allows organizations to evaluate the effectiveness of their security measures, identify areas for improvement, and optimize cybersecurity processes to ensure better protection of critical assets.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam, et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

### **3. Software used in cybersecurity analytics analysis in Industry 4.0 conditions**

The usage of business analytics software in cybersecurity analytics has become increasingly critical as organizations strive to protect their digital assets in a landscape of growing and evolving threats. These software solutions leverage advanced analytics, machine learning, and data integration techniques to enhance security operations and incident response capabilities.

One of the most prominent examples of business analytics software in this domain is Splunk. Known for its robust real-time data indexing and search capabilities, Splunk allows security teams to sift through vast amounts of machine-generated data to identify potential security threats. Its customizable dashboards and automated alerting features enable organizations to monitor their systems proactively and respond swiftly to anomalies or incidents accordingly (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecula, Wolniak, 2022; Olkiewicz et al., 2021).

IBM QRadar is another key player, offering a comprehensive security intelligence and analytics platform. QRadar excels in correlating events from diverse sources to provide a unified view of security incidents. Its capabilities include real-time log management, advanced threat detection, and automated incident response, all of which are essential for managing complex threat landscapes and ensuring timely reactions to security breaches.

Sumo Logic provides a cloud-native solution for log management and analytics, which is particularly valuable for organizations operating in a cloud environment. Its real-time analytics and machine learning-based anomaly detection help organizations to gain insights into their security data efficiently. The scalability and flexibility of Sumo Logic make it a suitable choice for modern enterprises seeking to manage and analyze large volumes of data across various platforms.

Elastic Security, built on the Elastic Stack, integrates with existing systems to enhance threat detection and response. It offers a unified search and analytics platform that supports real-time data ingestion and advanced querying. The open-source nature of Elastic Security allows for extensive customization and integration, making it a versatile tool for detecting and mitigating threats in diverse IT environments.

LogRhythm is well-regarded for its centralized log management and advanced correlation features. It combines behavioral analytics with traditional SIEM capabilities to provide a comprehensive view of security events. LogRhythm's automated response features further streamline the process of addressing security incidents, enabling organizations to act quickly and reduce the potential impact of threats.

ArcSight, from Micro Focus, delivers a powerful SIEM solution with real-time event correlation and threat intelligence integration. Its comprehensive log management and compliance reporting functionalities support effective security monitoring and regulatory adherence. ArcSight's ability to correlate events from multiple sources helps organizations to identify and address security issues with greater accuracy.

Microsoft Sentinel, a cloud-native SIEM solution, integrates seamlessly with the Azure ecosystem to provide advanced threat detection and response capabilities. Sentinel leverages AI-driven analytics to enhance threat detection and automate incident management. Its scalability and integration with other Microsoft services make it a compelling choice for organizations leveraging cloud technologies.

Rapid7 InsightIDR offers a cloud-based solution focused on user behavior analytics and endpoint detection. Its automated response capabilities and extensive integrations with other security tools facilitate a proactive approach to threat detection and management. InsightIDR's emphasis on user behavior and endpoint visibility provides valuable insights into potential security risks and vulnerabilities.

ThreatConnect provides a threat intelligence platform designed to aggregate, analyze, and operationalize threat data. It supports threat-sharing and advanced analytics to enhance the understanding of the threat landscape. By integrating threat intelligence into security operations, ThreatConnect helps organizations stay ahead of emerging threats and improve their defensive strategies (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

McAfee Enterprise Security Manager (ESM) provides a comprehensive SIEM solution that emphasizes real-time event correlation and customizable reporting. Its threat intelligence integration and automated response capabilities help organizations manage and respond to security threats effectively, ensuring robust protection for their digital assets (Adel., 2022).

Table 2 highlighting examples of software and applications used in cybersecurity analytics, along with descriptions of their usage.

**Table 2.**

*The usage of business analytics software in cybersecurity analytics*

Software/Application	Description	Key Features
Splunk	Splunk is a comprehensive platform for searching, monitoring, and analyzing machine-generated data in real-time.	Real-time data indexing, advanced search capabilities, customizable dashboards, and automated alerting.
IBM QRadar	IBM QRadar provides integrated security intelligence and analytics to detect and respond to cyber threats.	Log management, real-time correlation of events, advanced threat detection, and automated incident response.
Sumo Logic	Sumo Logic offers cloud-based log management and analytics to gain insights into application and security data.	Cloud-native architecture, real-time analytics, machine learning-based anomaly detection, and scalability.
Elastic Security	Elastic Security is an open-source solution that integrates with the Elastic Stack for threat detection and response.	Unified search and analytics, real-time data ingestion, advanced querying, and customizable visualizations.



Cont. table 2.

LogRhythm	LogRhythm provides security information and event management (SIEM) with advanced analytics for threat detection.	Centralized log management, advanced correlation, behavioral analytics, and automated response capabilities.
ArcSight	ArcSight, by Micro Focus, delivers SIEM solutions for identifying and responding to security threats.	Real-time event correlation, threat intelligence integration, comprehensive log management, and compliance reporting.
Microsoft Sentinel	Microsoft Sentinel is a cloud-native SIEM that leverages machine learning to provide threat detection and response.	Integration with Azure ecosystem, AI-driven threat detection, automated incident management, and scalable analytics.
Rapid7 InsightIDR	InsightIDR by Rapid7 is a cloud-based solution for threat detection and incident response, focusing on user behavior analytics.	User behavior analytics, endpoint detection, automated response, and extensive integrations with other security tools.
ThreatConnect	ThreatConnect offers a threat intelligence platform for aggregating, analyzing, and operationalizing threat data.	Threat intelligence aggregation, advanced analytics, threat-sharing capabilities, and integration with other security systems.
McAfee Enterprise Security Manager (ESM)	McAfee ESM provides a SIEM solution that helps organizations manage and respond to security threats effectively.	Real-time event correlation, customizable reporting, threat intelligence integration, and automated response capabilities.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam, et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

#### 4. Advantages and problems of business analytics usage in cybersecurity analytics

The advantages of utilizing business analytics in cybersecurity analytics are substantial and multifaceted, contributing significantly to the effectiveness and efficiency of security operations. One of the foremost advantages is enhanced threat detection. Business analytics leverage sophisticated algorithms and machine learning techniques to analyze vast amounts of data from various sources. This capability allows organizations to identify patterns and anomalies that might indicate potential security threats more accurately and swiftly than traditional methods. By processing data in real-time, analytics tools can detect irregularities that could signal the presence of a cyber threat, thus improving the chances of catching potential issues before they escalate into serious incidents (Charles et al., 2023).

Predictive capabilities are another crucial benefit of business analytics in cybersecurity. By examining historical data and identifying trends, analytics can forecast future threats and vulnerabilities. This foresight enables organizations to implement preventive measures proactively, thereby reducing the likelihood of successful attacks. Predictive analytics transforms reactive security strategies into proactive ones, allowing organizations to stay ahead

of emerging threats and safeguard their systems more effectively. Improved incident response is a significant advantage of integrating business analytics into cybersecurity practices. Real-time data analysis and automated alerting facilitate rapid detection of and response to security incidents. This timely response minimizes the impact of breaches, reduces downtime, and helps organizations recover more quickly from security events. The ability to automate and accelerate incident response is crucial in mitigating the damage and operational disruptions caused by cyber threats (Nourani, 2021).

Business analytics also enhances effective risk management by providing detailed insights into various risk factors. By analyzing data related to asset value, threat landscapes, and existing controls, organizations can prioritize their security measures based on the potential impact and likelihood of different threats. This targeted approach ensures that resources are allocated efficiently, focusing on the most critical vulnerabilities and threats, and thereby optimizing the overall security posture. Another notable advantage is the improved visibility and monitoring capabilities offered by business analytics. Advanced analytics tools provide comprehensive views of network activity and system performance, which enhance visibility into potential security issues. Continuous monitoring through these tools enables organizations to detect and address anomalies promptly, ensuring a proactive stance on security management.

Data-driven decision-making is significantly supported by business analytics, as these tools offer actionable insights derived from extensive data analysis. This information empowers security teams to make informed decisions regarding security strategies, resource allocation, and policy adjustments. Data-driven approaches enhance the effectiveness of security measures and help align them with organizational goals and risk management priorities. Automated threat intelligence is a further benefit of using business analytics in cybersecurity. By integrating threat intelligence feeds with analytics tools, organizations can automate the detection of known threats and vulnerabilities. This integration streamlines the process of identifying and addressing potential risks, reducing the manual effort required to keep up with the constantly evolving threat landscape.

Scalability and flexibility are additional advantages provided by modern business analytics solutions, particularly those that are cloud-based. These solutions allow organizations to handle large volumes of data efficiently and adapt to growing data needs as their operations expand. The ability to scale resources and manage data dynamically supports the effective analysis of complex and voluminous security data. Improved compliance and reporting are also facilitated by business analytics. Analytics tools generate detailed reports and dashboards that assist organizations in meeting regulatory requirements and internal security policies. These reports provide valuable insights into security performance and compliance status, ensuring better oversight and documentation of security practices. Also, behavioral analysis is an important aspect of business analytics in cybersecurity. By monitoring user and entity behavior, analytics tools can identify deviations from normal patterns that may suggest insider threats or

compromised accounts. This capability enhances the ability to detect and respond to potential threats originating from within the organization (Greasley, 2019).

Table 3 contains the advantages of using business analytics in cybersecurity analytics within Industry 4.0 conditions, along with descriptions for each advantage. This table highlights the key advantages of leveraging business analytics in cybersecurity analytics, demonstrating how these tools enhance threat detection, response, and overall security management.

**Table 3.**

*The advantages of using business analytics in cybersecurity analytics*

<b>Advantage</b>	<b>Description</b>
Enhanced Threat Detection	Business analytics utilize advanced algorithms and machine learning to identify patterns and anomalies in vast amounts of data, improving the accuracy and speed of detecting potential security threats.
Predictive Capabilities	By analyzing historical data and trends, business analytics can forecast potential future threats and vulnerabilities, allowing organizations to implement preventive measures before incidents occur.
Improved Incident Response	Real-time data analysis and automated alerting help cybersecurity teams respond quickly to threats, reducing the impact of incidents and minimizing downtime.
Effective Risk Management	Business analytics provide detailed insights into risk factors, helping organizations prioritize security measures based on the potential impact and likelihood of various threats.
Enhanced Visibility and Monitoring	Advanced analytics offer comprehensive views of network activity and system performance, enabling better visibility into potential security issues and facilitating continuous monitoring.
Data-Driven Decision Making	Analytics tools provide actionable insights based on data, supporting informed decision-making for security strategies and resource allocation.
Automated Threat Intelligence	Integration of threat intelligence feeds with business analytics helps automate the detection of known threats and vulnerabilities, streamlining the identification of potential risks.
Scalability and Flexibility	Business analytics solutions, particularly cloud-based ones, offer scalability and flexibility, allowing organizations to manage and analyze large volumes of data efficiently as their needs grow.
Improved Compliance and Reporting	Analytics tools help generate detailed reports and dashboards that facilitate compliance with regulatory requirements and internal security policies, ensuring better oversight and documentation.
Behavioral Analysis	Business analytics enable the monitoring of user and entity behavior, identifying deviations from normal patterns that may indicate insider threats or compromised accounts.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam, et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Table 4 contains the problems of using business analytics in cybersecurity analytics within Industry 4.0 conditions, along with descriptions for each advantage. This table highlights some of the common problems associated with the use of business analytics in cybersecurity, illustrating the challenges that organizations might face in leveraging these tools effectively.

**Table 4.***The problems of using business analytics in cybersecurity analytics*

<b>Problem</b>	<b>Description</b>
Data Overload	The sheer volume of data generated by cybersecurity systems can be overwhelming, making it challenging to identify and focus on relevant information.
False Positives	Analytics systems may generate false positives, flagging benign activities as threats, which can lead to unnecessary alerts and wasted resources.
Integration Challenges	Integrating business analytics tools with existing cybersecurity infrastructure and diverse data sources can be complex and may require significant customization.
Skill Gaps	Effective use of business analytics in cybersecurity requires specialized skills and knowledge, which may not be readily available within an organization.
Data Privacy Concerns	Analyzing large volumes of sensitive data raises concerns about data privacy and compliance with regulations, requiring stringent data protection measures.
High Costs	Implementing and maintaining advanced analytics solutions can be expensive, including costs for software, hardware, and skilled personnel.
Complexity of Analysis	The complexity of advanced analytics models can make it difficult to interpret results and take actionable steps, potentially leading to misinformed decisions.
Scalability Issues	As organizations grow, scaling analytics solutions to handle increasing volumes of data and more complex security environments can be challenging.
Dependence on Quality Data	Business analytics are highly dependent on the quality and accuracy of the data being analyzed. Poor data quality can lead to inaccurate or misleading results.
Over-Reliance on Automation	Excessive reliance on automated analytics tools might lead to overlooking contextual factors and nuanced threats that require human intervention and judgment.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam, et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

## 5. Conclusion

The integration of business analytics into cybersecurity practices within the context of Industry 4.0 represents a transformative advancement in protecting organizational assets from the evolving landscape of cyber threats. As industrial environments become increasingly complex and interconnected, the traditional security paradigms that focus solely on perimeter defenses are no longer sufficient. Instead, modern cybersecurity strategies must leverage sophisticated analytics to effectively manage and mitigate risks associated with this new era of digital transformation.

The application of business analytics in cybersecurity analytics offers significant benefits, including enhanced threat detection through advanced machine learning algorithms, predictive capabilities that allow organizations to anticipate and prepare for future threats, and improved incident response through real-time monitoring and automated alerts. These capabilities

collectively contribute to a more proactive and efficient approach to cybersecurity, enabling organizations to not only detect and respond to incidents more swiftly but also to make informed decisions based on comprehensive risk assessments and performance measurements. However, the use of business analytics in cybersecurity is not without its challenges. Issues such as data overload, false positives, integration difficulties, and the need for specialized skills can complicate the effective implementation of analytics solutions. Additionally, concerns about data privacy, high costs, and the complexity of analysis must be addressed to ensure that the benefits of analytics outweigh the potential drawbacks.

As organizations continue to adapt to the demands of Industry 4.0, it is essential to approach business analytics in cybersecurity with a balanced perspective, recognizing both its transformative potential and its inherent limitations. By addressing these challenges and leveraging the strengths of analytics, organizations can enhance their security posture, optimize resource allocation, and improve their overall resilience against cyber threats. The ongoing evolution of business analytics technologies and practices will undoubtedly play a critical role in shaping the future of cybersecurity, making it imperative for organizations to stay informed and agile in their approach to digital security.

## 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. Cam, J.D., Cochran, J.J., Ohlmann, M.J.F. (2021). *Business analytics: descriptive, predictive, prescriptive* Boston: Cengage.
6. Charles, V., Garg, P., Gupta, N., Agrawal, M. (2023). *Data Analytics and Business Intelligence: Computational Frameworks, Practices, and Applications*. New York: CRS Press.
7. 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.

8. Dameri, R.P. (2016). Smart City and ICT. Shaping Urban Space for Better Quality of Life. In: *Information and Communication Technologies in Organizations and Society*. Cham, Switzerland: Springer International Publishing.
9. 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.
10. Dutta, J., Roy, S., Chowdhury, C. (2019). Unified framework for IoT and smartphone based different smart city related applications. *Microsystem Technologies*, 25(1), 83-96.
11. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W. (2024). Diagnosis of the development of energy cooperatives in Poland - a case study of a renewable energy cooperative in the upper Silesian region. *Energies*, 17(3), 1-27, 647.
12. Gajdzik, B., Bartuś, K., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W.W. (2024). Evolution of Polish E-Consumers' Environmental Awareness and Purchasing Behavior over Ten Years. *Sustainability*, 16(11), 4686.
13. Gajdzik, B., Jaciow, M., Wolniak, R. (2024). Gastronomic curiosity and consumer behavior: the impact of television culinary programs on choices of food services. *Foods*, 13(1), 1-16, 115.
14. Gajdzik, B., Siwiec, D., Wolniak, R., Pacana, A. (2024). Approaching open innovation in customization frameworks for product prototypes with emphasis on quality and life cycle assessment (QLCA). *Journal of Open Innovation: Technology, Market, and Complexity*, 10(2), 100268.
15. Gajdzik, B., Wolniak, R. (2021a). 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.
16. Gajdzik, B., Wolniak, R. (2021b). 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.
17. Gajdzik, B., Wolniak, R. (2021c). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, 14(14), 1-22.
18. 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.
19. Gajdzik, B., Wolniak, R. (2022a). 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.
20. Gajdzik, B., Wolniak, R. (2022b). 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.

21. Gajdzik, B., Wolniak, R. (2022c). 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.
22. Gajdzik, B., Wolniak, R., Grebski, W. (2023a). Process of Transformation to Net Zero Steelmaking: Decarbonisation Scenarios Based on the Analysis of the Polish Steel Industry. *Energies*, 16(8), 3384, <https://doi.org/10.3390/en16083384>.
23. Gajdzik, B., Wolniak, R., Nagaj, R., Żuromskaitė-Nagaj, B., Grebski, W. (2024). The influence of the global energy crisis on energy efficiency: a comprehensive analysis. *Energies*, 17(4), 1-49, 947.
24. Gajdzik, B., Wolniak, R., Grebski, W. (2023b). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies*, 16(2), 1-29.
25. Gajdzik, B., Wolniak, R., Grebski, 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.
26. Gajdzik, B., Wolniak, R., Grebski, W.W. (2024). Challenges of industrial systems in terms of the crucial role of humans in the Industry 5.0 environment. *Production Engineering Archives*, 30(1), 1-16.
27. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies*, 16(21), 7364.
28. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government*. Philadelphia: CreativeSpace.
29. 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.
30. 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>.
31. 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".
32. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective*. New York: KDP Publishing.
33. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0*. Warszawa: CeDeWu.
34. Greasley, A. (2019). *Simulating Business Processes for Descriptive, Predictive, and Prescriptive Analytics*. Boston: deGruyter.

35. 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.
36. 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.
37. 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.
38. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, 220, 115-123.
39. 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.
40. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics*. New York: Wiley.
41. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, 9, 1000-1002.
42. 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.
43. 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.
44. Jonek-Kowalska, I., Wolniak, R. (2021a). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, 114, 1-6.
45. Jonek-Kowalska, I., Wolniak, R. (2021b). 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.
46. 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.
47. Jonek-Kowalska, I., Wolniak, R. (2023). *Towards sustainability and a better quality of life?* London: Routledge.
48. 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.
49. 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.



50. 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.
51. Michalak, A., Wolniak, R. (2023). The innovativeness of the country and the renewables and non-renewables in the energy mix on the example of European Union. *Journal of Open Innovation: Technology, Market, and Complexity*, 9(2), <https://doi.org/10.1016/j.joitmc.2023.100061>.
52. Nagaj, R., Gajdzik, B., Wolniak, R., Grebski, W. (2024). The impact of deep decarbonization policy on the level of greenhouse gas emissions in the European Union. *Energies*, 17(5), 1-23, 1245.
53. Nourani, C.F. (2021). *Artificial Intelligence and Computing Logic: Cognitive Technology for AI Business Analytics (Innovation Management and Computing)*. New York: CRC Press.
54. 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.
55. 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.
56. 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.
57. 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.
58. Peter, G.S., Amit, C.B., Deokar, V., Patel, N.R. (2023). *Machine Learning for Business Analytics: Concepts, Techniques and Applications in RapidMiner*. New York: Wiley.
59. 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.
60. Rosak-Szyrocka, J., Żywiołek J., Wolniak, R. (2023). Main reasons for religious tourism - from a quantitative analysis to a model. *International Journal for Quality Research*, 1(17), 109-120.
61. Scappini, A. (2016). *80 Fundamental Models for Business Analysts: Descriptive, Predictive, and Prescriptive Analytics Models with Ready-to-Use Excel Templates*. New York: Create Space.
62. Stawiarska, E., Sz wajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy*. Warszawa: CeDeWu.

63. Stawiarska, E., Szwałca, D., Matuszek, 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.
64. 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.
65. Stecuła, 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.
66. Wolniak, R., Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgia*, 53(4), 709-713.
67. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością*. Gliwice: Wydawnictwo Politechniki Śląskiej.
68. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji*, 3, 13-17.
69. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, 3, 20-25.
70. Wolniak, R. (2016a). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, 1, 109-122.
71. Wolniak, R. (2016b). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
72. Wolniak, R. (2016c). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, 87, 443-453.
73. Wolniak, R. (2016d). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji*, 3, 127-134.
74. Wolniak, R. (2017a). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie*, 2, 139-150.
75. Wolniak, R. (2017b). 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.
76. Wolniak, R. (2017c). 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.
77. Wolniak, R. (2017d). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji*, 6, 247-255.
78. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 151, 725-734.

79. Wolniak, R. (2022a). Innovations in Industry 4.0 conditions. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 169, 725-741.
80. Wolniak, R. (2022b). Functioning of real-time analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 659-677.
81. Wolniak, R. (2023a). Deskryptywna analiza danych. *Zarządzanie i Jakość*, 5(2), 282-290.
82. Wolniak, R. (2023b). Smart biking w smart city. *Zarządzanie i Jakość*, 5(2), 313-328.
83. Wolniak, R. (2023c). Analiza w czasie rzeczywistym. *Zarządzanie i Jakość*, 5(2), 291-312.
84. Wolniak, R. (2023d). Smart mobility jako element koncepcji smart city. *Zarządzanie i Jakość*, 5(2), 282-290.
85. Wolniak, R., Gajdzik, B., Grebski, M., Danel, R., Grebski, W.W. (2024). Business Models Used in Smart Cities—Theoretical Approach with Examples of Smart Cities. *Smart Cities*, 7(4), 1626-1669.
86. Wolniak, R., Jonek-Kowalska, I. (2021a). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon)*, 34(3), 376-398.
87. Wolniak, R., Jonek-Kowalska, I. (2021c). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, 37, 132-150.
88. 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.
89. 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.
90. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1*. Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
91. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach*. Gliwice: Wydawnictwo Politechniki Śląskiej.
92. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów*. Gliwice: Wydawnictwo Politechniki Śląskiej.
93. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the conditions of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, 7, 1-17.
94. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, 15(2), 1-23.
95. Wolniak, R., Skotnicka-Zasadzień, B. (2023). Development of Wind Energy in EU Countries as an Alternative Resource to Fossil Fuels in the Years 2016-2022. *Resources*, 12(8), 96.

96. 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.
97. Wolniak, R., Stecuła, K. (2024). Artificial Intelligence in Smart Cities—Applications, Barriers, and Future Directions: A Review. *Smart Cities*, 7(3), 1346-1389.
98. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości*, 9, 4-9.
99. 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.
100. 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.

## THE USAGE OF TAGUCHI METHODS IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK

Silesian University of Technology, Organization and Management Department, Economics and Informatics  
Institute; rwolniak@polsl.pl, ORCID: 0000-0003-0317-9811

**Purpose:** The purpose of this publication is to present the usage of Taguchi methods approach in Industry 4.0 conditions.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** The integration of Taguchi methods with Industry 4.0 signifies a profound advancement in manufacturing and quality management. Industry 4.0, with its advanced digital technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and cyber-physical systems, creates an environment that significantly enhances Taguchi's principles. This integration facilitates a more dynamic approach to process optimization, leveraging real-time data and sophisticated analytics to achieve superior quality and efficiency. Real-time data collection and advanced analytics enable precise application of Taguchi's experimental designs, enhancing responsiveness to process variations and improving product quality. Digital twins and automated process control systems further support robust design by allowing virtual testing and continuous adjustments. However, challenges such as data integration complexity, high implementation costs, and the integration of legacy systems must be addressed through strategic planning and investment. Overcoming these challenges can lead to substantial benefits, including improved data utilization, enhanced process optimization, and greater flexibility, driving significant advancements in manufacturing capabilities and operational excellence.

**Originality/Value:** Detailed analysis of all subjects related to the problems connected with the usage of Taguchi methods in Industry 4.0 conditions.

**Keywords:** Industry 4.0, Quality 4.0, quality management, quality methods, Taguchi methods.

**Category of the paper:** literature review.

### 1. Introduction

In the context of Industry 4.0, which represents a transformative era characterized by the integration of advanced technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and cyber-physical systems, the Taguchi methods find renewed

relevance and application. Industry 4.0 is marked by the digitalization and connectivity of manufacturing processes, resulting in unprecedented opportunities for optimization, efficiency, and quality improvement.

One of the primary ways in which Taguchi methods can be effectively utilized in Industry 4.0 is through the enhanced data collection and analysis capabilities provided by modern digital technologies. In traditional manufacturing settings, Taguchi's methods relied on physical experimentation and manual data collection. However, Industry 4.0 introduces sophisticated sensors and data acquisition systems that continuously monitor and record process parameters in real time. This real-time data facilitates the application of Taguchi's experimental design principles on a much larger scale, allowing for more precise and timely adjustments to processes.

Advanced analytics and machine learning algorithms can process the vast amounts of data generated in an Industry 4.0 environment to identify patterns and correlations that were previously difficult to discern. By integrating Taguchi methods with these analytical tools, organizations can perform more complex and refined analyses of the factors affecting quality and performance. For instance, using machine learning models, manufacturers can simulate various scenarios and predict the impact of different variables on process outcomes, enabling more informed decisions about process optimization (Yanamandra et al., 2023).

The purpose of this publication is to present the usage of Taguchi methods approach in industry 4.0 condition.

## **2. The basics of Taguchi methods approach**

The Taguchi methods, developed by the Japanese engineer and statistician Genichi Taguchi, represent an advanced approach to process optimization and experimental design in the fields of engineering and quality management. The primary goal of these methods is to minimize the impact of variability on product and process quality while simultaneously reducing production costs and enhancing operational efficiency.

A fundamental premise of Taguchi's methods is the belief that quality is influenced not only by controllable factors but also by the effects of random factors that introduce variability. Taguchi introduced the concept of the "loss function", which posits that even minor deviations from specifications can lead to costs for both the manufacturer and the consumer. Consequently, the objective is to design systems and processes to minimize these losses regardless of whether the factors are controllable or not (Barsalou, 2023; Maganga, Taifa, 2023).

The Taguchi methods rely on the application of "design of experiments" (DOE), which facilitates the systematic investigation of how various factors affect product or process quality. A key element is the use of "orthogonal arrays", which allow for efficient and economical

experimental planning. These arrays enable the simultaneous analysis of multiple variables, allowing for the drawing of conclusions with fewer experiments and resources. By using orthogonal arrays, Taguchi methods help identify the most influential factors and their optimal levels, thus improving the overall performance and robustness of processes. Moreover, Taguchi emphasized the importance of designing products and processes to be robust to variations, which means that they should perform consistently under a wide range of conditions. This approach shifts the focus from merely meeting specifications to achieving performance that remains stable despite external fluctuations. In essence, the Taguchi methods advocate for a proactive stance on quality improvement, where the aim is to make products and processes resilient to uncertainties and variations inherent in real-world scenarios.

Industry 4.0 technologies enable greater flexibility and adaptability in manufacturing processes. The real-time feedback provided by digital systems allows for immediate adjustments based on the results of Taguchi-based experiments. This dynamic capability ensures that processes can be continually optimized, rather than relying on static adjustments based on periodic evaluations (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

In the case of cyber-physical systems, where digital and physical processes are tightly integrated, Taguchi methods can be applied to optimize not only individual components but also the entire system's performance. By utilizing digital twins—virtual replicas of physical systems—manufacturers can simulate and analyze the effects of various factors on system behavior without disrupting actual operations. This approach aligns well with Taguchi's emphasis on (Jokovic et al., 2023) design and optimization, as it allows for thorough testing and refinement in a virtual environment before implementation in the physical world. Additionally, the principles of Taguchi methods can be incorporated into the design and implementation of smart manufacturing systems. By embedding Taguchi-based algorithms into production control systems, manufacturers can automate the adjustment of process parameters to maintain optimal performance despite variations and uncertainties. This integration ensures that the principles of robust design are applied consistently across all stages of production (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023).

Overall, the synergy between Taguchi methods and Industry 4.0 technologies enhances the ability to achieve high-quality outcomes, reduce variability, and optimize processes in an increasingly complex and interconnected manufacturing landscape. The combination of real-time data, advanced analytics, and adaptive systems allows for more effective application of Taguchi principles, leading to improved product quality, increased efficiency, and reduced operational costs (Singh et al., 2023).

Table 1 contains description of Taguchi methods key principles. This expanded table provides a thorough explanation of each key principle of Taguchi methods, outlining their significance and application in the context of quality management and process optimization.

**Table 1.**  
*Key principles of Taguchi methods*

Key principle	Description
Robust Design	Robust design is centered on creating products and processes that maintain performance and quality despite variations in external conditions and uncontrollable factors. This principle aims to enhance the reliability and durability of a product by minimizing sensitivity to factors such as material inconsistencies, environmental changes, and operational variations. By incorporating this principle, manufacturers can achieve consistent performance and high quality across a range of conditions, reducing the likelihood of defects and enhancing customer satisfaction.
Loss Function	The loss function introduced by Taguchi quantifies the economic impact of deviations from the target specification of a product or process. According to this principle, any deviation from the desired target results in a loss, even if the product still meets the basic requirements. This loss can manifest as increased costs for repairs, warranty claims, or customer dissatisfaction. The loss function emphasizes that quality improvement should focus not only on meeting specifications but also on minimizing the total cost of quality, which includes both tangible and intangible costs associated with deviations. By applying this principle, organizations can better understand the financial implications of quality and strive for designs and processes that minimize these losses.
Design of Experiments (DOE)	Taguchi's methods incorporate the design of experiments (DOE) to systematically investigate and optimize the effects of various factors on product and process performance. DOE involves planning, conducting, and analyzing controlled experiments to identify the relationships between input factors and output performance. By using Taguchi's orthogonal arrays and other experimental designs, manufacturers can efficiently explore multiple variables and their interactions while minimizing the number of experiments required. This approach helps in identifying the most significant factors and their optimal settings, leading to more informed decision-making and improved process efficiency. It also aids in achieving robust designs by testing products and processes under varied conditions to ensure consistent performance.
Orthogonal Arrays	Orthogonal arrays are a key tool in Taguchi's methods, providing a structured approach to experimental design. These arrays allow for the efficient testing of multiple factors and their interactions while using a reduced number of experiments. By organizing factors into arrays that balance the levels of each factor, Taguchi methods enable a comprehensive analysis of how different variables affect outcomes. This systematic approach helps in identifying the critical factors that influence performance and quality, facilitating more effective optimization and reducing the experimental workload. Orthogonal arrays also support robust design by enabling thorough testing of various conditions to ensure that the product or process remains reliable across different scenarios.
Signal-to-Noise Ratio (SNR)	The Signal-to-Noise Ratio (SNR) is a measure used in Taguchi's methods to quantify the robustness of a product or process. It evaluates the ratio of the desired signal (performance or quality) to the variability (noise) affecting it. By maximizing the SNR, manufacturers aim to enhance the consistency and reliability of their products and processes. High SNR indicates that the product or process performs well relative to the impact of noise factors, resulting in reduced variability and improved quality. Taguchi methods use SNR as a key metric in experimental design and analysis to optimize processes and achieve robust performance.
Control Factors vs. Noise Factors	Taguchi methods differentiate between control factors (variables that can be managed or adjusted) and noise factors (variables that cause variability but cannot be controlled). The objective is to optimize control factors to improve performance while making the system less sensitive to noise factors. By focusing on controlling the impact of noise factors through robust design and optimizing the control factors, manufacturers can enhance product quality and process reliability. This principle emphasizes the importance of designing systems that can maintain consistent performance despite the presence of uncontrollable variations.



Cont. table 1.

Continuous Improvement	Continuous improvement, also known as Kaizen in the context of Taguchi methods, involves an ongoing effort to enhance products, processes, and systems. This principle underscores the importance of regularly evaluating and refining designs and processes to achieve higher quality and efficiency over time. By applying Taguchi's methods to continuously monitor and improve performance, organizations can adapt to changing conditions, incorporate new insights, and maintain competitiveness. Continuous improvement aligns with the overall goal of achieving robust design and minimizing the impact of variability, ensuring sustained progress and excellence in manufacturing and quality management.
------------------------	--

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

### 3. How Taguchi methods method can be integrated with Industry 4.0 and Quality 4.0 concept

The integration of Taguchi methods with Industry 4.0 represents a significant advancement in manufacturing and quality management practices. Industry 4.0, characterized by the seamless integration of digital technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and cyber-physical systems, provides a robust framework for enhancing the application of Taguchi's principles in modern industrial settings. One of the primary benefits of integrating Taguchi methods with Industry 4.0 is the enhancement of real-time data collection capabilities. Industry 4.0 technologies enable continuous monitoring of production parameters through advanced sensors and data acquisition systems. This real-time data allows for immediate feedback and adjustments, aligning well with Taguchi's emphasis on robust design. By leveraging this continuous stream of data, manufacturers can apply Taguchi's experimental designs more dynamically, optimizing processes and maintaining high quality despite variations (Alrabadi et al., 2023).

Advanced analytics and AI further amplify the effectiveness of Taguchi methods in an Industry 4.0 environment. The vast amounts of data generated in modern manufacturing settings can be processed using sophisticated analytics tools and machine learning algorithms. These technologies enable manufacturers to identify intricate patterns and correlations that may not be evident through traditional analysis methods (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). By integrating Taguchi principles with these advanced analytical tools, organizations can perform more nuanced analyses of factors affecting performance and make more informed decisions to optimize process variables. The use of digital twins, which are virtual replicas of physical systems, represents another crucial aspect of integrating Taguchi methods with Industry 4.0. Digital twins allow for the simulation and

analysis of manufacturing processes in a virtual environment. This capability aligns with Taguchi's approach of robust design and optimization by enabling extensive testing and refinement without disrupting actual operations. Through digital twins, manufacturers can evaluate how different factors and conditions impact performance, leading to more effective and efficient process improvements (Bousdekis et al., 2023).

Automated process control systems, empowered by Industry 4.0 technologies, also play a significant role in integrating Taguchi methods. These systems can continuously adjust process parameters based on real-time data, ensuring that performance remains optimal. By applying Taguchi's principles within these automated control systems, manufacturers can maintain robust quality and performance, minimizing deviations and responding swiftly to changes in production conditions. Furthermore, Industry 4.0 enhances the scope and efficiency of experimental design, a core component of Taguchi methods. With the ability to process large datasets and automate experimentation, manufacturers can utilize Taguchi's orthogonal arrays more effectively. This advancement allows for a comprehensive analysis of multiple factors and their interactions, facilitating more precise optimization of processes and designs (Maganga, Taifa, 2023).

Adaptive manufacturing systems, which are integral to Industry 4.0, also benefit from the integration with Taguchi methods. These systems can quickly adapt to changes in production requirements or external conditions, and by applying Taguchi's principles, they can be continuously optimized to ensure robustness and efficiency. This adaptability ensures that processes remain consistent and reliable even as conditions evolve. Predictive maintenance, another significant aspect of Industry 4.0, leverages real-time data and analytics to foresee equipment failures before they occur. Integrating Taguchi methods into predictive maintenance strategies allows for the optimization of maintenance schedules and processes, ensuring that equipment performance is consistently maintained and operational disruptions are minimized (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Industry 4.0 facilitates scalable optimization across multiple production lines and facilities. Taguchi methods can be applied on a larger scale to maintain consistent quality and performance across diverse environments. By utilizing data from various sources, manufacturers can achieve comprehensive improvements and uphold high standards of quality throughout their operations (Jonek Kowalska, Wolniak, 2021; Jonek-Kowalska, Wolniak, 2022).

Table 2 is listing examples of integration of Taguchi methods method with Industry 4.0. This table illustrates how Taguchi methods can be integrated with Industry 4.0 technologies to enhance process optimization, quality control, and overall efficiency in modern manufacturing environments.

**Table 2.**  
*Taguchi methods integration with industry 4.0*

Aspect	Description
Real-Time Data Collection	Industry 4.0 technologies, such as IoT sensors and data acquisition systems, enable continuous monitoring of production parameters. Integrating Taguchi methods with real-time data collection allows for dynamic adjustments and more accurate application of experimental designs to improve process robustness.
Advanced Analytics and AI	The vast amounts of data generated in Industry 4.0 environments can be processed using advanced analytics and artificial intelligence. This integration helps in identifying complex patterns and correlations, allowing for more precise application of Taguchi's experimental designs and optimizing process variables.
Digital Twins	Digital twins—virtual replicas of physical systems—allow for the simulation and analysis of processes in a virtual environment. By integrating Taguchi methods with digital twins, manufacturers can test and optimize designs and processes virtually, reducing the need for physical experiments and enhancing robustness.
Automated Process Control	Industry 4.0 enables the use of automated control systems that can continuously adjust process parameters based on real-time data. Applying Taguchi principles in these systems helps maintain optimal performance by adjusting variables to minimize deviations and ensure robust quality.
Enhanced Experimental Design	With Industry 4.0 technologies, the scope and efficiency of experimental designs are significantly improved. Taguchi's orthogonal arrays can be utilized more effectively to analyze complex interactions between multiple factors, thanks to the ability to process large datasets and automate experimentation.
Adaptive Manufacturing	Industry 4.0 supports adaptive manufacturing systems that can quickly respond to changes in production requirements or external conditions. Integrating Taguchi methods allows these systems to be optimized continuously, ensuring they remain robust and efficient despite variability in the manufacturing environment.
Predictive Maintenance	Predictive maintenance, powered by real-time data and analytics, helps in anticipating equipment failures before they occur. By applying Taguchi methods to maintenance strategies, manufacturers can optimize maintenance schedules and processes to ensure equipment performance remains consistent and robust.
Scalable Optimization	Industry 4.0 technologies facilitate the scaling of optimization efforts across multiple production lines and facilities. Taguchi methods can be applied to large-scale operations to maintain consistent quality and performance across diverse environments, leveraging data from multiple sources for comprehensive improvements.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

Table 3 is describe the advantages Taguchi methods approach usage in industry 4.0. This table provides a clear overview of the various advantages of integrating Taguchi methods with Industry 4.0 technologies, emphasizing the enhanced capabilities and improvements that result from this integration.

**Table 3.***The advantages of Taguchi methods integration with industry 4.0*

<b>Advantage</b>	<b>Description</b>
Enhanced Data Utilization	Industry 4.0 technologies provide access to vast amounts of real-time data through IoT sensors and monitoring systems. Integrating Taguchi methods with these technologies allows for more effective use of this data in optimizing processes and identifying critical factors affecting quality. This results in more precise and informed decision-making.
Improved Process Optimization	The combination of Taguchi's robust design principles with advanced analytics and AI from Industry 4.0 enables more effective and dynamic optimization of manufacturing processes. This integration helps identify optimal settings for various process parameters, leading to improved performance and efficiency.
Real-Time Performance Monitoring	Industry 4.0 provides continuous monitoring capabilities, which when combined with Taguchi methods, allows for real-time adjustments based on experimental results. This leads to immediate improvements in process performance and quality, as deviations can be promptly addressed.
Increased Experimentation Efficiency	With Industry 4.0 tools, such as digital twins and automated experimentation systems, the efficiency of applying Taguchi's experimental designs is greatly enhanced. This results in reduced time and resource expenditure for testing and optimizing processes, while providing more accurate results.
Enhanced Predictive Maintenance	Integrating Taguchi methods with predictive maintenance systems powered by Industry 4.0 technologies helps in optimizing maintenance schedules. By predicting potential failures and adjusting maintenance strategies accordingly, manufacturers can reduce downtime and extend equipment life.
Scalable Quality Improvement	Industry 4.0 technologies enable scalable implementation of Taguchi methods across multiple production lines and facilities. This scalability ensures consistent quality and performance improvements across diverse manufacturing environments, leading to uniform high standards.
Greater Flexibility and Adaptability	The adaptive capabilities of Industry 4.0 systems, when combined with Taguchi's principles, provide greater flexibility in manufacturing. Processes can be adjusted in real-time to accommodate changes in production requirements or external conditions, maintaining robustness and efficiency.
Enhanced Robust Design	Taguchi methods emphasize robust design, and Industry 4.0 technologies support this by allowing comprehensive simulation and analysis through digital twins. This helps ensure that products and processes are designed to perform reliably under various conditions, reducing variability and improving overall quality.
Cost Reduction	By leveraging real-time data, advanced analytics, and automated systems, the integration of Taguchi methods with Industry 4.0 can significantly reduce costs associated with quality control and process optimization. Efficient experimentation and real-time adjustments lead to lower production costs and fewer defects.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

Table 4 is describe the problems of Taguchi methods approach usage in Industry 4.0 and methods to overcome them. This table highlights the potential challenges faced when integrating Taguchi methods with Industry 4.0 technologies, along with strategies for addressing these issues effectively.

**Table 4.**

*The problems of Taguchi methods integration with industry 4.0*

<b>Problems</b>	<b>Description of Problem</b>	<b>Overcoming Strategies</b>
Data Integration Challenges	Integrating data from diverse sources such as IoT sensors, manufacturing systems, and enterprise software can be complex. Inconsistent data formats and communication protocols may hinder effective use of Taguchi methods.	Develop a unified data integration framework or middleware that standardizes data formats and facilitates seamless communication between systems. Employ data integration platforms to manage and harmonize data flows.
High Implementation Costs	Implementing Industry 4.0 technologies alongside Taguchi methods may involve significant costs related to new technologies, infrastructure, and training. This can be a barrier for some organizations.	Conduct a cost-benefit analysis to prioritize investments in technology that offers the highest return on investment. Explore phased implementation and incremental upgrades to manage costs more effectively.
Complexity of Systems Integration	The integration of Taguchi methods with complex Industry 4.0 systems, such as digital twins and automated control systems, can be technically challenging and may require specialized knowledge.	Invest in training and upskilling for personnel to handle the complexities of new systems. Collaborate with technology providers and consultants to facilitate smoother integration and implementation processes.
Data Security and Privacy Concerns	The use of real-time data and interconnected systems in Industry 4.0 raises concerns about data security and privacy. Ensuring that sensitive information is protected while integrating with Taguchi methods is crucial.	Implement robust cybersecurity measures, including encryption, access controls, and regular security audits. Develop a comprehensive data protection policy to address privacy concerns and comply with relevant regulations.
Over-Reliance on Automated Systems	Dependence on automated systems for process control and optimization, driven by Industry 4.0 technologies, may lead to reduced human oversight. This can potentially overlook nuanced issues that Taguchi methods aim to address.	Maintain a balance between automation and human oversight. Ensure that key decision points and quality checks involve human expertise to complement automated systems and prevent potential oversight.
Scalability Issues	While Industry 4.0 offers scalability, integrating Taguchi methods across multiple sites or production lines may present challenges, including ensuring consistency and uniformity in process optimization.	Develop standardized procedures and protocols for applying Taguchi methods across different sites. Use centralized data management systems to ensure consistency in process optimization and quality control.

Cont. table 4.

Complexity in Experimental Design	The application of Taguchi's experimental design principles can become more complex when integrated with the high volume of data and multiple variables in Industry 4.0 environments.	Use advanced analytical tools and software to manage and simplify experimental design. Implement automated systems for running and analyzing experiments to reduce complexity and improve efficiency.
Resistance to Change	Employees and management may resist adopting new technologies and methods, such as Taguchi principles integrated with Industry 4.0 tools, due to a lack of familiarity or perceived disruption.	Implement change management strategies, including training programs and clear communication about the benefits of integration. Engage stakeholders early in the process to gain buy-in and support.
Integration of Legacy Systems	Many industries still rely on legacy systems that may not be easily compatible with new Industry 4.0 technologies. Integrating these older systems with Taguchi methods can be problematic.	Explore options for bridging legacy systems with modern technologies through middleware or custom interfaces. Gradually phase out outdated systems while integrating new solutions to ensure compatibility.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

## 4. Conclusion

The integration of Taguchi methods with Industry 4.0 represents a significant leap forward in manufacturing and quality management practices. Industry 4.0, characterized by its use of advanced digital technologies such as IoT, big data analytics, AI, and cyber-physical systems, provides a transformative environment that enhances the application of Taguchi's principles. This convergence allows for a more dynamic and robust approach to process optimization, leveraging real-time data and advanced analytics to achieve superior quality and efficiency.

The real-time data collection capabilities introduced by Industry 4.0 technologies enable more immediate and precise application of Taguchi's experimental designs. This integration facilitates a more agile response to process variations, leading to improved process robustness and product quality. Additionally, the use of advanced analytics and machine learning algorithms in Industry 4.0 environments enriches the analysis of complex data sets, enabling a deeper understanding of factors affecting performance and supporting more informed decision-making.

Digital twins, which offer virtual simulations of physical systems, align closely with Taguchi's emphasis on robust design by allowing extensive testing and optimization in a controlled virtual environment. This capability reduces the need for disruptive physical

experiments and enhances process refinement. Moreover, automated process control systems in Industry 4.0, empowered by Taguchi principles, ensure that processes maintain optimal performance and quality through continuous adjustments based on real-time data.

Despite these advancements, integrating Taguchi methods with Industry 4.0 is not without its challenges. Issues such as data integration complexity, high implementation costs, and the integration of legacy systems require thoughtful strategies and investments. Overcoming these challenges involves developing unified data frameworks, conducting cost-benefit analyses, and implementing robust cybersecurity measures. Additionally, addressing scalability issues, complexity in experimental design, and resistance to change is crucial for successful integration.

The synergy between Taguchi methods and Industry 4.0 technologies promises significant benefits, including enhanced data utilization, improved process optimization, and increased flexibility. This integration not only advances manufacturing capabilities but also contributes to achieving higher standards of quality and operational excellence. By effectively addressing the associated challenges, organizations can harness the full potential of this integration to drive sustained improvements and competitive advantage in the modern industrial landscape.

## References

1. Almeida, S., Abreu, L.P.M. (2024). The Quality Manager in the Industry 4.0 Era. *Lecture Notes in Mechanical Engineering*, 468-474.
2. Alrabadi, T.D.S., Talib, Z.M., Abdullah, N.A.B. (2023). The role of quality 4.0 in supporting digital transformation: Evidence from telecommunication industry. *International Journal of Data and Network Science*, 7(2), 717-728.
3. Amat-Lefort, N., Barravecchia, F., Mastrogiacomo, L. (2023). Quality 4.0: big data analytics to explore service quality attributes and their relation to user sentiment in Airbnb reviews. *International Journal of Quality and Reliability Management*, 40(4), 990-1008.
4. Antony, J., McDermott, O., Sony, M., Cudney, E.A., Doulatbadi, M. (2023). Benefits, challenges, critical success factors and motivations of Quality 4.0—A qualitative global study. *Total Quality Management and Business Excellence*, 34(7-8), 827-846.
5. Antony, J., Sony, M., McDermott, O., Jayaraman, R., Flynn, D. (2023). An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions. *International Journal of Quality and Reliability Management*, 40(2), 582-606.
6. Antony, J., Swarnakar, V., Sony, M., McDermott, O., Jayaraman, R. (2023). How do organizational performances vary between early adopters and late adopters of Quality 4.0? An exploratory qualitative study. *TQM Journal*.

7. Barsalou, M. (2023). Root Cause Analysis in Quality 4.0: A Scoping Review of Current State and Perspectives. *TEM Journal*, 12(1), 73-79.
8. Bousdekis, A., Lepenioti, K., Apostolou, D., Mentzas, G. (2023). Data analytics in quality 4.0: literature review and future research directions. *International Journal of Computer Integrated Manufacturing*, 36(5), 678-701.
9. Escobar, C.A., Macias-Arregoyta, D., Morales-Menendez, R. (2023). The decay of Six Sigma and the rise of Quality 4.0 in manufacturing innovation. *Quality Engineering*.
10. Gajdzik B., Jaciow, M. Wolniak R., Wolny R., Grebski, W. (2024). Diagnosis of the development of energy cooperatives in Poland - a case study of a renewable energy cooperative in the upper Silesian region. *Energies*, 17(3), 1-27.
11. Gajdzik, B., Bartuś, K, Jaciow, M., Wolniak, R., Wolny, R., Grebski, W.W. (2024). Evolution of Polish E-Consumers' Environmental Awareness and Purchasing Behavior over Ten Years. *Sustainability*, 16(11), 4686.
12. Gajdzik, B., Jaciow, M., Wolniak, R. (2024). Gastronomic curiosity and consumer behavior: the impact of television culinary programs on choices of food services. *Foods*, 13(1), 1-16.
13. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny R., Grebski, W.W. (2023). Energy Behaviors of Prosumers in Example of Polish Households. *Energies*, 16(7), 3186; <https://doi.org/10.3390/en16073186>.
14. Gajdzik, B., Siwiec, D., Wolniak, R., Pacana, A. (2024). Approaching open innovation in customization frameworks for product prototypes with emphasis on quality and life cycle assessment (QLCA). *Journal of Open Innovation: Technology, Market, and Complexity*, 10(2), 100268.
15. Gajdzik, B., Wolniak, R. (2021a). 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.
16. Gajdzik, B., Wolniak, R. (2021b). 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.
17. Gajdzik, B., Wolniak, R. (2021c). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, 14(14), 1-22.
18. 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.
19. Gajdzik, B., Wolniak, R. (2022a). 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.



20. Gajdzik, B., Wolniak, R. (2022b). 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.
21. Gajdzik, B., Wolniak, R. (2022c). 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.
22. Gajdzik, B., Wolniak, R., Grebski, W. (2023a). Process of Transformation to Net Zero Steelmaking: Decarbonisation Scenarios Based on the Analysis of the Polish Steel Industry. *Energies*, 16(8), 3384, <https://doi.org/10.3390/en16083384>.
23. Gajdzik, B., Wolniak, R., Nagaj, R., Žuromskaitė-Nagaj, B., Grebski, W. (2024). The influence of the global energy crisis on energy efficiency: a comprehensive analysis. *Energies*, 17(4), 1-49.
24. Gajdzik, B., Wolniak, R., Grebski, W. (2023b). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies*, 16(2), 1-29.
25. Gajdzik, B., Wolniak, R., Grebski, 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.
26. Gajdzik, B., Wolniak, R., Grebski, W.W. (2024). Challenges of industrial systems in terms of the crucial role of humans in the Industry 5.0 environment. *Production Engineering Archives*, 30(1), 1-16.
27. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies*, 16(21), 7364.
28. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government*. Philadelphia: CreativeSpace.
29. Gimerská, V., Šoltés, M., Mirdala, R. (2023). Improving Operational Efficiency through Quality 4.0 Tool: Blockchain Implementation and Subsequent Market Reaction. *Quality Innovation Prosperity*, 27(2), 16-32.
30. 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>.
31. 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".
32. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective*. New York: KDP Publishing.
33. 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.

34. 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.
35. 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.
36. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, 220, 115-123.
37. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, 9, 1000-1002.
38. Jokovic, Z., Jankovic, G., Jankovic, S., Supurovic, A., Majstorović, V. (2023). Quality 4.0 in Digital Manufacturing – Example of Good Practice. *Quality Innovation Prosperity*, 27(2), 177-207.
39. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, 114, 1-6.
40. Jonek-Kowalska, I., Wolniak, R. (2021a). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, 114, 1-6.
41. Jonek-Kowalska, I., Wolniak, R. (2021b). 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.
42. 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.
43. Jonek-Kowalska, I., Wolniak, R. (2023). *Towards sustainability and a better quality of life?* London: Routledge.
44. Khourshed, N., Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. *Quality Innovation Prosperity*, 27(2), 96-121.
45. 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.
46. 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.
47. 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.
48. Liu, H.-C., Liu, R., Gu, X., Yang, M. (2023). From total quality management to Quality 4.0: A systematic literature review and future research agenda. *Frontiers of Engineering Management*, 10(2), 191-205.

49. Maganga, D.P., Taifa, I.W.R. (2023). Quality 4.0 conceptualisation: an emerging quality management concept for manufacturing industries. *TQM Journal*, 35(2), 389-413.
50. Michalak, A., Wolniak, R. (2023). The innovativeness of the country and the renewables and non-renewables in the energy mix on the example of European Union. *Journal of Open Innovation: Technology, Market, and Complexity*, 9(2), <https://doi.org/10.1016/j.joitmc.2023.100061>.
51. Nagaj, R., Gajdzik, B., Wolniak, R., Grebski, W. (2024). The impact of deep decarbonization policy on the level of greenhouse gas emissions in the European Union. *Energies*, 17(5), 1-23, 1245.
52. 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.
53. 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.
54. 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.
55. 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.
56. 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.
57. Rosak-Szyrocka, J., Żywiołek J., Wolniak, R. (2023). Main reasons for religious tourism - from a quantitative analysis to a model. *International Journal for Quality Research*, 1(17), 109-120.
58. Saihi, A., Awad, M., Ben-Daya, M. (2023). Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review. *International Journal of Quality and Reliability Management*, 40(2), 628-650.
59. Salimbeni, S., Redchuk, A. (2023). Quality 4.0 and Smart Product Development. *Lecture Notes in Networks and Systems*, 614 LNNS, 581-592.
60. Singh, J., Ahuja, I.S., Singh, H., Singh, A. (2023). Application of Quality 4.0 (Q4.0) and Industrial Internet of Things (IIoT) in Agricultural Manufacturing Industry. *AgriEngineering*, 5(1), 537-565.
61. 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.

62. Stawiarska, E., Szwajca, D., Matuszek, 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.
63. 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.
64. Stecuła, 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.
65. Sureshchandar, G.S. (2023). Quality 4.0 – a measurement model using the confirmatory factor analysis (CFA) approach. *International Journal of Quality and Reliability Management*, 40(1), 280-303.
66. Wang, Y., Mo, D.Y., Ma, H.L. (2023). Perception of time in the online product customization process, *Industrial Management and Data Systems*, 123(2), pp. 369-385.
67. Wolniak, R., Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija*, 53(4), 709-713.
68. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością*. Gliwice: Wydawnictwo Politechniki Śląskiej.
69. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji*, 3, 13-17.
70. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, 3, 20-25.
71. Wolniak, R. (2016a). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, 1, 109-122.
72. Wolniak, R. (2016b). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
73. Wolniak, R. (2016c). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, 87, 443-453.
74. Wolniak, R. (2016d). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji*, 3, 127-134.
75. Wolniak, R. (2017a). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie*, 2, 139-150.
76. Wolniak, R. (2017b). 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.

77. Wolniak, R. (2017c). 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.
78. Wolniak, R. (2017d). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji*, 6, 247-255.
79. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 151, 725-734.
80. Wolniak, R. (2022a). Innovations in Industry 4.0 conditions. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 169, 725-741.
81. Wolniak, R. (2022b). Functioning of real-time analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 659-677.
82. Wolniak, R. (2023a). Deskryptywna analiza danych. *Zarządzanie i Jakość*, 5(2), 282-290.
83. Wolniak, R. (2023b). Smart biking w smart city. *Zarządzanie i Jakość*, 5(2), 313-328.
84. Wolniak, R. (2023c). Analiza w czasie rzeczywistym. *Zarządzanie i Jakość*, 5(2), 291-312.
85. Wolniak, R. (2023d). Smart mobility jako element koncepcji smart city. *Zarządzanie i Jakość*, 5(2), 282-290.
86. Wolniak, R., Gajdzik, B., Grebski, M., Danel, R., Grebski, W.W. (2024). Business Models Used in Smart Cities—Theoretical Approach with Examples of Smart Cities. *Smart Cities*, 7(4), 1626-1669.
87. Wolniak, R., Jonek-Kowalska, I. (2021a). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon)*, 34(3), 376-398.
88. Wolniak, R., Jonek-Kowalska, I. (2021c). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, 37, 132-150.
89. 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.
90. 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.
91. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1*. Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
92. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach*. Gliwice: Wydawnictwo Politechniki Śląskiej.
93. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów*. Gliwice: Wydawnictwo Politechniki Śląskiej.
94. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the conditions of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, 7, 1-17.

95. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, 15(2), 1-23.
96. Wolniak, R., Skotnicka-Zasadzień, B. (2023). Development of Wind Energy in EU Countries as an Alternative Resource to Fossil Fuels in the Years 2016-2022. *Resources*, 12(8), 96.
97. 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.
98. Wolniak, R., Stecula, K. (2024). Artificial Intelligence in Smart Cities—Applications, Barriers, and Future Directions: A Review. *Smart Cities*, 7(3), 1346-1389.
99. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości*, 9, 4-9.
100. 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.
101. 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.
102. Yanamandra, R., Abidi, N., Srivastava, R., Kukunuru, S., Alzoubi, H.M. (2023). *Approaching Quality 4.0: The Digital Process Management as a Competitive Advantage*. 2nd International Conference on Business Analytics for Technology and Security, ICBATS 2023.

## MOVING TOWARDS BETTER DIGITAL ACCESSIBILITY – CURRENT STATUS AND CHALLENGES

Marzena WÓJCIK-AUGUSTYNIAK<sup>1\*</sup>, Marek SZAJCZYK<sup>2</sup>, Mariusz CIELEMEŃCKI<sup>3</sup>,  
Stanisław SZAREK<sup>4</sup>

<sup>1</sup> University of Siedlce, Faculty of Social Sciences; marzena.wojcik-augustyniak@uws.edu.pl,  
ORCID: 0000-0001-5096-2863

<sup>2</sup> University of Siedlce, Faculty of Social Sciences; marek.szajczyk@uws.edu.pl,  
ORCID: 0000-0002-0591-8174

<sup>3</sup> University of Siedlce, Faculty of Social Sciences; mariusz.cielemecki@uws.edu.pl,  
ORCID: 0000-0002-3593-3455

<sup>4</sup> University of Siedlce, Faculty of Social Sciences; Stanislaw.szarek@uws.edu.pl,  
ORCID: 0000-0003-1623-6379

\* Correspondence author

**Purpose:** This article aims to identify the current challenges faced by various stakeholder groups in increasing digital accessibility in EU countries.

**Design/methodology/approach:** The main assumption of this article is that in order to enhance the level of digital accessibility, it is necessary to take not only legal actions but also engage in social and training initiatives. The basic research problem is: What challenges related to acquiring new competencies are currently being faced by stakeholders involved in ensuring website accessibility. The research was based on quantitative data collection methods.

**Findings:** The results of quantitative research based on 432 surveys collected among project stakeholders in four countries: Slovenia (N = 173), Poland (N = 135) Greece (N = 89) and Spain (N = 35) shows that IT/Web development professionals, young adults, and those with higher education are more knowledgeable about accessibility standards and regulations. Preferences for additional training on web accessibility varied, with uniform importance placed on international certification. Training plans were positively correlated with occupation, particularly among IT professionals, but showed no correlation with age, country, education level, or employment status.

**Research limitations/implications:** Implications resulting from the conducted research include both social and practical aspects. Socially, the findings highlight the need to engage non-IT professionals and older individuals in digital accessibility training to ensure broader inclusion. Practically, the research points to the necessity of developing comprehensive training programs and certification standards, as well as streamlining recognition systems for digital accessibility qualifications, to enhance overall digital competency and inclusion.

**Originality/value:** The value and originality of this article lie in its dual focus on the legal and social dimensions of digital accessibility, particularly within the European Union. It provides a comprehensive analysis of the current challenges faced by stakeholders in ensuring website

accessibility, emphasizing the necessity of both regulatory measures and practical training initiatives.

**Keywords:** digital accessibility, digital inclusion, digital accessibility skills, digital accessibility professions.

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

## 1. Introduction

In the digital era, where technology permeates every aspect of our lives, ensuring equal access to digital content and services for all people is of paramount importance. This is where the concept of digital accessibility comes into play. Digital accessibility refers to the design and development of digital information that can be accessed and used by people with disabilities, providing them with equal opportunities to use online content and services. The current status of digital accessibility reveals both progress and challenges. On the other hand, there is also growing awareness and recognition of the importance of accessibility in the digital space.

Some laws and regulations, such as the Web Accessibility Directive – WAD (European Union, 2016) in the European Union, Americans with Disabilities Act – ADA (1990) in the United States and the Web Content Accessibility Guidelines – WCAG (W3C, 2004) internationally, have been established to enforce accessibility standards and promote inclusive design practices. As a result, many organizations are beginning to prioritize accessibility, understanding that it not only fulfils legal obligations but also opens up new markets and improves user experiences for a broader group of recipients. However, despite the progress made, there are still significant challenges for new IT professionals entering the field of digital accessibility. One key challenge is the need for specialized knowledge and skills and one of the answers to such a challenge was the Certified Digital Accessibility Training (DigitalAccessibility) project implemented under the Erasmus+ Program: KA2 - Cooperation for innovation and the exchange of good practices, type of action: KA202 - Strategic partnerships for vocational education and training. As part of the project, extensive quantitative research was carried out in four countries of the European Union: Slovenia, Poland, Greece and Spain.

This article aims to identify the current challenges faced by various stakeholder groups in increasing digital accessibility in EU countries.

The article attempts to illustrate the importance of not only targeted digital accessibility training, but also the establishment of robust recognition systems and social initiatives to address the shortage of skilled experts and improve overall digital competence in society. This study is particularly relevant for policy makers, educators, IT professionals and organisations concerned with increasing digital inclusion.



## **2. Digital inclusion and digital accessibility**

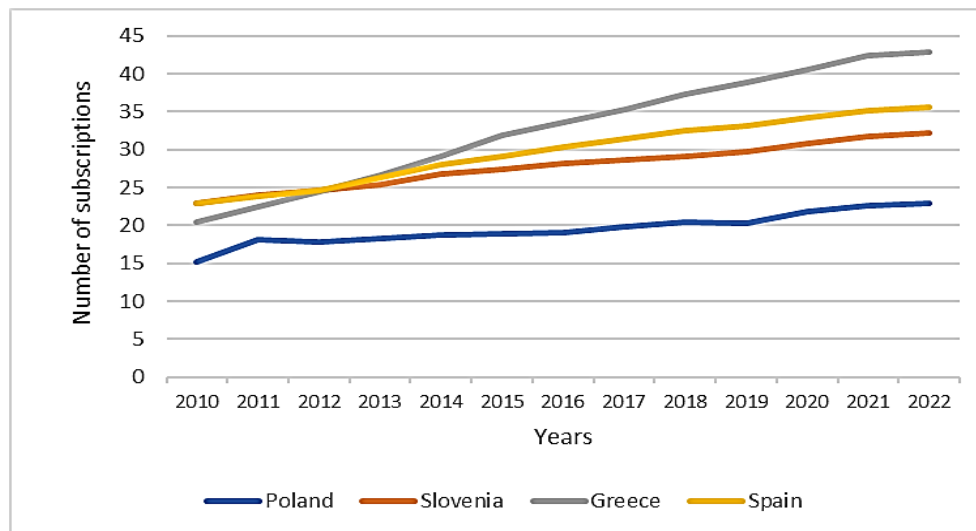
### **2.1. Legal basis of Digital Inclusion**

Living in an era of ubiquitous access to goods and services, both physical and digital, benefits individuals and organizations alike. However, while the digital world offers convenience to many, it poses significant barriers for some, hindering their social participation and inclusion. International organizations have developed directives and standards to address this issue, rooted in principles of equality and human rights. The Universal Declaration of Human Rights asserts the right to freedom of expression and access to information (United Nations, 1948). The 2030 Agenda for Sustainable Development emphasizes the commitment to leaving no one behind (United Nations, 2015). The Convention on the Rights of Persons with Disabilities highlights accessibility in the digital realm (United Nations, 2007). The Web Accessibility Directive aims to make public sector websites and mobile apps more accessible (European Union, 2016). Despite efforts, a 2023 review showed minimal impact, necessitating stronger enforcement (European Union, 2023). Lack of supervision and sanctions for non-compliance lead to low motivation for implementation, making digital accessibility training essential. Such initiatives align with Europe's growth and sustainability strategies (European Commission, 2020), including the EU Green Deal (European Union, 2019). Improving digital accessibility fosters social inclusion, aligning with the Green Deal's vision of a sustainable society.

### **2.2. Digital inclusion as a part of social inclusion of people with disabilities**

As per the European Parliament (Media Access Australia, 2014), only one-third of EU public sector websites complied with basic accessibility standards, leaving over 167 million citizens struggling to access online services. The 2022 evaluation may indicate improved compliance with the 2016 Directive, yet challenges persist for people with disabilities, leading to social exclusion (European Union, 2022). Social inclusion for disabled and elderly individuals encompasses access to employment, leisure, and social life (Rankin, 2005; Spandler, 2007). While physical access has improved, a 2018 audit in Poland revealed shortcomings in government efforts (NIK, 2018).

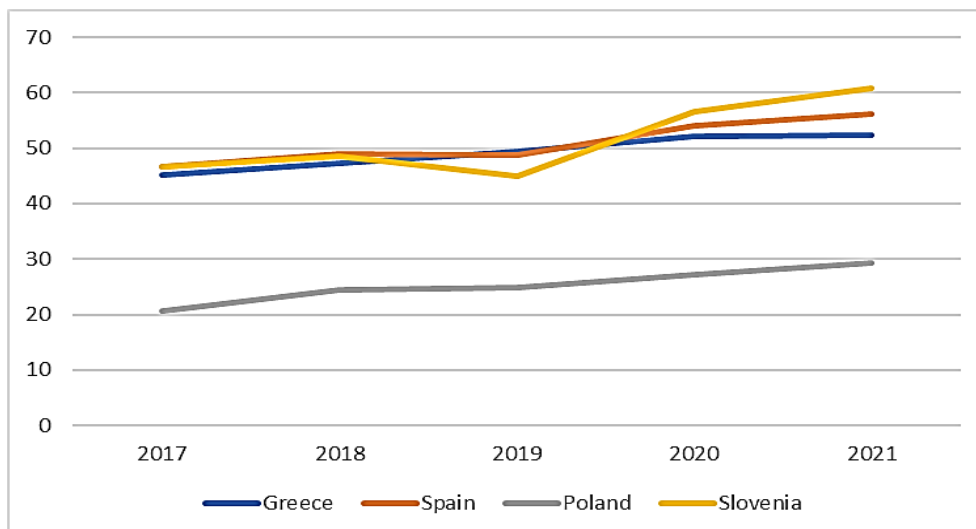
In today's digitized society, access extends to the digital realm, where "digital inclusion" means unrestricted access for all (NIK, 2018). Essential ICT infrastructure, including broadband, facilitates this access. Figure 1 illustrates the rate of change in access to broadband connections per 100 people in selected European Union countries from in 2010 to 2021. Considering the upward trend in this pace over the analysed years, it can be concluded that more and more people will be able to use the Internet in the future. Consequently, the creation of accessible websites will play an increasingly vital role in the digital inclusion of individuals who rely on it.



**Figure 1.** Fixed broadband subscriptions (per 100 people) - Poland, Spain, Slovenia, Greece in 2000 – 2021.

Source: own study based on data from World Bank (World Bank, 2023).

Figure 2 depicts the upward trend in the number of individuals using the internet to interact with public authorities in the analysed countries. Consequently, it can be inferred that in the future, the percentage of people using the Internet to communicate with public entities will continue to rise. This underscores the growing importance of creating their websites in an accessible manner.



**Figure 2.** Individuals using the internet for interacting with public authorities in 2017-2021.

Source: own study based on (European Commission, 2023).

However, it's crucial to emphasize that digital inclusion is not solely a matter of the availability of tools (hardware, software, and Internet) (OECD, 2022; Fung et al., 2023). It also depends on users' proficiency in using these tools. Proficiency in navigating digital technologies, comprehending online content, and effectively utilizing digital tools are essential for individuals to fully participate in the digital world. Therefore, digital skills play a pivotal role in digital inclusion. Regrettably, significant disparities in these skills exist among different

populations, particularly among older adults (Kärnä et al., 2022), people with disabilities, and those with limited educational opportunities (Beaunoyer et al., 2020; Nguyen, et al., 2021). Moreover, differences in digital skills based on one's place of residence, whether in urban or rural areas, (OECD, 2021), and disparities between low- and high-income households across countries (Notley & Aziz, 2024) should also be taken into consideration.

Given that contemporary life unfolds in both the physical and digital realms concurrently, the subject of digital inclusion holds immense importance. Navigating this digital reality has become a matter of "to be or not to be included" in normal social and professional life. Hence, many authors address the issue of digital inclusion and exclusion concerning disabled and elderly individuals in their research and publications (Verdegem, 2011; Hill et al., 2015; Costi Santarosa, Conforto, 2016; Tsatsou, 2020; Lin et al., 2018; Martínez-Alcalá et al., 2018).

### 2.3. Digital Accessibility

To reduce digital exclusion and social exclusion among vulnerable populations, it's crucial to implement measures for digital space access. Approximately 87 million EU citizens have some form of disability, a number expected to rise due to population aging (European Commission, 2023). Accessibility is thus vital for ensuring their equal participation and contributing to smart, sustainable, and inclusive growth (European Commission, 2015). But what does digital accessibility entail? In general, it means being "easy to understand, assimilate; comprehensible, accessible" (Polish Language Dictionary, 2021). For websites, it's about creating sites accessible to a wide audience, particularly those prone to exclusion, like those with disabilities or lower education levels (Wikipedia, 2023). Accessibility ensures equal opportunities, just as it's unjust to hinder building access due to mobility issues; it's wrong to exclude due to hearing, vision, or cognitive impairments (mozilla, 2023). Accessibility refers to how easily persons with disabilities or special needs can access products, services, or environments. Digital accessibility focuses on technology, including hardware and software (Kulkarni, 2019). The European Accessibility Act mandates accessibility for various products and services, including computers, e-books, e-commerce platforms, and mobile apps (European Union, 2019). Achieving this requires adherence to specific guidelines detailed in Annex WCAG 2.1.

Web accessibility standards first emerged in 1999 with the release of WCAG 1.0. Since then, they undergone two updates: in 2016 (WCAG 2.0) and 2018 (WCAG 2.1). As of 2023, a draft version of WCAG 2.2 has been made available (W3C, 2023). According to data from W3C WAI website and the Scopus database, between 1999 and mid-2023, issues related to WCAG standards were discussed in 2,273 articles.

Since the release of the first version, the guidelines and success criteria of the WCAG standards have been structured around four fundamental principles that serve as the foundation of web accessibility: *perceivable*, *operable*, *understandable*, and *robust* (W3C, 2023).

The primary objective of efforts related to Digital Accessibility is to develop web content that is perceivable, operable, understandable by the broadest possible audience, and robust while also being compatible with a wide range of assistive technologies, particularly screen readers (W3C, 2004; W3C WAI, 2019). Perceivable entails presenting information and user interface components in a manner that users can perceive through one or more of their senses. Operable means that users should have the capability to interact with the website and all its features. Understandable involves ensuring that web content and usage are easily comprehensible. Robust signifies that websites should function reliably across various technologies and be prepared for emerging technologies (University of Minnesota, 2021; mozilla, 2023).

Research conducted in numerous countries among individuals with disabilities has revealed various issues concerning the accessibility of existing websites (Kulkarni, 2019; Ismail, Kuppusamy, 2019).

#### **2.4. Digital accessibility skills - challenges for new professions**

One of the significant challenges associated with the digital inclusion of people with disabilities and the elderly is to create facilities that enable them to navigate the digital world as effectively as possible

Despite the implementation of the Directive, which obliges all public organizations to create web content in an accessible manner (EU Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016), a mandatory number of public institution websites do not adhere to accessibility standards. The latest evaluation by WAD has revealed this situation in various EU countries (European Union, 2023).

One of the reasons contributing to this unfavourable state may be the scarcity of individuals with the necessary skills to create and design accessible web content in the job market. Addressing this skills gap is achievable by preparing individuals capable of creating and designing websites in an accessible manner.

The response to the demand for individuals proficient in creating accessible web content was the project titled *Certified Digital Accessibility Training* (DigitalAccessibility).

It's worth noting that, at the time of the project's inception, digital accessibility professions were already present in the labour markets, primarily in the United States and Australia (WebAxe, 2019; Šumak et al., 2019). Today the number of digital accessibility jobs in Europe is on the rise. According to Europe's largest job offer database, EURES, there were 144 accessibility-related job vacancies in the information and communication sector as of July 12, 2023 (European Commission, 2023).

Digital Accessibility poses numerous challenges for those involved in designing, creating, and administering websites. A. Ismail and K.S. Kuppusamy emphasize that "awareness about web accessibility is the initial step for web developers and designers to design and develop accessible websites" (Ismail, Kuppusamy, 2019).

As part of the Certified Digital Accessibility Training project, specific competency areas in the field of digital accessibility were identified for two existing professions, enriched with Digital Accessibility skills: Web Developer with expertise in Digital Accessibility and Web Designer with expertise in Digital Accessibility. Additionally, two non-technical professions were identified: Digital Accessibility Manager and Digital Accessibility Tester. A comprehensive description of the skills required for each of these professions was presented in the project reports (Digital Accessibility, 2019). It's important to recognize that accessible web content is not solely the responsibility of website authors. In various types of organizations, the success of accessibility also hinges on its integration into the organizational culture, existing processes, and practices. This entails aligning digital accessibility with existing organizational approaches, setting clear and measurable goals, and involving stakeholders to ensure understanding and support throughout the organization. Hence, it is crucial for all involved parties to possess skills related to digital accessibility (W3C, 2011). It should be noted that in terms of the availability of training and courses in the field of digital accessibility for professionals, there have been significant developments. As of July 2023, according to data published on the W3C website, there were 80 courses, training and certifications on digital accessibility are offered from various providers in 17 countries. Among them, there are 66 training courses, 6 professional certifications, 2 graduate/undergraduate programs and 6 others. Considering the audiences, the courses/training are: 36 for content writers, 38 for designers, 41 for developers, 25 for managers, 37 for testers, 38 general and 21 others. Among them, there are 59 courses at basic level and 21 at intermediate level, in face-to-face (4), online (45) and hybrid (31) formats. Some of these are free/non-fee, with certificates to purchase (9); paid, with a reduced fee for some (14) and 57 (W3C WAI, 2022).

### **3. Methodology and characteristics of the research sample**

#### **3.1. Development of hypotheses**

The basic research problem is: What challenges related to acquiring new competencies are currently being faced by stakeholders involved in ensuring website accessibility? To address this problem, three specific research questions were formulated:

- RQ1. What is the relationship between stakeholders' level of awareness and knowledge of digital accessibility and their occupation, age, country, level of education and employment status?
- RQ2. What is the relationship between stakeholders' level of competence in the field of digital accessibility and their occupation, age, country, level of education and employment status?

RQ3. What is the relationship between stakeholders' training plans to increase (acquire new) digital accessibility skills and their occupation, age, country, level of education and employment status?

The research objective of this article is to identify the current status and challenges faced by stakeholders involved in ensuring web accessibility.

The results of the research conducted under the DIGITAL ACCESSIBILITY project have allowed for the verification of the main hypothesis, which posits that to increase the level of digital inclusion, website accessibility training activities should be pursued. These training activities will enable individuals to enhance or acquire the new digital accessibility skills necessary to ensure digital accessibility.

In line with the research questions, the following research hypotheses have been formulated:

H1: There is a positive relationship between stakeholders' level of awareness and knowledge of digital accessibility and their occupation, age, country, level of education, and employment status.

H2: There is a positive relationship between stakeholders' level of competence in the field of digital accessibility and their occupation, age, country, level of education, and employment status.

H3: There is a positive correlation between stakeholders' training plans to enhance or acquire new digital accessibility skills and their occupation, age, country, level of education, and employment status.

### 3.2. Data collection

The research component of the *Certified Digital Accessibility Training project* was based on quantitative data collection methods. The survey questionnaire was developed with the assistance of the online tool "1KA OneClick Survey" (1ka Online Survey, 2019) and was distributed to interested stakeholders, such as marketing and PR specialists, IT specialists, web content authors, etc. through email and social networks such as Facebook and LinkedIn. The questionnaire was made available in five language versions: Slovenian, Greek, Spanish, Polish and English. It was sent to stakeholders in four countries: Slovenia, Spain, Greece and Poland. The questionnaire consisted of 49 questions with different types of response scales, including those with only one possible answer (e.g. Likert scale) or with several possible answers. All questions were grouped in three main areas: I - *Awareness and proficiency in online content accessibility*; II - *Current practices*; III - *Learning preferences and stakeholder training related to the digital accessibility of web content* (Digital Accessibility, 2019).

### 3.3. Research sample

Initially, a total of 3,049 respondents participated in the survey. However, during the initial stages 2,616 of them discontinued their participation. It is highly likely that the complexity and length of the questionnaire, which took approximately 30 minutes to complete, contributed to

this dropout rate. In the final stage of the survey, an additional 191 individuals withdrew their participation. Ultimately, 244 participants completed the survey, providing responses to all the questions. Consequently, all percentage analyses for specific questions pertain to the number of participants who responded to that particular question, not to the initial total number of participants, unless otherwise stated. Among those who answered all the questions, 60% (N = 148) were men, 32.4% (N = 79) were women, and 7% (N = 17) chose not to indicate their gender.

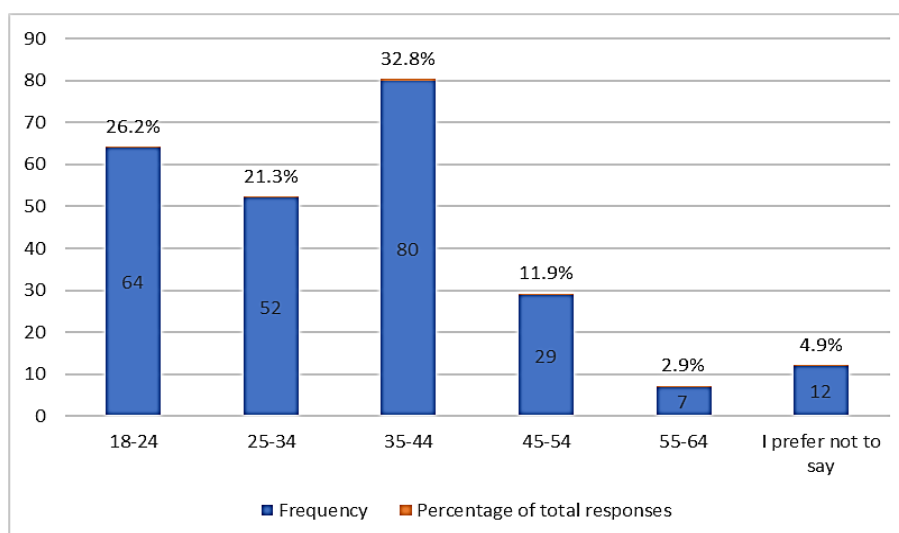
For a more comprehensive view of the respondents, including their occupational field and language preferences, please refer to Table 1.

**Table 1.**  
*Field of occupation and respondents' language*

Field of occupation or studies	Slovene	Polish	Greek	Spanish	English	Total
IT/Web development/programming	125	24	31	10	0	190
Design/web design	22	2	14	7	0	45
Management	3	25	10	7	2	47
PR/marketing	10	6	5	1	1	23
VET teaching/training	0	16	20	1	0	37
Other	13	62	9	9	0	93
<b>Total</b>	<b>173</b>	<b>135</b>	<b>89</b>	<b>35</b>	<b>3</b>	<b>435</b>

Source: own study based on the Stakeholder Survey for Digital Accessibility report (Digital Accessibility, 2019).

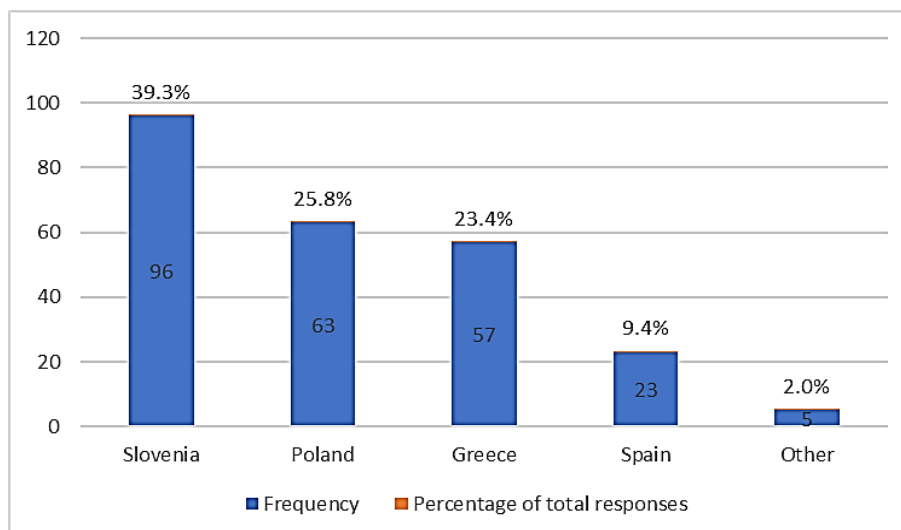
It's important to note that the overwhelming majority of respondents, accounting for 80.3% (N = 196), fell within the age bracket of up to 44 years. For a more detailed breakdown of respondent age distribution, please refer to Figure 3.



**Figure 3.** Percentage and number distribution of respondents according to the age.

Source: own study based on the Stakeholder Survey for Digital Accessibility report (Digital Accessibility, 2019).

The percentage and number distribution of respondents by country of origin is illustrated in Figure 4.



**Figure 4.** Percentage and number distribution of respondents according to country of origin criterion.

Source: own study based on the Stakeholder Survey for Digital Accessibility report (Digital Accessibility, 2019).

The level of education of the respondents, assessed according to categories based on the ISCED International Standard Classification of Education (UNESCO Statistical Institute, 2011) is presented in Table 2.

**Table 2.**

*Level of education of respondents according to the ISCED classification*

Respondents' level of education	Frequency	Percent
ISCED level 3 – Upper secondary education	30	12.3
ISCED level 4 – Post-secondary non-tertiary education	28	11.5
ISCED level 5 – Short-cycle tertiary education	11	4.5
ISCED level 6 – Bachelor's or equivalent level	75	30.7
ISCED level 7 – Master's or equivalent level	83	34.0
ISCED level 8 – Doctoral or equivalent	12	4.9
Other	5	2.0
<b>Total</b>	<b>244</b>	<b>100.0</b>

Source: own study based on the Stakeholder Survey for Digital Accessibility report (Digital Accessibility, 2019).

Table 3 provides an overview of the employment status of the respondents.

**Table 3.**

*Respondents' employment status*

Employment status	Frequency	Percent
Student	63	25.8
Employed	166	68
Unemployed	8	3.3
Other (freelancer, self-employed, contract worker, student and employee)	7	2.9
<b>Total</b>	<b>244</b>	<b>100</b>

Source: own study based on the Stakeholder Survey for Digital Accessibility report (Digital Accessibility, 2019).



The majority of respondents who completed the entire survey (N = 244) were employed, making up 68% (N = 166) of the total. Students accounted for 25.8% (N = 63), while the unemployed represented 3.3% (N = 8), and 2.9% (N = 7) did not fit into any of the specified employment categories. Of those employed, 50.6% of survey participants (N = 84) worked in the public sector, and 53.6% (N = 89) in the private sector (7 participants worked for both private and public companies). In terms of enterprise size, 27.1% of participants (N = 45) were employed in micro-enterprises, 19.9% (N = 33) in small enterprises, 24.7% (N = 41) in medium enterprises, and 28.3% (N = 47) in large enterprises.

## 4. Results

The results of quantitative research presented in this part are based on 432 surveys collected among project stakeholders in four countries: Slovenia (N = 173), Poland (N = 135) Greece (N = 89) and Spain (N = 35).

### 4.1. The level of awareness and knowledge about digital accessibility in the selected European Union countries

Table 4 shows the results from the I part of the Survey on the level of awareness of digital accessibility. For the purpose of this article, the focus was on the responses for four questions: Q1\_2: How well are you familiar with the concept of web accessibility? Q2: How important is it to provide accessibility to the web in your opinion? Q3: Are you aware of the EU directive 2016/2102 on the accessibility of the websites and mobile applications of public sector bodies? Q4: Are you aware of any other national or international directive/legislation about web accessibility?

**Table 4.**

*Survey results regarding the level of awareness and knowledge about digital accessibility in the selected European Union countries*

Variable	Median	St. Deviation	Variance	Minimum	Maximum
Slovenia					
Q1_2	4	1.994	3.975	1	5
Q2	4	2.158	4.659	1	5
Q3	1	1.68	2.823	1	5
Q4	2	1.633	2.667	1	3
Poland					
Q1_2	4	2.576	6.636	1	5
Q2	4	2.917	8.507	1	5
Q3	2	2.474	6.122	1	5
Q4	2	2.257	5.096	1	3

Cont. table 4.

Greece					
Q1_2	3	1.651	2.724	1	5
Q2	5	1.693	2.866	1	5
Q3	3	1.617	2.614	1	5
Q4	2	1.206	1.454	1	3
Spain					
Q1_2	4	1.931	3.728	1	5
Q2	5	1.88	3.534	1	5
Q3	3	1.9	3.61	1	5
Q4	2	1.577	2.487	1	3

Q1\_2: 1 - Not familiar at all (have never heard of it), 2 - Not familiar, 3 - Somewhat familiar, 4 - Familiar, 5 - Very familiar.

Q2: 1 - Not important at all, 2 - Not important, 3 - Somewhat important, 4 - Important, 5 - Very important.

Q3: 1 - I have never heard of it, 2 - I have heard of it, 3 - I have some basic knowledge, 4 - I know it, 5 - I know it very well.

Q4: 1 - Yes, 2 - No, 3 - I don't know/I don't remember.

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019).

From the results presented in Table 4, it can be concluded that the values of the standard deviation for Slovenia, Greece and Spain do not show large differences. On the other hand, significant differences were observed in the case of data obtained in Poland. This proves that respondents from Poland gave more extreme answers in their opinions.

**Table 5.**

*Spearman rank order correlations - the level of awareness and knowledge about digital accessibility in the selected European Union countries*

Variable	Means	Std. Dev.	Occupation (Q1)	Age (Q25)	Country (Q26)	Level of education (Q27)	Employment status (Q28)
Q1_2	3.623	0.873	-0.064	0.035	-0.007	0.108	0.012
Q2	4.443	0.623	<b>0.189</b>	<b>0.065</b>	-0.047	-0.030	-0.126
Q3	2.373	1.157	<b>0.400</b>	<b>0.263</b>	-0.027	0.112	-0.119
Q4	2.225	0.631	-0.114	-0.150	-0.156	-0.161	-0.028

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019) (Note: Marked correlations are significant at  $p < 0,05000$ ).

Considering the results of the correlation analysis (Table 5), it can be concluded that: first, people in the IT/Web development/ programming field of occupation consider that it is important to ensure the accessibility of online content and have better knowledge of EU Directive 2016/2102 on the accessibility of public sector bodies' websites and mobile applications compared to other professions (Q2, Q3). Spearman's rank correlation coefficient for the variables Q2, Q3 and occupation is 0.189 and 0.400, respectively. Second, 18-24 and 25-34 year old are more aware of national or international regulations on online content accessibility than representatives of other age groups (Q3). The Spearman rank correlation coefficient for the Q3 variable and age is 0.263. However, no correlations were observed between respondents' country of origin, employment status and level of education and Q1\_2, Q2, Q3, Q4.

#### 4.2. The current level of competence in the field of digital accessibility

Table 6 shows the results of the second part of the survey on current practices. For the purposes of this article, the focus was on responses to three questions: Q5a - Do you know the WCAG 2.0 web accessibility standard? Q5b - Do you know the WCAG 2.1 web accessibility standard? and Q6 - How proficient do you feel you are in web accessibility?

**Table 6.**

*Survey results regarding the current level of competence in the field of digital accessibility*

Variable	Median	St. Dev.	Variance	Minimum	Maximum
Slovenia					
Q5a	1	1.549	2.401	1	5
Q5b	1	1.518	2.305	1	5
Q6	3	2.084	4.344	1	5
Poland					
Q5a	2	2.678	7.174	1	5
Q5b	1	2.412	5.817	1	5
Q6	3	2.772	7.681	1	5
Greece					
Q5a	2	1.689	2.851	1	5
Q5b	2	1.655	2.74	1	5
Q6	3	1.735	3.01	1	5
Spain					
Q5a	2	2.351	5.526	1	5
Q5b	2	2.203	4.852	1	5
Q6	3	2.265	5.129	1	5

Q5a/Q5b: 1 - I have never heard of it, 2 - I have heard of it, 3 - I have some basic knowledge, 4 - I know it, 5 - I know it very well.

Q6: 1 - Not proficient at all, 2 - Not proficient, 3 - Somewhat proficient, 4 - Proficient, 5 - Very proficient.

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019).

From the results presented in Table 6, it can be concluded that in terms of the availability of online content, respondents from Spain and Poland showed more extreme opinions (they know or do not know at all) compared to Greece and Slovenia, where the respondents' answers were not so extreme. Moreover, the knowledge of WCAG 2.0 and WCAG 2.1 is lower in Slovenia than in the other surveyed countries. Whereas the lowest level of proficiency in web accessibility is among respondents from Greece, and the highest among ones from Poland. In turn, there is a similar average level of proficiency among people from Slovenia and Spain.

**Table 7.**

*Spearman rank order correlations - the current level of competence in the field of digital accessibility*

Variable	Means	Std. Dev.	Occupation (Q1)	Age (Q25)	Country (Q26)	Level of education (Q27)	Employment status (Q28)
Q5a	2.131	1.260	0.474	0.317	-0.060	0.227	-0.081
Q5b	1.889	1.085	0.397	0.293	-0.044	0.172	-0.020
Q6	3.045	0.913	0.041	0.145	-0.037	0.050	0.167

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019) (Note: Marked correlations are significant at  $p < ,05000$ ).

Considering the results of the correlation analysis (Table 7), it can be concluded that those in the IT/web development/programming fields of occupation are more familiar with WCAG 2.0 and WCAG 2.1 than respondents from other fields of occupation or study. The Spearman's rank correlation coefficient for the variables Q5a, Q5b and occupation is 0.474 and 0.397, respectively. Those aged 18-24 and 25-34 are more familiar with WCAG 2.0 and WCAG 2.1 than representatives of other age groups. Spearman's rank correlation coefficient for the variables Q5a, Q5b and age is 0.317 and 0.293, respectively. Those with higher levels of education (ISCED levels 6, 7, 8) are more familiar with WCAG 2.0 and WCAG 2.1 web content accessibility standards than those with educational levels below ISCED level 5 (Q5a, Q5b). The Spearman rank correlation coefficient for the variables Q5a, Q5b and level of education is 0.227 and 0.172, respectively. For Q6, no correlation was observed between the analysed variables.

#### 4.3. The employees' plans to improve their digital accessibility competence

Table 8 shows the results for the three questions from Part III of the Survey: Q18a - Do you think it is important for your work to gain some additional knowledge in web accessibility? Q22 - If you were to join a web accessibility training/course, how long would you prefer it to be? And Q23 - Is it important to you that the web accessibility training/course that you would take was (internationally) certified?

**Table 8.**

*Survey results regarding the employees' plans to improve their digital accessibility competence*

Variable	Means	Std. err.	Median	St. Deviation	Variance	Minimum	Maximum
Slovenia							
Q18a	3.600	0.177	4.000	0.968	0.938	1	5
Q22	2.100	0.268	2.000	1.470	2.162	1	7
Q23	1.667	0.161	1.000	0.884	0.782	1	3
Poland							
Q18a	3.786	0.166	4.000	0.876	0.767	2	5
Q22	2.464	0.339	2.000	1.795	3.221	1	7
Q23	1.536	0.150	1.000	0.793	0.628	1	3
Greece							
Q18a	4.091	0.285	4.000	0.944	0.891	3	5
Q22	1.818	0.296	2.000	0.982	0.964	1	4
Q23	1.273	0.195	1.000	0.647	0.418	1	3
Spain							
Q18a	3.867	0.114	4.000	0.991	0.982	1	5
Q22	2.800	0.171	3.000	1.480	2.189	1	7
Q23	1.400	0.078	1.000	0.678	0.459	1	3

Q18a: 1 - Not important at all, 2 - Not important, 3 - Somewhat important, 4 - Important, 5 - Very important.

Q22: 1 - A day or two, 2 - One week, 3 - Two weeks, 4 - A month or two, 5 - six months/half a year, 6 - One year, 7 - Other.

Q23: 1 - Yes, 2 - No, 3 - I don't know.

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019).

From the results presented in Table 8, it can be concluded that acquiring some additional knowledge on web accessibility is equally important for respondents from all countries (Q18a). Regarding the duration of additional training on web accessibility, respondents from Spain, Poland and Slovenia are interested in either long or short training - opinions are more polarized, while responses from Greece are more uniform in this regard and point to monthly or bi-monthly training duration of such courses (Q22). Moreover, for respondents from all countries, it is equally important that web accessibility training was (internationally) certified (Q23).

**Table 9.**

*Spearman rank order correlations - the employees' plans to improve their digital accessibility competence*

Variable	Means	Std. Dev.	Occupation (Q1)	Age (Q25)	Country (Q26)	Level of education (Q27)	Employment status (Q28)
Q18a	3.791	0.952	0.170	-0.002	-0.025	0.009	-0.043
Q22	2.463	1.683	0.424	0.079	-0.075	-0.020	-0.111
Q23	1.525	0.777	-0.185	0.064	0.007	0.035	0.012

Source: own study based on the Stakeholder Survey (Digital Accessibility, 2019) (Note: Marked correlations are significant at  $p < 0,05000$ ).

Considering the results of the correlation analysis (Table 9), it can be concluded that respondents' training plans to increase (acquire new) digital accessibility skills (Q18a, Q22 and Q23) are positively correlated only with their occupation. People with an IT/web development/programming field of occupation are interested in the development of web content accessibility and visual design of websites, taking into account the principles of web content accessibility (Q18a). It is also important for them that the training would last for 1-2 days (Q22) and internationally certified (Q23). Spearman's rank correlation coefficient for variables Q18a, Q22 and Q23 and occupation is 0.170, 0.424 and 0.185, respectively. However, there is no correlation between questions Q18a, Q22 and Q3 and respondents' age, country of origin, level of education or employment status.

## 5. Discussion

To achieve full inclusion of individuals with disabilities in the digital space, it is essential to create online content that is accessible to people with various disabilities. This article's main premise is that increasing digital accessibility in European Union countries requires not only legal measures but also social and training initiatives.

Legal actions have been taken through the introduction of Directive (EU) 2016/2102 by the European Parliament and the Council on the accessibility of public sector websites and mobile applications, as well as the European Accessibility Act in 2019 (EAA). These directives mandate that both public and private entities adhere to accessibility principles, including digital accessibility.

However, as discussed in this article, the implementation of these provisions still faces challenges. These challenges include issues with Internet access in certain regions (Eurostat, 2023), low digital competence in specific social groups, in terms of age, disability, economic reasons, etc. (Pérez-Escobar, Canet, 2023) and a shortage of digital accessibility experts (European Union, 2022). Additionally, the lack of official skill-certification systems in most Member States hinders the identification of appropriately trained experts and the assessment of auditors' expertise. Monitoring bodies often rely on the expert's professional experience rather than formal qualifications (European Union, 2022).

It's worth noting that globally, the Internet user base has expanded significantly, with over 1 billion new Internet users added in the last five years, and the COVID-19 pandemic has further accelerated Internet adoption, with an estimated 466 million new Internet users in 2020 (ITU, 2022).

By 2021, the share of individuals using the internet in the EU had risen to 90%, some 20 percentage points higher than in 2011. In 2022, the share of individuals interacting online with public authorities in the EU had risen to 63% (for 25 to 64 years old) and 38% (for 65 to 74 years old) 57 from 48% and 17% respectively in 2012 (European Union, 2022).

Addressing the challenges arising from the expanding internet user base requires a combination of technical expertise, ongoing learning, collaboration, and a deep understanding of accessibility principles. New professionals entering the digital accessibility field should seek training opportunities, stay updated with industry advancements, collaborate with experienced accessibility experts, and engage with the broader accessibility community. In addition to professional training, training citizens in digital competencies is a vital aspect of the knowledge society (Morte-Nadal, Esteban-Navarro, 2022).

Apart from training initiatives also social activities, often overlooked but with significant potential for change, can greatly enhance digital inclusivity. Among the initiatives undertaken by communities and individuals, noteworthy initiatives include awareness campaigns - organized by communities - aimed at educating the public about the importance of digital accessibility. These campaigns can be as simple as sharing informative posts on social media or conducting workshops within neighbourhoods.

It is especially worth paying attention to initiatives led by users with disabilities who often take the initiative in organizing events and activities that highlight their challenges and successes in navigating the digital world. By sharing their experiences, they can foster understanding and empathy among the wider community (Integracja.org, 2023).

Mentoring programs also play an important role among social activities, in which people with technical knowledge will mentor people less familiar with digital technologies. Such personalized guidance can brighten up the digital world and enable individuals to use technology effectively. Valuable social initiatives also include: digital inclusion workshops for seniors, who often face barriers in using digital technologies. Such a workshop can be tailored to their needs and teach them basic digital skills, online safety or how to access relevant resources. More and more often initiatives such as Accessible Gaming Tournaments or Adaptive Esport Tournaments are also organized. Accessible games and esports not only promotes inclusion but also showcases the importance of accessible design in the gaming industry (Logitech Adaptive Esports Tournaments, 2023).

These examples of social action have a significant impact on increasing digital accessibility. They not only benefit people with disabilities but also contribute to a more inclusive and equitable digital landscape for society as a whole.

In terms of increasing the number of specialists in digital accessibility, it is necessary to include digital accessibility content in school curricula as well (Oncins et al., 2020; Inal et al., 2020; Cielemecki, 2021). In addition, organizing training/courses for employees not directly related to the creation of accessible websites (managers, marketers, HR, etc.) is also necessary to increase their awareness and skills to work on and with accessible websites (Gay, 2023).

## 6. Conclusions

The basic research problem was: What challenges related to acquiring new competencies are currently being faced by stakeholders involved in ensuring website accessibility? The research objective of this paper was to identify the current status and challenges faced by stakeholders involved in ensuring website accessibility. The main hypothesis assumed that to increase the level of digital inclusion, website accessibility training activities should be pursued. These training activities will enable individuals to enhance or acquire the new digital accessibility skills necessary to ensure digital accessibility.

Based on the results of the conducted quantitative research and the statistical analysis of correlations between selected variables, several conclusions can be drawn.

The first hypothesis was partially confirmed, as only the occupation and age of stakeholders exhibited a positive correlation with their level of awareness and knowledge regarding digital accessibility. Individuals in IT-related occupations and those of a younger age tended to rate their awareness and knowledge in the realm of creating websites in accordance with accessibility standards higher than individuals in other professions.

The second hypothesis was partly validated, with positive correlations observed for the occupation, age, and level of education of stakeholders with their competence in digital accessibility. Individuals in IT-related occupations, younger individuals, and those with higher levels of education tended to rate their knowledge in creating websites in compliance with accessibility standards more highly compared to representatives of other professions, older individuals, and those with lower levels of education.

The third hypothesis was partially supported, as only the occupation of stakeholders demonstrated a positive correlation with their inclination to pursue training for enhancing or acquiring new digital accessibility skills. Individuals in IT-related occupations expressed interest in participating in short-term and certified digital accessibility training. Interestingly, individuals in IT-related occupations noted that knowledge and skills in digital accessibility were of lesser importance to a larger group of individuals responsible for web content accessibility.

In our rapidly evolving digital age, a significant challenge is the need for specialized knowledge and skills, especially in achieving digital inclusion for people with disabilities and the elderly. Overcoming these challenges requires a combination of technical expertise, continuous learning, collaboration, and a deep understanding of accessibility principles.

Training citizens in digital competencies is a primary challenge in our knowledge society. To address this, it's crucial to provide digital accessibility (DA) training to various professions and age groups. Organizations can offer DA training to employees from diverse backgrounds, and educational institutions at all levels play a crucial role in equipping the next generation with digital competencies.

Another challenge in digital accessibility is the lack of recognition systems and complex procedures for digital accessibility qualifications, both nationally and internationally. Streamlining the recognition of DA qualifications, similar to the European Credit System for Vocational Education and Training (ECVET), is vital to ensure global recognition of these skills.

In summary, the path to digital inclusion and competency comes with challenges. However, with a focus on specialized knowledge, accessibility, and qualifications recognition, we can navigate the digital landscape effectively and ensure that everyone can participate in our increasingly connected world.

## **Acknowledgements**

The authors acknowledge DigitalAccessibility Project Partners, in particular Associate Professor Bostjan Šumak (University of Maribor) for consultation on some statistical analysis. This article uses some data that was obtained through the Certified Digital Accessibility



Training (DigitalAccessibility) project implemented under the Erasmus + Program: KA2 - Cooperation for innovation and the exchange of good practices, type of action: KA202 - Strategic partnerships for vocational education and training (Project reference number: KA2-VET-16/18).

## References

1. *Ika Online Survey* (2019). Retrieved from: <https://www.ika.si/d/en>, December 14, 2022.
2. Beaunoyer, E., Dupéré, S., Guitton, M. (2020, October). COVID-19 and digital inequalities: Reciprocal impacts and mitigation strategies. *Computers in Human Behavior*, *111*, p. 106424. doi: <https://doi.org/10.1016/j.chb.2020.106424>
3. Costi Santarosa, L., Conforto, D. (2016, July). Educational and digital inclusion for subjects with autism spectrum disorders in 1:1 technological configuration. *Computers in Human Behavior*, *60*, pp. 293-300. doi: <https://doi.org/10.1016/j.chb.2016.02.021>
4. Digital Accessibility (2019, February 28). *IO1 - A1 Desktop research: The analysis of digital accessibility*. Retrieved from: Digital Accessibility: [https://digital-accessibility.eu/wp-content/uploads/2020/11/DA\\_IO1\\_A1-Desktop-reseach-report-FINAL\\_Accessible.pdf](https://digital-accessibility.eu/wp-content/uploads/2020/11/DA_IO1_A1-Desktop-reseach-report-FINAL_Accessible.pdf), November 17, 2023.
5. Digital Accessibility (2019, February 28). *IO1 – A2 Digital Accessibility Survey for stakeholders*. Retrieved from: Digital Accessibility: [https://digital-accessibility.eu/wp-content/uploads/2020/11/DA\\_IO1\\_A2Survey-report\\_FINAL\\_Accessible.pdf](https://digital-accessibility.eu/wp-content/uploads/2020/11/DA_IO1_A2Survey-report_FINAL_Accessible.pdf), November 15, 2022.
6. European Commission (2015, December 2). *Commission proposes to make products and services more accessible to the disabled persons*. Retrieved from: [https://ec.europa.eu/commission/presscorner/detail/en/IP\\_15\\_6147](https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6147), July 12, 2023.
7. European Commission (2020, March 3). *Communication From The Commission Europe 2020, A strategy for smart, sustainable and inclusive growth*. Retrieved from: EUR-Lex: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:en:PDF>, December 20, 2022.
8. European Commission (2023, July 10). *Individuals using the internet for interaction with public authorities*. Retrieved from: data.europa.eu - The official portal for European data: <https://data.europa.eu/data/datasets/mxkqqdbovbfreyxg3xwa?locale=en>, August 15, 2023.
9. European Commission (2023). *Job results*. Retrieved from: EURES: [https://ec.europa.eu/eures/portal/jv-se/search?page=1&resultsPerPage=10&orderBy=BEST\\_MATCH&keywordsEverywhere=accessibility&sector=j&lang=en](https://ec.europa.eu/eures/portal/jv-se/search?page=1&resultsPerPage=10&orderBy=BEST_MATCH&keywordsEverywhere=accessibility&sector=j&lang=en) July, 12, 2023.

10. European Commission (2023). *Persons with disabilities*. Retrieved from: Social protection & social inclusion: <https://ec.europa.eu/social/main.jsp?catId=1137&langId=en>, August 10, 2023.
11. European Union (2016, October 26). DIRECTIVE (EU) 2016/2102 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies. Retrieved from: EUR-Lex: <https://eur-lex.europa.eu/eli/dir/2016/2102/oj>, December 17, 2022.
12. European Union (2019, December 11). Communication from the commission to the european parliament, the european council, the council, the european economic and social committee and the committee of the regions. The European Green Deal. Retrieved from: EUR-Lex: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640>, December 16, 2022.
13. European Union (2019, April 17). Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services (Text with EEA relevance). Retrieved from: EUR-Lex: <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32019L0882>, September 20, 2023.
14. European Union (2022, December 7). COMMISSION STAFF WORKING DOCUMENT EVALUATION Review of the application of Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies (WAD). Retrieved from: EUR-Lex: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2022:410:FIN>, August 17, 2023.
15. European Union (2023, January 27). *Web Accessibility Directive Review*. Retrieved from: European Union of the Deaf: <https://www.eud.eu/web-accessibility-directive-review%EF%BF%BC/>, June 25, 2023.
16. Eurostat (2023, August 1). *How many EU people can afford an internet connection?* Retrieved from: Eurostat: <https://ec.europa.eu/eurostat/web/products-eurostat-news/w/edn-20230801-1>, August 15, 2023.
17. Fung, K.-K., Hung, S.S.-L., Lai, D.W., Shum, M.H., Fung, H.-W., He, L. (2023, June 23). Access to Information and Communication Technology, Digital Skills, and Perceived Well-Being among Older Adults in Hong Kong. *International Journal of Environmental Research and Public Health*, 20(12), p. 6208. doi: <https://doi.org/10.3390/ijerph20136208>
18. Gay, G. (2023, February 23). Open curriculum for teaching digital accessibility. *Frontiers in Computer Science*, p. 1113936. doi: <https://doi.org/10.3389/fcomp.2023.1113936>
19. Hill, R., Betts, L., Gardner, S. (2015, July). Older adults' experiences and perceptions of digital technology: (Dis)empowerment, wellbeing, and inclusion. *Computers in Human Behavior*, 48, pp. 415-423. doi: <https://doi.org/10.1016/j.chb.2015.01.062>
20. Inal, Y., Guribye, F., Rajanen, D., Rajanen, M., Rost, M. (2020). Perspectives and Practices of Digital Accessibility: A Survey of User Experience Professionals in Nordic Countries. In: D. Lamas, H. Sarapuu (Eds.), *NordiCHI '20: Proceedings of the 11th Nordic*

- Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society* (pp. 1-11). Tallin, Estonia: Association for Computing Machinery. New York, United States. doi: <https://doi.org/10.1145/3419249.3420119>
21. Integracja.org (2023). *Integracja*. Retrieved from: Integracja: <https://www.integracja.org/>, August 12, 2023.
  22. ISAP (2019, April 4). *Polish Act of 4 April 2019 on the digital accessibility of websites and mobile applications of public entities*. Retrieved from: ISAP: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20190000848>, June 7, 2023.
  23. Ismail, A., Kuppusamy, K. (2019, April 1). Web accessibility investigation and identification of major issues of higher education websites with statistical measures: A case study of college websites. *Journal of King Saud University - Computer and Information Sciences*, 34, pp. 901-911. doi: <https://doi.org/10.1016/j.jksuci.2019.03.011>
  24. ITU (2022, October). *Digital inclusion of all*. Retrieved from: ITU Committed to connecting the world, <https://www.itu.int/en/mediacentre/backgrounders/Pages/digital-inclusion-of-all.aspx>, May 5, 2023.
  25. Kärnä, E., Aavikko, L., Rohner, R., Gallistl, V., Pihlainen, K., Müller, C. et al. (2022, November 25). A Multilevel Model of Older Adults' Appropriation of ICT and Acquisition of Digital Literacy. *International Journal of Environmental Research and Public Health*, 19(23), p. 15714. doi: <https://doi.org/10.3390/ijerph192315714>
  26. Kulkarni, M. (2019, April 24). Digital accessibility: Challenges and opportunities. *IIMB Management Review*, pp. 91-98. doi: <https://doi.org/10.1016/j.iimb.2018.05.009>
  27. Lin, Z., Yang, L., Zhi'an, Z. (2018). To include, or not to include, that is the question: Disability digital inclusion and exclusion in China. *New Media & Society*, 20(12), pp. 4436-4452. doi: <https://doi.org/10.1177/1461444818774866>
  28. Logitech Adaptive Esports Tournaments (2023). *Logitech Adaptive Esports Tournaments*. Retrieved from: Logitech Adaptive Esports Tournaments: <https://aet.gg/>, August 12, 2023.
  29. Martínez-Alcalá, C., Alejandra, R.-L., de los Ángeles Alonso-Lavernia, M., Ramírez-Salvador, J., Jiménez-Rodríguez, B., Cepeda-Rebollar, R., Agis-Juárez, R. (2018, August 28). Digital Inclusion in Older Adults: A Comparison Between Face-to-Face and Blended Digital Literacy Workshops. *Frontiers in ICT*, 5, pp. 1-17. doi: <https://doi.org/10.3389/fict.2018.00021>
  30. Media Access Australia (2014, March 12). *European Union Legislates For Web Accessibility*. Retrieved from: Media Access Australia: [https://mediaaccess.org.au/latest\\_news/general-online-media-policy-legislation-international-policy-and-legislation-news/european-union-legislates-for-web](https://mediaaccess.org.au/latest_news/general-online-media-policy-legislation-international-policy-and-legislation-news/european-union-legislates-for-web), December 18, 2021.
  31. Morte-Nadal, T., Esteban-Navarro, M. (2022, January-December 18). Digital Competences for Improving Digital Inclusion in E-Government Services: A Mixed-Methods Systematic Review Protocol. *International Journal of Qualitative Methods*, 21. doi: <https://doi.org/10.1177/16094069211070935>

32. mozilla. (2023). *What is accessibility?* Retrieved from: developer mozilla: [https://developer.mozilla.org/pl/docs/Learn/Accessibility/What\\_is\\_accessibility](https://developer.mozilla.org/pl/docs/Learn/Accessibility/What_is_accessibility), June 17, 2023.
33. Nguyen, M., Hargittai, E., Marler, W. (2021, July). Digital inequality in communication during a time of physical distancing: The case of COVID-19. *Computers in Human Behavior*, 120, p. 106717. doi: <https://doi.org/10.1016/j.chb.2021.106717>
34. Notley, T., Aziz, A. (2024). The unjust burden of digital inclusion for low-income migrant parents. *Policy & Internet*, 1-15. <https://doi.org/10.1002/poi3.383>
35. NIK (2018, October 30). *Dostępność przestrzeni publicznej dla osób starszych i niepełnosprawnych*. Retrieved from: Najwyższa Izba Kontroli: <https://www.nik.gov.pl/kontrola/P/17/094/LKA/>, May (1)7, 2022.
36. OECD (2021). *Bridging digital divides in G20 countries*. OECD. doi: <https://doi.org/10.1787/35c1d850-en>
37. OECD (2022). *Access to computers from home*. doi:10.1787/a70b8a9f-en
38. Oncins, E., Armony, A., Fitzpatrick, D. (2020). *Mapping The European Digital Accessibility Field: The IMPACT Project*. 9th International Conference on Software Development and Technologies for for Enhancing Accessibility and Fighting Info-exclusion (pp. 33-37). Portugal: Association for Computing Machinery. New York, United States. doi: 10.1145/3439231.3440608
39. Pérez-Escobar, M., Canet, F. (2023, August). Research on vulnerable people and digital inclusion: toward a consolidated taxonomical framework. *Universal Access in the Information Society*, 22, pp. 1059-1072. doi: <https://doi.org/10.1007/s10209-022-00867-x>
40. Polish Language Dictionary (2021). *Słownik języka polskiego (sjp)*. Retrieved from: dostępny: <https://sjp.pl/dostępny>, June 3, 2021.
41. Rankin, J. (2005, January). *Mental Health and Social Inclusion*. Retrieved from: Mental Health in the Mainstream: [https://www.ippr.org/files/images/media/files/publication/2011/05/mental\\_health\\_paper2\\_1342.pdf](https://www.ippr.org/files/images/media/files/publication/2011/05/mental_health_paper2_1342.pdf), August 25, 2023.
42. Spandler, H. (2007, November 01). From Social Exclusion to Inclusion? A Critique of the Inclusion Imperative in Mental Health. *Medical Sociology online*, 2(2), pp. 3-16. Retrieved from: From Social Exclusion to Inclusion? A Critique of the Inclusion Imperative in Mental Health: <https://britsoc.co.uk/files/MSo-Volume-2-Issue-2.pdf#page=7>, June 15, 2023.
43. Šumak, B., Podgorelec, V., Karakatič, S., Dolenc, K., Sorgo, A. (2019). Development of an Autonomous, Intelligent and Adaptive E-learning System. *42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 1492-1497). Opatija, Croatia: IEEE. doi: 10.23919/MIPRO.2019.8756889
44. The Americans with Disabilities Act (ADA) (1990). Retrieved from: <https://www.ada.gov/law-and-regs/ada/>, June 24, 2024.

45. Tsatsou, P. (2020). Digital inclusion of people with disabilities: a qualitative study of intra-disability diversity in the digital realm. *Behaviour & Information Technology*, 39(9), pp. 995-1010. doi: 10.1080/0144929X.2019.1636136
46. United Nations (1948, December 10). *Universal Declaration of Human Rights*. Retrieved from: United Nations: <https://www.un.org/en/about-us/universal-declaration-of-human-rights>, April 17, 2021.
47. United Nations (2007, January 24). *Convention on the Rights of Persons with Disabilities [A/RES/61/106]*. Retrieved from: United Nations. Department of Economic and Social Affairs. Disability: <https://www.un.org/development/desa/disabilities/resources/general-assembly/convention-on-the-rights-of-persons-with-disabilities-ares61106.html>, December 3, 2021.
48. United Nations (2015, October 21). Resolution adopted by the General Assembly on 25 September 2015. Transforming our world: the 2030 Agenda for Sustainable Development. Retrieved from: United Nations. General Assembly: [https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A\\_RES\\_70\\_1\\_E.pdf](https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf), May 25, 2022,
49. Verdegem, P. (2011, January). Social Media for Digital and Social Inclusion: Challenges for Information Society 2.0 Research & Policies. *TripleC*, 9(1), pp. 28-38. doi: 10.31269/vol9iss1pp28-38
50. W3C (2004, March 11). *Web Content Accessibility Guidelines 2.0: W3C Working Draft 11 March 2004*. B. Caldwell, W. Chisholm, G. Vanderheiden, J. White (Eds.). Retrieved from: W3C: <https://www.immagic.com/eLibrary/ARCHIVES/TECH/W3C/W040311C.pdf>, May 15, 2021.
51. W3C (2011, November). *Selecting and Using Authoring Tools for Web Accessibility*. Retrieved from: W3C Web Accessibility Initiative (WAI): <https://www.w3.org/WAI/impl/software>, November 3, 2021.
52. W3C (2023). *Web Accessibility Initiative WAI*. Retrieved from: Introduction to Understanding WCAG - Understanding the Four Principles of Accessibility: <https://www.w3.org/WAI/WCAG21/Understanding/intro#understanding-the-four-principles-of-accessibility>, August 7, 2023.
53. W3C (2023, July 20). *Web Content Accessibility Guidelines (WCAG) 2.2*. Retrieved September 10, 2023, from W3C: <https://www.w3.org/TR/WCAG22/>
54. W3C WAI (2019, October 4). *How to Meet WCAG (Quick Reference)*. Retrieved from: Web Accessibility Initiative WAI: <https://www.w3.org/WAI/WCAG21/quickref/>, October 17, 2021.
55. W3C WAI (2022, September 15). *Course List - Digital Accessibility Education, Training, and Certification*. Retrieved from: W3C Web Accessibility Initiative: <https://www.w3.org/WAI/courses/list/>, July 17, 2023.

56. WebAxe (2019, November 17). *Digital Accessibility Jobs, November 2019*. Retrieved from: WebAxe: <https://www.webaxe.org/digital-accessibility-jobs-november-2019/>, September 17, 2023.
57. Wikipedia (2023). *Dostępność WWW*. Retrieved from: Wikipedia Wolna encyklopedia: [https://pl.wikipedia.org/wiki/Dostępność\\_\(WWW\)](https://pl.wikipedia.org/wiki/Dostępność_(WWW)), July 15, 2023.
58. World Bank (2023). *Fixed broadband subscriptions (per 100 people)*. Retrieved from: The World Bank Data: [https://data.worldbank.org/indicator/IT.NET.BBND.P2?end=2022&locations=PL-ES-SI-GR&name\\_desc=false&start=2010&view=chart](https://data.worldbank.org/indicator/IT.NET.BBND.P2?end=2022&locations=PL-ES-SI-GR&name_desc=false&start=2010&view=chart), August 12, 2023.

## ECONOMIC BASIS OF PRODUCTION OF AGRICULTURAL CROPS IN UKRAINE IN THE CONTEXT OF MANAGEMENT AND CLIMATE CHANGE

Alina YAKYMCHUK<sup>1</sup>, Małgorzata BZOWSKA-BAKALARZ<sup>2</sup>, Oksana BALANDA<sup>3</sup>,  
Justyna JUPOWICZ-KOZAK<sup>4</sup>

<sup>1</sup> University of Information Technologies and Management, Rzeszów, Polska; mbzowska@wsiz.edu.pl,  
ORCID: 0000-0001-6031-8529

<sup>2</sup> Research Service of the Verkhovna Rada of Ukraine, Kyiv, Ukraine; alinayakim@ukr.net,  
ORCID: 0000-0002-5038-5215

University of Information Technologies and Management, Rzeszów, Polska; ayakymchuk@wsiz.edu.pl

<sup>3</sup> University of Information Technologies and Management, Rzeszów, Polska; obalanda@wsiz.edu.pl,  
ORCID: 0000-0003-2074-8182

<sup>4</sup> University of Information Technologies and Management, Rzeszów, Polska; jjupowicz@wsiz.edu.pl,  
ORCID: 0000-0001-5945-7070

\* Correspondence author

**Purpose:** The purpose of the research is to examine the existing literature on the economic foundations of agricultural crop production in Ukraine, focusing on the evolving management strategies in light of climate change challenges during the war.

**Design/methodology/approach:** The systemic method applied to research involves an integrated approach focusing on interconnected elements within agricultural systems.

The analysis was based on the official data of crops growing in Ukraine in 1991-2022, constituting a list of scientific publications. The systemic method applied to research involves an integrated approach focusing on interconnected elements within agricultural systems. Combining multiple methods provided a more comprehensive and nuanced understanding of the complex interactions between crops growing and analyzing the structure of the information about new plant cultures.

**Findings:** The study embraced an adaptive approach, recognizing that the agricultural system is dynamic and subject to constant change. It aimed to adapt strategies based on evolving insights and feedback from stakeholders involved in the system.

**Research limitations/implications:** The implications of this study underscore the importance of stakeholder engagement and adaptive management for effective integration. Practical implications suggest the need for policy coordination, capacity building, and innovative incentive mechanisms to foster harmonious coexistence between economic development and agricultural crops production.

**Originality/value:** Before the war, 45 agricultural enterprises controlled a total of about 4.1 million hectares of agricultural land. Their total income exceeded 10.8 billion US dollars. The average farm in Ukraine occupies an area of 1000 hectares, while in the EU - only 16 hectares, and in Poland – 11 hectares. It is not difficult to calculate that one Ukrainian tycoon owns the area of approximately 46,000 Polish farmers. This might be a new direction in

correction of modern agricultural policy. These results could be especially interesting for researchers whose studies are interdisciplinary.

**Keywords:** agricultural crops, management, climate changes, production.

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

**JEL:** Q57, G28 O44.

## 1. Introduction

Ukraine boasts a rich agricultural heritage, with its fertile lands serving as the bedrock of the nation's economy. However, in the face of evolving climatic patterns and the need for efficient management practices, the economic underpinnings of agricultural crop production in the country have come under scrutiny. Ukraine's agricultural sector stands as a cornerstone of its economy, contributing significantly to its GDP and providing employment to a substantial portion of its population. The cultivation of key crops such as wheat, corn, sunflower, and barley forms the bedrock of the nation's agricultural landscape, driving economic growth and export revenues.

Ukraine's agricultural sector holds paramount significance in its economic landscape, contributing substantially to the nation's GDP and employment. This article aims to explore the existing literature on the economic foundations of agricultural crop production in Ukraine, focusing on the evolving management strategies in light of climate change challenges during the war.

The main goals of this work are:

- To examine the economic factors influencing agricultural crop production in Ukraine and Europe affected by climate change.
- To assess the impact of war conditions on crop yields, economic output, and farmer livelihoods.
- To analyze management strategies employed by different regions to adapt agricultural practices to changing climates.
- To understand the interplay between economic indicators, climate variability, and management decisions in the agricultural sector.
- To identify successful approaches and best practices for mitigating economic challenges posed by climate change in crop production.
- To propose recommendations for policymakers and stakeholders aimed at enhancing the economic resilience of agricultural systems in the face of climate change.

Object of this investigation: the study focuses on the economic dimensions of agricultural crop production, encompassing various elements:

1. Economic indicators: Including production costs, market prices, revenue, and profitability of crop production.



2. Climate variables: Assessing the impact of temperature, precipitation patterns, droughts, and extreme weather events on agricultural productivity.
3. Management strategies: Analyzing practices such as precision farming, crop diversification, irrigation methods, and technology adoption.
4. Farmer communities and stakeholders: Understanding the economic implications and responses of farmers and stakeholders to climate-induced challenges.
5. Policy frameworks: Evaluating government policies and interventions related to agricultural adaptation and economic sustainability in changing climates.

## 2. An overview of the literature

Numerous studies underscore the pivotal role of agriculture in Ukraine's economy. Research by Petrov et al. (2020) highlights that the cultivation of staple crops such as wheat, corn, sunflower, and barley forms the backbone of agricultural output, driving economic growth and export revenues. These crops serve as essential commodities, impacting both domestic consumption and international trade.

The literature emphasizes a shift towards modern management strategies in Ukrainian agriculture. Precision farming techniques, as outlined by Tkachenko and Ivanov (2020), have gained traction, integrating technology for enhanced resource efficiency. Examples include the use of satellite imagery and data analytics to optimize fertilizer application and irrigation, leading to improved yields and cost reduction. These authors emphasize the importance of adopting precision farming technologies in Ukrainian agriculture and discuss the efficiency gains achievable through technology while shedding light on the challenges and barriers faced during implementation.

Studies by Kovalenko et al. (2021) and Zhukovsky et al. (2023) highlight the vulnerability of Ukrainian agriculture to climate change. Erratic weather patterns, temperature fluctuations, and shifting precipitation adversely affect traditional farming practices. Yet, adaptations are emerging; for instance, the introduction of drought-resistant crop varieties and altered planting schedules help mitigate risks associated with changing climatic conditions. The authors highlight the adverse effects of climate change on Ukraine's agricultural productivity. It probably delves into trends, vulnerabilities, and explores adaptation strategies aimed at mitigating the impacts of changing climate patterns.

Efforts to enhance economic resilience are evident in the literature. Government policies promoting sustainable agriculture, noted by Vasiliev and Petrova (2020), encourage farmers to adopt conservation practices and crop diversification. These measures aim to bolster soil health, reduce environmental impact, and mitigate the economic consequences of climate variability. The scientists discuss the role of government policies in promoting sustainable agriculture,

particularly through a case study on crop diversification in Ukraine and explore how policy interventions can encourage diversification for long-term agricultural sustainability.

Looking forward, the literature calls for continued investment in research and technology. Collaborations between domestic institutions and international organizations, as suggested by Kovalev and Sidorova (2020), drive innovation in developing climate-resilient crop varieties and advanced farming machinery suited to changing environmental conditions. This study likely focuses on the opportunities and challenges associated with investments in agricultural research, specifically targeting climate-resilient crops in Ukraine. It probably assesses the potential benefits and obstacles in developing crops resilient to changing climatic conditions.

A group of scientists Petrov, I., Smith, A., & Johnson, B. (2020) underscore the significant role of agricultural crop production in Ukraine's economic landscape. It emphasizes the comprehensive nature of the analysis conducted, likely highlighting how the sector contributes to employment, GDP, and overall economic stability.

In the work of Zhukovsky, V., & Romanova, E. (2020) authors focus on assessing vulnerabilities in Ukrainian agriculture concerning climate variability and its direct impact on crop yield. It likely examines the challenges posed by erratic climate patterns and the susceptibility of crops to these variations.

Some researchers emphasize the importance of employing advanced technologies such as precision agriculture and modern farming methods to enhance the efficiency of agricultural production amid climate change. They may analyze how these technologies can reduce vulnerability to weather conditions. Some scientists highlight the significance of developing adaptation strategies aimed at increasing the resilience of agricultural systems to climate change. They analyzed the effectiveness of these strategies and their impact on the economy.

Other researchers might focus on the importance of effective government policies to support agriculture in the face of climate change. They analyze the state's role in incentivizing sustainable practices and investments in the sector. Some scientists emphasize the importance of increased investment in scientific research to develop innovative approaches and new plant varieties that are more resilient to climate change. Other researchers emphasize the importance of global cooperation among countries and organizations to exchange knowledge, experiences, and technologies aimed at adapting agriculture to climate change.

These perspectives encompass a variety of views and may reflect different schools of thought among agricultural and climate change researchers. Actual research takes into account context, data, and real experiences, so scientists' views might be more specific and detailed.

### 3. Research methods

The systemic method applied to research involves an integrated approach focusing on interconnected elements within agricultural systems.

The research began by identifying and understanding the complex interrelationships between economic factors, agricultural practices, climate change, and management strategies affecting crop production. This step aimed to recognize the multifaceted nature of the agricultural system.

A systematic mapping of the components and subsystems of agricultural systems was conducted. This included economic indicators, climatic variables, farming practices, policy frameworks, and socio-economic factors. This mapping helped visualize the interdependencies and feedback loops within the system.

Rather than focusing on isolated components, the study adopted a holistic view, considering the entire agricultural ecosystem. It examined how changes in one aspect, such as climate conditions, affected multiple elements within the system, including crop yields, economic output, and farmer livelihoods. Understanding feedback loops and their impact on the system dynamics was a crucial aspect. The research assessed how economic changes influenced agricultural practices and, in turn, how altered farming methods affected economic outcomes, creating a cyclical effect.

Various data sources and modeling techniques were integrated to analyze the complex interactions within the agricultural system. Quantitative data on economic variables and climate patterns were combined with qualitative insights gathered through interviews and surveys. Using the systemic method involved scenario planning, where different future scenarios of climate change and management strategies were envisioned. This allowed for an assessment of potential impacts on economic aspects of crop production under varying conditions.

The study embraced an adaptive approach, recognizing that the agricultural system is dynamic and subject to constant change. It aimed to adapt strategies based on evolving insights and feedback from stakeholders involved in the system. Utilizing statistical methods to analyze large datasets can reveal trends and correlations between economic indicators, agricultural productivity, and climatic factors. Regression analysis can assess the relationship between climatic variables and crop yields.

Conducting a comprehensive review of existing literature provides a foundation for understanding the current state of research, identifying gaps, and synthesizing various perspectives on economic aspects, management strategies, and climate change impacts on agricultural crop production. Implementing controlled experiments in agricultural fields can evaluate the effectiveness of different management strategies in mitigating the impact of climate change on crop yields. These experiments can involve testing new varieties, irrigation methods, or soil management practices.

Conducting interviews with experts, farmers, or policymakers can provide qualitative insights into their experiences, challenges, and perceptions regarding economic aspects and management strategies in agriculture amid climate change.

Developing economic models that incorporate variables such as climate data, market prices, and agricultural inputs can help forecast the economic impacts of climate change on crop production and assess the cost-effectiveness of adaptation measures.

In summary, the systemic method applied to this research involved a comprehensive analysis of the interconnected components and relationships within agricultural systems, considering their dynamic nature and interdependencies to understand the economic aspects of crop production in the context of climate change and management strategies. In the process of analysis and processing of agricultural production data, were used such formulas.

Profitability of agricultural crops productivity:

$$\text{Profitability} = (\text{Total Revenue} - \text{Total Costs}) / \text{Total Costs} \times 100\% \quad (1)$$

Resource Utilization Ratio:

$$\text{Resource Utilization Ratio} = \text{Output} / \text{Input} \quad (2)$$

Net Income:

$$\text{Net Income} = \text{Total Revenue} - \text{Total Costs} \quad (3)$$

Average Gross Revenue per Hectare:

$$\text{Average Gross Revenue per Hectare} = \text{Total Gross Revenue} / \text{Total Hectares Cultivated} \quad (4)$$

Economic Efficiency of agricultural crops production:

$$\text{Economic Efficiency} = \text{Output Value} / \text{Input Value} \times 100\% \quad (5)$$

Gross Productivity Index:

$$\text{Gross Productivity Index} = \text{Total Output} / \text{Total Input} \quad (6)$$

Various formulas contribute to evaluating different aspects of agricultural production. These formulas encompass profitability, resource utilization ratios, net income, average gross revenue per hectare, economic efficiency, and gross productivity index. Each formula serves as a quantitative measure to assess financial, resource utilization, and productivity aspects of agricultural endeavors. These formulas serve as tools for farmers, policymakers, and researchers to make informed decisions regarding crop selection, resource allocation, investment strategies, and policy implementations. By applying these formulas, stakeholders can optimize resource usage, enhance profitability, and drive sustainable agricultural practices.

## 4. Main Results

The success of agricultural crop production amidst evolving climatic conditions serves as a beacon of inspiration for nations worldwide. Various countries have showcased remarkable resilience, employing innovative strategies to navigate the challenges posed by climate change

while maintaining economic stability.

The Netherlands stands as a paragon of efficient agricultural practices despite its small landmass. Embracing precision agriculture techniques, Dutch farmers utilize advanced technology such as precision irrigation and sensor-based crop management. For instance, in the province of Flevoland, farmers deploy drones equipped with multispectral cameras to monitor crop health, optimizing yields while conserving resources. Additionally, initiatives promoting sustainable practices like crop rotation and integrated pest management have fortified the resilience of Dutch agriculture against climate variability.

In the arid landscapes of Australia, where droughts pose substantial risks to agriculture, innovative approaches have emerged. Australian farmers have pioneered the adoption of drought-tolerant crop varieties, such as drought-resistant wheat strains developed through advanced breeding programs. Moreover, effective water management practices, exemplified by the Murray-Darling Basin Plan, have been instrumental in conserving water resources, ensuring agricultural sustainability even during prolonged dry spells.

Brazil's success in agricultural crop production owes much to its implementation of agroforestry systems. The integration of trees within farming landscapes not only enhances biodiversity but also provides natural shields against adverse climatic conditions. In the southern region of Brazil, where erratic weather patterns are prevalent, farmers have adopted agroforestry practices, which combine crops with trees, mitigating the impacts of climate fluctuations while improving soil fertility and crop yields.

Israel, known for its expertise in desert agriculture, has set exemplary standards in water management and efficient resource utilization. Through the use of advanced irrigation techniques like drip irrigation and desalination technologies, Israel maximizes water efficiency, enabling successful cultivation even in arid regions. The Negev Desert showcases thriving agricultural production, with methods like hydroponics and vertical farming revolutionizing crop cultivation in challenging environments.

Ukraine possesses vast arable land and favorable agro-climatic conditions, contributing to its significant agricultural productivity. The country is known for its production of grains, oilseeds, and other crops, leveraging its fertile soils and favorable weather conditions. Despite its agricultural potential, Ukraine faces challenges in fully optimizing crop yields due to factors such as inconsistent agricultural practices, insufficient infrastructure, and varying governmental policies. These limitations can hinder the realization of the country's full agricultural potential. Efforts towards modernization and the adoption of advanced agricultural technologies are underway in Ukraine. However, there's room for further investment in modern farming practices, machinery, and infrastructure to enhance productivity and efficiency. Military activities have a negative impact on the entire ecosystem, but the soil ecosystem suffers the most. As a result of ammunition explosions, various chemical reactions occur and soil and atmosphere are polluted. In the summer of 2022, a significant part of agricultural land in Kherson, Zaporozhye, Mykolaiv and other bombed regions was burned along with harvests.

In addition to the relatively safe CO<sub>2</sub> and water vapor, during the oxidation of 1 kg of explosives, several dozen cubic meters of toxic gases are released into the air: SO<sub>2</sub>, NO<sub>x</sub>, CO (including aromatic hydrocarbons). Sulfur and nitrogen oxides from the atmosphere return to the soil in the form of acid rain, which changes its pH and causes plant burns. Chemical compounds that do not undergo biological decomposition are also used to produce military weapons and explosives, which poses a real risk of soil and surface water contamination and negatively affects fauna and flora. After the explosion, some of the metal debris and unreacted substances remain in the ground, and the rest scatters and settles (metal fragments up to 300 m, unused reagents up to 35 m), entering the soil substance cycle and becoming involved in trophic chains. After restoration, such soil may be suitable for cultivation, but the natural regeneration of individual chemical pollutants may take hundreds of years (Simonov, Vasyliuk, Spinova, 2022).

Surface disturbance and compaction resulting from war events have a negative impact on the biological soil crust (Rowlands, 1980), leads to loss of diversity and biomass of the surface soil layer.

During Russia's invasion of Ukrainian territory, thousands of hectares of fertile Ukrainian chernozem lands were destroyed as a result of hostilities (bombings, explosions, arson, movement of military equipment in the fields, etc.). Thus, already in March 2022, there were approximately 110,053 km<sup>2</sup> of arable land in the agricultural risk zone in Ukraine, which constituted over 30% of the total arable land in Ukraine (Chaika, Korotkova, 2023).

It should be noted that the situation with maintaining soil resources in Ukraine was already insufficient in the pre-war period, as almost 26% (16 million ha) of the soil cover was considered eroded, and over 15% of it required removal from cultivation and conservation. Devastating effects on this scale were the result of unsustainable farming methods. During the war, erosion processes will have an even greater cumulative effect (Vasylyuk, Kolodezhna, 2023).

Poland maintains a diverse agricultural landscape, characterized by a mix of small-scale family farms and larger commercial enterprises. This diversity contributes to a balanced agricultural output across various crops and livestock. Now Poland prioritizes sustainable agricultural practices and innovation. The country's agricultural sector is increasingly adopting modern technologies, precision farming methods, and sustainable approaches, fostering higher productivity while minimizing environmental impact. Poland's integration with EU agricultural standards has led to advancements in quality control, product diversification, and market access. Compliance with EU regulations has bolstered the competitiveness and quality of Polish agricultural products in international markets. The country emphasizes investment in agricultural research and development, fostering innovation and the creation of climate-resilient crops and techniques. Such initiatives aim to address challenges posed by climate change and ensure long-term productivity.

According to the analysis of official statistics, it was found that 123 oligarchic farms in Ukraine occupy 11.3% of the total area of the territory of Ukraine, which is a significant indicator. Compared to the cultivated area of the country (28,387.5 thousand hectares in 2021), this number will be as much as  $6,842,127 / 28,387.5 = 0.241 * 100 = 24.1\%$ . Moreover, Ukrainian capital occupied approximately 80% of the total area of agricultural holdings. Foreign oligarchs own a smaller share of agricultural land, estimated at 20%.

Before the war, 45 agricultural enterprises controlled a total of about 4.1 million hectares of agricultural land. Their total income exceeded 10.8 billion US dollars. The average farm in Ukraine occupies an area of 1,000 hectares, while in the EU - only 16 hectares, and in Poland - 11 hectares. It is not difficult to calculate that one Ukrainian tycoon owns the area of approximately 46,000 Polish farmers (table 1).

**Table 1.**

*Analyzing the structure of the information about it new cultures in Ukraine*

Land area, thousand hectares (agro-holdings)	Ukrainian land capital of oligarchs, thousand ha	Foreign land capital of the oligarchs, one thousand hectares	As a percentage of the total area of Ukraine
6842,127	5403,627	1438,500	60357,712 (100%)
100%	78,98%	21,02%	11,335%

Source: The data is based on the latest available statistics from Statista, 2024; European Commission, 2023, 6.06.2024.

In 2022, the planted areas of sugar beet decreased by 8.5 times compared to the data of 1991. Sown areas of vegetables in 2022 were reduced by a quarter compared to the base year of 1991. During the same period, the area of fruit crops decreased by 4.36 times and amounted to only 193 thousand hectares compared to the comparative base of 842 thousand hectares (Table 2). Potato cultivation, for which Ukraine has always been famous, has reduced its area by 22%. The same applies to grain and leguminous crops, which in 2022 fell in price by 17%. All these data are available in open statistics, we have analyzed them and are observing such a situation.

In the structure of land ownership, the majority of land is in private hands, approximately 31 million hectares, and 10.4 million hectares - in state and communal ownership. At the same time, about a third of the land, or 32.7 million hectares, is arable. According to the Constitution, the Ukrainian people are the owners of a unique good – land, which they can neither use nor dispose of. Although, according to the Constitution of Ukraine, "on behalf of the Ukrainian people, the rights of the owner are exercised by state authorities and local self-government bodies within the limits established by this Constitution", neither the Constitution nor the legislation of Ukraine fix the rights of the owner on the rights of the owner. So, out of 25 million land holdings and ways of their use in Ukraine, the land cadastre currently contains information on only 17 million plots - these are the data of the National University of Bioresources and Nature Management of Ukraine. Due to the lack of a land market (from the point of view of use), the value of agricultural land in Ukraine is significantly undervalued. In Ukraine in 2017,

the average rent per hectare of agricultural land was 1,369 hryvnias (41 euros), while, for example, in the Czech Republic it was 96 euros, in Bulgaria it was 225 euros, and in Austria it was 348 euros. euro. Currently, the average estimated value of one hectare of land in Ukraine is 27.5 thousand hryvnias, that is, about 840 euros, while in Europe it ranges between 5-6 thousand euros per hectare (Czech Republic and Bulgaria) to 100,000 euros (in Italy and Spain). For example, in Slovakia and Slovenia, the minimum price per hectare of arable land is 14,000 euros.

It is necessary to create institutions that will actually set the "rules of the game" in this market in the name and in the interests of people and future generations. But the introduction of any land market is blocked and will be blocked by "land oligarchs", because paying for land rent 41 euros per hectare (as in Ukraine) and 225 euros (as in Bulgaria, for example) are "two big differences". And if the rent (land tax) for the use of 42 million hectares of agricultural land in Ukraine is 1% of their real value (5-10 thousand euros per hectare), then the total amount of rent payments in general (before the budgets) of municipalities and the state, a special fund, etc.) amounted to at least 2 billion euros per year, i.e. more than 60 billion UAH! Also, taking into account the fact that in Ukraine the state owns more than 10 million hectares of agricultural land, the rental rate of which is 225 euros per hectare (similar to Bulgaria), the state should receive another 2.25 billion euros from the budget (or a separate fund), i.e. more than 60 billion hryvnias. The authors believe that these funds should serve those from whom we draw these resources - nature and our next generations, and not "pass" through state or local budgets.

We have already "eaten" enough resources at the expense of our children and grandchildren. And part of this rent should be returned to nature in exchange for what we took from it, in the form of restoration or reclamation of land, forests, rivers, landscapes, etc. The remaining part of the rent would have, according to the authors, every year go to the special accounts of every child in Ukraine, who can spend them on their own development.

Analysis of crops growing in Ukraine, from 1991 to 2022 has been represent in table 2.

**Table 2.**  
*Analysis of crops – growing in Ukraine, 1991-2022*

Year	Planted area of agricultural crops, thsd.ha					Area of fruit and berry plantations (total) <sup>1</sup>
	Cereal and leguminous crops	Sugar beet (for processing)	Sunflower	Potatoes	Vegetables	
1991	14671	1558	1601	1533	477 <sup>2</sup>	842
1992	13903	1498	1641	1702	500 <sup>2</sup>	834
1993	14305	1530	1637	1552	474 <sup>2</sup>	818
1994	13527	1485	1784	1532	461	804
1995	14152	1475	2020	1532	507	794
1996	13248	1359	2107	1547	479	772
1997	15051	1104	2065	1579	483	752
1998	13718	1017	2531	1513	461	468
1999	13154	1022	2889	1552	499	450
2000	13646	856	2943	1629	541	425
2001	15586	970	2502	1604	492	402



Cont. table 2.

2002	15448	897	2834	1590	482	369
2003	12495	773	4001	1585	483	338
2004	15434	732	3521	1556	478	316
2005	15005	652	3743	1514	467	299
2006	14515	815	3964	1464	471	281
2007	15115	610	3604	1453	454	271
2008	15636	380	4306	1413	460	267
2009	15837	322	4232	1409	453	260
2010	15090	501	4572	1408	465	255
2011	15724	532	4739	1439	501	255
2012	15449	458	5194	1440	498	255
2013	16210	280	5051	1388	488	253
2014 <sup>3</sup>	14801	331	5257	1348	467	239
2015 <sup>3</sup>	14739	237	5105	1291	446	235
2016	14401	292	6073	1312	447	224
2017	14624	316	6034	1323	445	226
2018	14839	276	6117	1319	439	228
2019	15318	222	5928	1309	452	225
2020	15392	220	6457	1325	464	219
2021	15995	227	6622	1283	460	217
2022	12171	184	5293	1208	378	193

Source: The data is based on the latest available statistics from Market insights, 2023; International cooperation, 2024; European Commission, 2024, 6.06.2024.

The authors made such calculations for farms with an area of up to 100 and over 1000 ha, where crops such as cereals and legumes, wheat, corn, barley, soybean, winter and spring rapeseed, sunflower, and sugar beet are grown (table 3).

**Table 3.**

*List of farms up to 100 ha and over 1000 ha and their efficiency in relation to average productivity*

Indicator	Number of enterprises		Production volume (gross acceptance)		Yield, quintals per 1 ha of harvested area	In % of the average yield of this plant from 1 ha of harvested area
	Units	In % of the total amount	Thousand tonnes	in % of total production volume		
<b>Growing cereals and legumes</b>						
Enterprises up to 100 ha	13624	55,9	1792,0	4,2	36,4	72,4
Enterprises over 1000 ha	2152	8,8	26525,8	62,7	54,5	108,3
<b>Wheat</b>						
Enterprises up to 100 ha	11482	61,7	1362,6	8,4	34,2	83,6
Enterprises over 1000 ha	782	4,2	6456,2	39,7	44,8	109,6
<b>Corn</b>						
Enterprises up to 100 ha	7856	61,6	1602,7	7,2	55,5	80,3
Enterprises over 1000 ha	604	4,7	11771	52,8	73,9	106,9

Cont. table 3.

<b>Barley</b>						
Enterprises up to 100 ha	6967	77,1	660,9	22,4	31,0	88,3
Enterprises over 1000 ha	65	0,7	401,8	13,6	41,1	117,1
<b>Soy</b>						
Enterprises up to 100 ha	6310	72,7	403,2	12,9	19,5	84,4
Enterprises over 1000 ha	239	2,8	1438,3	45,9	25,05	108,4
<b>Winter rapeseed, spring rapeseed</b>						
Enterprises up to 100 ha	2467	47,6	301,4	9,1	25,8	89,9
Enterprises over 1000 ha	170	3,3	867,8	26,3	30,2	105,2
<b>Sunflower</b>						
Enterprises up to 100 ha	10546	58,0	733,0	7,3	18,2	81,3
Enterprises over 1,000 ha	141	0,8	1950,1	19,5	27,6	123,2
<b>Factory sugar beet</b>						
Przedsiębiorstwa do 100 ha	287	59,1	676,6	7,1	569,2	1,03
Enterprises over 1,000 ha	36	7,4	5952,0	62,6	517,9	0,94

Source: The data is based on the latest available statistics from Market insights, 2023; International cooperation, 2021; European Commission, 2021, 21.06.2023.

Calculations show that large farms (1000 ha and more, except for sugar beet cultivation) are more efficient than small farms (up to 100 ha), because their productivity per hectare is 5-23% higher. The exception are small farms up to 100 ha growing sugar beets - their productivity is 3% higher compared to large farms (over 1000 ha).

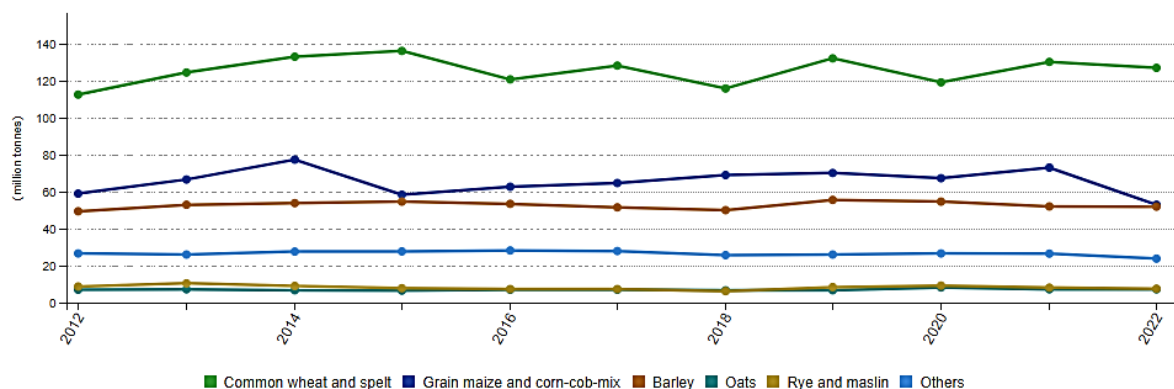
In recent years, Ukrainian agriculture has undergone a transformation, embracing modern management strategies alongside traditional practices. The adoption of precision farming techniques has gained momentum, integrating technology to optimize resource use and enhance crop yields. For instance, farmers in the Cherkasy region have implemented precision agriculture methods, utilizing satellite imagery and data analytics to precisely apply fertilizers and manage irrigation, resulting in increased efficiency and reduced input costs.

However, this progress confronts challenges posed by climate change. Erratic weather patterns, shifting precipitation, and temperature fluctuations have disrupted traditional farming practices. In response, innovative adaptations are emerging. For instance, in the drought-prone southern regions, farmers have introduced drought-resistant crop varieties like drought-tolerant maize hybrids, ensuring stable yields despite water scarcity.

To bolster economic resilience, initiatives are underway. Government policies promoting sustainable agriculture and conservation practices receive support, encouraging the adoption of agroforestry and crop rotation methods. In the Chernihiv region, farmers have diversified crops, introducing legumes alongside cereals to enhance soil fertility and mitigate climate risks, resulting in improved economic stability.

Looking ahead, the future of Ukrainian agriculture hinges on adaptive measures and technological advancements. Investments in research for climate-resilient crops and machinery suited to changing conditions are crucial. For example, collaborations with international research institutions have facilitated the development of heat-tolerant wheat varieties, ensuring consistent yields in the face of rising temperatures.

In the marketing year 2022/2023, China was the leading wheat producing country with production volume of over 137 million metric tons. This was followed by the European Union with production volume of over 134 million metric tons. Wheat is the second most important grain that is cultivated in the United States, following only corn. Wheat is a cereal crop that can be classified into five major classes. These 5 wheat categories are comprised of: hard red winter, hard red spring, soft red winter, white and durum wheat. Each class has a different end-use and the cultivation tends to be region-specific. Hard red winter wheat is mainly cultivated in the Great Plains area ranging from Montana to Texas. This type is primarily used for the manufacturing of bread flour. Hard red spring wheat is mainly grown in the Northern Plains area. Their wheat ears are mostly taken for protein blending uses. Durum wheat, which is primarily grown in North Dakota and Montana, is well-known for their excellent qualities for producing pasta. The wheat class everyone is familiar with from their breakfast cereal is known as white wheat. Almost every U.S. state is involved in agricultural production of wheat. The latest figures show that North Dakota, Kansas and Montana were the leading wheat producing states among the United States (Statista, 2024).



**Figure 1.** Production of main cereals in EU, 2012-2022.

Source: The data is based on the latest available statistics from Market insights, 2023; International cooperation, 2021; European Commission, 2021, 23.03.2024.

The EU produced 270.9 million tonnes of cereals in 2022, 26.7 million tonnes less than in 2021. The full-scale war since February 2022 has negatively impacted the production of agricultural crops in several aspects. The harvested production of many crops was impacted by drought conditions in large parts of the EU, including grain maize (down 27.4%), sunflowers (down 10.1%), and olives for olive oil (down 38.1%).

In Ukraine normal production processes have been disrupted during the war, access to fields, production means, and markets was limited and became unsafe, complicating agricultural work. Agricultural infrastructure has been destroyed. The war in Ukraine has led to damage or destruction of infrastructure, such as roads, grain storage facilities, irrigation systems, and other agricultural objects. All of this significantly affected production and crop storage. Mass displacement of population and workers from rural areas has reduced the availability of labor for cultivation and harvesting.

In the conflict zone in eastern Ukraine, areas for crop cultivation have decreased due to lack of access to land, movement restrictions, or changes in land ownership and management. Numerous economic challenges have emerged for agricultural enterprises due to decreased production, export difficulties, and changes in pricing and financial conditions. Necessary changes in accounting and reporting have arisen. Military actions have caused economic instability and changes in the accounting and reporting systems for agricultural enterprises, significantly complicating planning and management.

## 5. Conclusions

In this study, the authors summarized the main points presented in the article, proved the essential importance of agricultural crops production in the sustainable development of territorial communities. The main results are:

1. The economic foundation of agricultural crop production in Ukraine faces multifaceted challenges in the wake of climate change. However, through strategic management, technological innovations, and adaptive practices, the nation can fortify its agricultural sector, ensuring economic stability and sustainable crop production in the long run.
2. The literature underscores the intricate relationship between economic aspects, management strategies, and climate change challenges in Ukraine's agricultural sector. While facing vulnerabilities, the sector showcases resilience through adaptive measures and technological advancements. Policies supporting sustainable practices and ongoing research investments emerge as crucial elements in ensuring economic stability and sustained crop production amidst evolving climatic conditions.
3. The success stories from diverse nations underscore the importance of adaptive strategies, technological innovations, and sustainable practices in managing agricultural crop production amidst changing climates. These examples serve as valuable benchmarks for countries worldwide, offering insights and inspiration for achieving agricultural resilience in the face of climate change.

4. Due to the lack of a land market (from the point of view of use), the value of agricultural land in Ukraine is significantly undervalued. In Ukraine in 2017, the average rent per hectare of agricultural land was 1,369 hryvnias (41 euros), while, for example, in the Czech Republic it was 96 euros, in Bulgaria it was 225 euros, and in Austria it was 348 euros. euro. Currently, the average estimated value of one hectare of land in Ukraine is 27.5 thousand zlotys. hryvnias, that is, about 840 euros, while in Europe it ranges between 5-6 thousand. euros per hectare (Czech Republic and Bulgaria) to 100,000 euros (in Italy and Spain). In Slovakia and Slovenia, the minimum price per hectare of arable land is 14,000 euros. The authors made such calculations for farms with an area of up to 100 and over 1000 ha, where crops such as cereals and legumes, wheat, corn, barley, soybean, winter and spring rapeseed, sunflower, and sugar beet are grown. Calculations show that large farms (1000 ha and more, except for sugar beet cultivation) are more efficient than small farms (up to 100 ha), because their productivity per hectare is 5-23% higher. The exception are small farms up to 100 ha growing sugar beets - their productivity is 3% higher compared to large farms (over 1000 ha).
5. Ukraine's agricultural sector faces the dual challenge of maintaining economic growth while mitigating the impacts of climate change. By embracing innovative management strategies, leveraging technology, and adapting farming practices, the nation can fortify its agricultural base. Policies supporting sustainable agriculture and investments in research will be pivotal in ensuring economic stability and sustained crop production amidst evolving climatic conditions.
6. While both Ukraine and Poland possess substantial agricultural potential, each faces distinct challenges and adopts different approaches to enhance productivity. Ukraine grapples with optimization issues and infrastructure limitations, while Poland places emphasis on sustainability, innovation, and compliance with EU standards to drive agricultural productivity and quality. Continued investment in modernization, technology adoption, and sustainable practices remains crucial for both countries to further improve their agricultural productivity.

## References

1. Chaika, T., Korotkova, I. (2023). Restoration of soil fertility in Ukraine after hostilities. In: *Protecting and restoring ecological balance and ensuring self-renewal of ecosystems: a collective monograph* (pp. 232-281). Astraya Publishing House.
2. Kovalenko, N., Petrova, K., Ivanova, M. (2020). Impact of Climate Change on Agricultural Productivity in Ukraine: Trends and Adaptation Strategies. *Climate Change Economics*, 8(4), 301-320.
3. Kovalev, D., Sidorova, T. (2020). Investments in Agricultural Research for Climate-Resilient Crops: Opportunities and Challenges in Ukraine. *International Journal of Agricultural Development*, 40(3), 217-235.
4. Petrov, I., Smith, A., Johnson, B. (2020). Contribution of Agricultural Crop Production to Ukraine's Economy: A Comprehensive Analysis. *Journal of Agricultural Economics*, 25(3), 45-62.
5. Rowlands, P.G. (1980). Soil crusts. The effects of disturbance on desert soils, vegetation and community processes with emphasis on off-road vehicles: A critical review: Special Publication. In: P.G. Rowlands (ed.), *California: Desert Plan Staff*. Riverside: U.S. Department of the Interior, Bureau of Land Management, pp. 46-62.
6. Simonov, E., Vasyliuk, O., Spinova, Y. (2022). *Ukraine War Environmental Consequences Work Group*. UWEC. Edition 2.
7. Statista (2024). *Agriculture – Europe. Statista Market Forecast*. <https://www.statista.com/outlook/io/agriculture/europe>.
8. *Statistics about Agriculture in EU* (2024). <https://www.statista.com/map/europe/branch/agriculture>.
9. Tkachenko, O., Ivanov, P. (2020). Adoption of Precision Farming Technologies in Ukrainian Agriculture: A Case Study of Efficiency and Implementation Challenges. *Agricultural Technology Research*, 12(2), 87-104.
10. Vasiliev, S., Petrova, L. (2020). Government Policies and Sustainable Agriculture: A Case Study of Crop Diversification in Ukraine. *Agricultural Policy Review*, 30(2), 150-168.
11. Vasylyuk, O., Kolodezhna, V. (2024). *What should be the fate of Ukrainian territories damaged by explosions?* <https://uncg.org.ua/iakoIU-maie-butY-dolia-poshkodzhenykh-vybukhamy-ukrainskykh-terytorij>.
12. Yakymchuk, A. (2024). The Carbon Dioxide Emissions' World Footprint: Diagnosis of Perspectives. *Scientific Papers of Silesian University of Technology – Organization and Management Series*, No. 195. Wydawnictwo Politechniki Śląskiej. Doi: <http://dx.doi.org/10.29119/1641-3466.2024.195.41>.  
<https://managementpapers.polsl.pl/wp-content/uploads/2024/05/195-Yakymchuk.pdf>.

13. Yakymchuk, A., Halachenko, O., Irtysheva, I., Maksymchuk, M., Blishchuk, K., Bilinska, O., Sydoruk, O., Boiko, Y., Hryhoruk, I., Popadynets, N. (2021). *The Socio-Cultural and Economic Aspects of Tourism in Ukraine*. 4th International Conference on Human Systems Engineering and Design: Future Trends and Applications (IHSED 2021). Virtual Conference, September 23-25, 2021. <http://www.ihsed.org>.
14. Yakymchuk, A., Skomorovskyi, A., Pokusa, T., Pokusa, K., Łukawiecki, K. (2022). *Basics of the Public Administration: Economy, Environmental Protection and Security of the State*. Monograph. Opole: WSMiA w Opolu. ISBN: 978-83-66567-46-7.
15. Yakymchuk, A., Valyukh, A. et al. (2020). Public Administration and Economic Aspects of Ukraine's Nature Conservation in Comparison with Poland. In: J. Kantola, S. Nazir, V. Salminen (eds.) (2020). *Advances in Human Factors, Business Management and Leadership. AHFE 2020. Advances in Intelligent Systems and Computing, vol. 1209*. Cham: Springer. 978-3-030-50791-6.
16. Zhukovsky, V., Romanova, E. (2020). Climate Variability and Crop Yield: Assessing Vulnerabilities in Ukrainian Agriculture. *Environmental Studies Journal*, 18(1), 55-70.





## **FIRMS' INNOVATION ACTIVITIES AS AN ADAPTIVE ATTRIBUTE OF FIRMS' RESILIENCE TO ECONOMIC SHOCKS: EVIDENCE FROM POLISH NUTS-2 REGIONS**

Aleksandra ZYGMUNT

Opole University of Technology; a.zygmunt@po.opole.pl, ORCID: 0000-0001-5879-56840

**Purpose:** The aim of this article is to examine how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as an adaptive attribute of firms' resilience to economic shocks.

**Design/methodology/approach:** The research applied a comparative analysis, zero unitarization method and a multivariate analysis. These methods made it possible to divide Polish NUTS-2 regions into four groups according to the level of variables related to firms' innovation activities. For the research, data from Local Bank Data, Statistics Poland, were used with special attention to data on firms' internal potential for innovation processes. The study covers the period from 2018 to 2022 when Polish firms were operating under severe conditions.

**Findings:** The results show that despite the economic shocks that occurred during the period analysed, the highest diversity among Polish NUTS-2 regions in the variables considered can be found almost between the very same regions. The results also highlight that the majority of Polish NUTS-2 regions, despite the severe conditions, have a very high, high or average level of variables related to innovation activities of firms.

**Research limitations/implications:** This study has paid particular attention to the variables related to firms' innovation activities in the context of firms' internal potential for innovation processes, such as: firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland. In order to better understand the relationship between firms' innovativeness and firms' resilience, future research could consider other drivers of firms' innovation activities. There is also a need to look more closely at how firms' and regional competitiveness interact to make firms more resilient.

**Practical implications:** The findings point to the need to further improve the innovation potential of firms in order to make them more resilient to economic shocks. The research also suggests that public institutions should continue to create conditions that encourage firms to innovate.

**Originality/value:** This article contributes to the existing discussion on firms' innovation activities and firms' resilience. In this respect, the research provides evidence on the differences between Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks.

**Keywords:** firms' innovation activities, firms' resilience, NUTS-2 regions in Poland.

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

## 1. Introduction

There is a consensus in the literature that resilience to economic shocks is a complex phenomenon (Samborski, 2022). This results from viewing of resilience as a multifaceted phenomenon that can be considered from different perspectives, such as, among others, firms' or regional (Pacheco et al., 2023). For this reason, issues addressed by theoretical and empirical studies on resilience are very diverse. The growing interest in resilience issues is especially seen in recent years (Iammarino et al., 2021; Wziątek-Kubiak, Pęczkowski, 2021; Do et al., 2022; Samborski, 2022; Pacheco et al., 2023). This stems from the need for firms and regions to adapt to changes in the environment in order to maintain or increase their competitive advantage (Teixeira et al., 2013). This is particularly important in the occurrence of economic shocks, such as the covid pandemic, when changes have a multifaceted and rapid impact on firms and regions (Pinto et al., 2019, Gupta, 2020; Brada et al., 2021; Pyrkosz-Pacyna, 2021). In this respect, the resilience of firms can lead to their survival and development apart from the occurrence of severe conditions (Pacheco et al., 2023). Therefore, while the competitiveness of firms and the competitiveness of regions are interrelated (Fritsch et al., 2020), understanding the resilience of firms is of particular importance. In this respect, the growing body of research can be observed in this area (Kantabutra, Ketprapakorn, 2021; Dovbischuk, 2022, Destefanis, Rehman, 2023). Researchers highlight the diversity of issues in this field and call for the need for further research (Conz, Magnani, 2020). One strand of the research in this area emphasizes the role of firms' innovation performance in supporting the resilience of firms and regions (Muštra et al., 2020; Asheim, Herstad, 2021). According to this strand, innovation processes can be seen as crucial for maintaining the resilience of firms and regions under difficult conditions (Gupta, 2020; Engelen et al., 2021; Iammarino et al., 2021). This is because innovation activities of firms stimulate the competitiveness of firms and, consequently, the competitiveness of regions (D'Este et al., 2012; Zygmunt, A., 2017). In this respect, the studies point to the crucial role of firms' innovation performance in responding quickly to changes in the environment and to maintaining resilience (Pacheco et al., 2023). Here, studies have found, among others, an important role of knowledge diffusion (Bristow, Healy, 2018) and access to finance for firms' innovation processes (Dyduch et al., 2021). This is in line with the theories of knowledge spillovers, endogenous growth and resilience, which form the basis of this research.

It should be highlighted that although previous studies have focused on innovation and firms' resilience, there is a limited understanding of Polish firms' innovation activities in the context of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. This study is motivated by this gap in the literature and the need to further comprehend the attitude of Polish firms towards severe conditions related to changes in the environment. Thus, the aim of this research is to examine how Polish regions at the NUTS-2 level differ in

terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. The study uses data from Local Bank Data, Statistics Poland, for the period from 2018 to 2022 when Polish firms were operating under challenging conditions related to inflationary pressures and the covid pandemic. The research employs a comparative analysis, zero unitarization method and a multivariate analysis as hypothesis testing methods.

The study contributes to the rising body of knowledge on innovation and firms' resilience by showing how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. In this context, the study pays particular attention to the resilience of Polish firms under severe conditions associated with inflationary pressures and the covid pandemic, by showing that the internal potential of firms' innovation activities may be a response to the changes in the environment.

This article is structured as follows: the first section explores firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks and presents the hypothesis. This is followed by the presentation of the methodology applied for the research. Subsequently, the results are presented and discussed in following section: the comparative analysis, zero unitarization method and the multivariate analysis. The paper concludes with implications, limitations and future research suggestions.

## **2. Theoretical framework and hypothesis development**

Studies linking firms' innovation performance and resilience highlight that issues related to innovation processes have been relatively well studied, in contrast to resilience issues (Pacheco et al., 2023). This may stem from the view of firms' innovation activities as crucial for the competitive advantage of not only firms, but also regions (Fritsch et al., 2020). For this reason, the drivers and sources of firms' innovation performance have been of particular interest to theoretical and empirical studies over the years (Zygmunt, A., 2017; Zygmunt, J., 2017; Audretsch, Belitski, 2024). As firms' innovation performance is considered crucial for competitive advantage, it is argued that it can ensure survival in the occurrence of severe conditions (Teixeira et al., 2013). Therefore, as issues related to resilience have gained particular importance in recent years, firms' innovation performance has attracted considerable attention from researchers (Bristow, Healy, 2018; Destefanis, Rehman, 2023). In particular, this is seen in the context of firms' and regional resilience, and is related to understanding how firms' innovation processes enable them to adapt to change and maintain or increase their competitive advantage (Gupta, 2020; Do et al., 2022).

Considering that innovation performance affects many aspects of firms, studies on innovation processes as a support for firms' and regional resilience are very extensive and multifaceted (Conz, Magnani, 2020; Kantabutra, Ketrapakorn, 2021). In this regard, Do et al.

(2022), investigating small and medium-sized firms (SMEs) from Vietnam under the conditions of the covid pandemic, highlight innovation strategy and human resources policy as important to provide high quality human resources and conditions for knowledge diffusion as necessary to increase firms' innovation activities and support firms' resilience (Do et al., 2022). Dovbischuk (2022) also emphasises knowledge diffusion processes as important for the adaptability of firms to changes in the environment. In this respect, Dovbischuk (2022), analysing selected variables related to the resilience of firms in the context of the covid pandemic suggests that knowledge, as a result of collaboration within firms and with other firms, is crucial for innovation processes and, consequently, for the resilience of firms. Another study, by Pinto et al. (2019), on the resilience of Spanish firms during the financial crisis of 2008, among the variables used in the study, put the focus on expenditures on innovation activities, as the potential of firms for innovation processes under the occurrence of severe conditions. On the other hand, Gupta (2020) emphasises in particular the investment of firms in research and development (R&D) as crucial for innovation performance and adaptation to changes. Gupta (2020), who analyses the resilience of industrial firms in Spain during the financial crisis of 2008, provides evidence that, among others, firms' R&D expenditures, which indicate the ability to innovate, support firms' resilience to the occurrence of severe conditions. Firms' R&D expenditures are also an interest of the research by Destefanis and Rehman (2023) on the resilience of the European Union NUTS-2 regions in the period 2010–2016. In this vein, Bristow and Healy (2018) also support the view that firms' R&D expenditures are important for maintaining resilience. In addition, Bristow and Healy (2018) highlight the importance of patent applications as an effect of firms' innovation activities that can support regional resilience. The emphasis on firms' R&D expenditures and patent applications is also seen in the research by Engelen et al. (2021) on the resilience of firms from the United States during the financial crisis of 2008 and the covid pandemic. In this regard, Engelen et al. (2021) suggest that firms' R&D expenditures and patent applications can support firms' resilience especially when profitability of firms is low prior to the occurrence of severe conditions.

With regard to studies on innovation performance and firms' and regional resilience in the example of Poland, the multidimensionality of the issues addressed in this area should also be highlighted. For instance, the study by Pyrkosz-Pacyna et al. (2021) on the resilience of Polish SMEs during the covid pandemic, suggests that innovation processes are important for the resilience of firms but not the introduction of innovation in the occurrence of severe conditions as firms are focused on survival. On the other hand, Dyduch et al. (2021), who analyse the resilience of Polish SMEs during the covid pandemic point to, among others, the ability of firms to innovate and the availability of funds for innovation as crucial for the firms' resilience. Another study, by Wziątek-Kubiak and Pęczkowski (2021), provides evidence on the resilience of Polish firms during the financial crisis of 2008 by analysing forty-two drivers of firms' innovation activities. Among them, Wziątek-Kubiak and Pęczkowski (2021) particularly highlight firms' expenditures on innovation and R&D as the strongest for firms' adaptability to

economic shocks. However, apart from previous studies, there is still little evidence on firms' innovation processes and their adaptation to the occurrence of high constraints at the NUTS-2 level in Poland. Therefore, in order to address the importance of firms' innovation performance in firms' and regional resilience, it seems essential to examine how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as an adaptive attribute of firms' resilience to economic shocks. Hence, the hypothesis of this research is stated as follows:

H: Firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks differ at the NUTS-2 level in Poland.

### 3. Methodology

The research is based on data retrieved from Local Bank Data, Statistics Poland. This dataset provides information allowing the analysis of how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. In this respect, particular attention has been paid to data on the average share of innovative firms in the total number of firms and such firms' internal innovation potential as: firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland. The study refers to the period from 2018 to 2022, which allows to analyse the resilience of Polish firms under severe conditions associated with inflationary pressures and the covid pandemic. Table 1 presents the description and descriptive statistics of the variables applied for the study.

**Table 1.**  
*Descriptive statistics of the variables*

Variable	Description	Mean	St. Dev.	Min.	Max.
the average share of innovative firms in the total number of firms ( $X_1$ )	the average share of innovative firms in the total number of firms (%)	22.75	3.99	10.20	39.00
firms' own funds for innovation activities ( $X_2$ )	own funds for innovation activities of firms (PLN) per inhabitant	337.73	307.05	63.61	1648.73
internal R&D expenditures in the business sector ( $X_3$ )	internal R&D expenditures in the business sector (PLN) per inhabitant	644.01	548.59	100.57	3554.08
internal R&D personnel in the business sector ( $X_4$ )	internal R&D personnel in the business sector per 1000 inhabitants	2.50	1.90	0.63	10.01
patent applications of firms filed at the Patent Office of the Republic of Poland ( $X_5$ )	patent applications of firms filed at the Patent Office of the Republic of Poland per 100000 inhabitants	3.78	1.05	1.33	7.19

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

To investigate of how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks the comparative analysis, zero unitarization method and the multivariate analysis were applied. The comparative analysis enables to observe how the variables used in the study evolved during a difficult economic period, while the multivariate analysis and zero unitarization method were used to understand how Polish NUTS-2 regions differ in firms' innovation activities as the adaptive attribute of firms' resilience to the covid pandemic. These methods are regularly used to compare the variables and to analyse the differences between regions and countries (Zygmunt, A., 2017; Kiselakova et al., 2020). For this purpose, four classes were distinguished to illustrate: (i) regions with a very high level of variables related to firms' innovation activities, (ii) regions with a high level of variables related to firms' innovation activities, (iii) regions with an average level of variables related to firms' innovation activities, (iv) regions with a low level of variables related to firms' innovation activities. The first step was to use a constant reference point to normalise the variables (Kukuła, Bogocz, 2014).

$$R(X_{jt}) = \max_{it} x_{ijt} - \min_{it} x_{ijt} \quad (1)$$

The variables used in the study are stimulants. They were standardised using the following formula (Kukuła, Bogocz, 2014, p. 7):

$$z_{ijt} = \frac{x_{ijt} - \min_{it} x_{ijt}}{\max_{it} x_{ijt} - \min_{it} x_{ijt}} \quad (2)$$

where  $z_{ijt} \in [0,1]$ ; ( $i = 1,2, \dots, n$ ); ( $j = 1,2, \dots, m$ ); ( $t = 1,2, \dots, l$ ).

Next, the synthetic index was used (Kiselakova et al., 2020):

$$SM_{it} = \frac{1}{m} \sum_{j=1}^m z_{ijt} \quad (3)$$

where  $z_{ijt} \in [0,1]$ ;  $SM_{it} \in [0,1]$ ; ( $i = 1,2, \dots, n$ ); ( $j = 1,2, \dots, m$ ); ( $t = 1,2, \dots, l$ ).

In the following step, the division of Polish NUTS-2 regions was made according to the formula:

(i) regions with a very high level of variables related to firms' innovation activities:

$$SM_{it} \geq \overline{SM_{it}} + S(SM_{it}) \quad (4)$$

where ( $i = 1,2, \dots, n$ ); ( $t = 1,2, \dots, l$ ).

(ii) regions with a high level of variables related to firms' innovation activities:

$$\overline{SM_{it}} \leq SM_{it} < \overline{SM_{it}} + S(SM_{it}) \quad (5)$$

where ( $i = 1,2, \dots, n$ ); ( $t = 1,2, \dots, l$ )

(iii) regions with an average level of variables related to firms' innovation activities:

$$\overline{SM_{it}} - S(SM_{it}) \leq SM_{it} < \overline{SM_{it}} \quad (6)$$

where ( $i = 1,2, \dots, n$ ); ( $t = 1,2, \dots, l$ ).

(iv) regions with an average level of variables related to firms' innovation activities:

$$SM_{it} < \overline{SM_{it}} - S(SM_{it}) \quad (7)$$

where ( $i = 1,2, \dots, n$ ); ( $t = 1,2, \dots, l$ )

Where (Zygmunt, A., 2017):

$$\overline{SM}_{it} = \frac{1}{n} \sum_{j=1}^n SM_{it} \quad (8)$$

where  $(i = 1, 2, \dots, n)$ ;  $(t = 1, 2, \dots, l)$ .

$$S(SM_{it}) = \sqrt{\frac{1}{n} \sum_{i=1}^n (SM_{it} - \overline{SM}_{it})^2} \quad (9)$$

where  $(i = 1, 2, \dots, n)$ ;  $(t = 1, 2, \dots, l)$ .

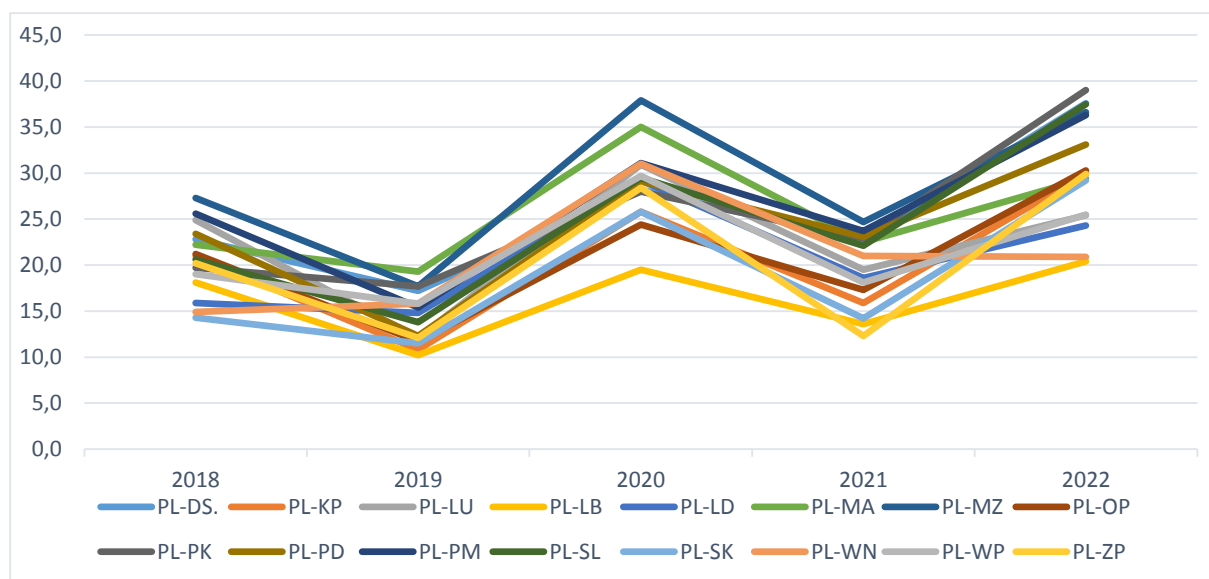
This procedure makes it possible to analyse how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks.

## 4. Results and discussion

### 4.1. The results of the comparative analysis

Figures 1-5 show the results of the comparative analysis of the variables used in the study. A comparison of the average share of innovative firms in the total number of firms, firms' own funds for innovation activities, internal R&D expenditures in the business sector, internal R&D personnel in the business sector, patent applications of firms filed at the Patent Office of the Republic of Poland at the NUTS-2 level reveals some key characteristics. In terms of the average share of innovative firms in the total number of firms the results show that changes in the environment have a similar impact on innovative attitude of firms in all Polish NUTS-2 regions (Figure 1).

The findings indicate that the average share of innovative firms in the total number of firms decreased in 2019 and 2021, while an increase in the average share of share of innovative firms in the total number of firms is observed for the years 2020 and 2022. The observed increase in the innovative attitude of the Polish firms, as an adaptation to economic shocks, is in line with the research by Iammarino et al. (2021) and Dovbischuk (2022), suggesting that the innovativeness of firms increases their resilience to changes in the environment. This feature requires further, detailed investigation, especially for 2019 and 2021, when the innovative attitude of Polish firms was contrary to expectations.

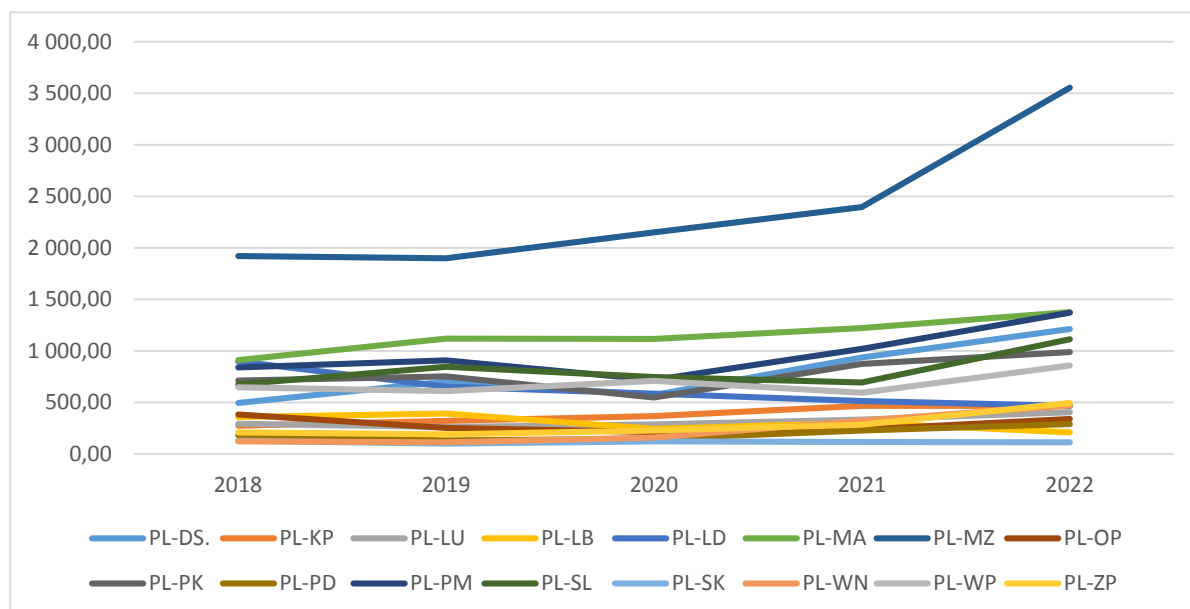


Legend: PL-DS – Lower Silesian Voivodship; PL-KP – Kuyavian-Pomeranian Voivodship; PL-LU – Lublin Voivodship; PL-LB – Lubusz Voivodship; PL-LD – Łódź Voivodship; PL-MA – Lesser Poland Voivodship; PL-MZ – Masovian Voivodship; PL-OP – Opole Voivodship; PL-PK – Subcarpathian Voivodship; PL-PD – Podlaskie Voivodship; PL-PM – Pomeranian Voivodship; PL-SL – Silesian Voivodship; PL-SK – Świętokrzyskie Voivodship; PL-WN – Warmian-Masurian Voivodship; PL-WP – Greater Poland Voivodship; PL-ZP – West Pomeranian Voivodship.

**Figure 1.** The average share of innovative firms in the total number of firms in Poland in 2018-2022 (%).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

Taking into account the internal expenditures on innovation activities, the results show that firms in the majority of Polish NUTS-2 regions spend most of their own funds on R&D expenditures (Figures 2-3).

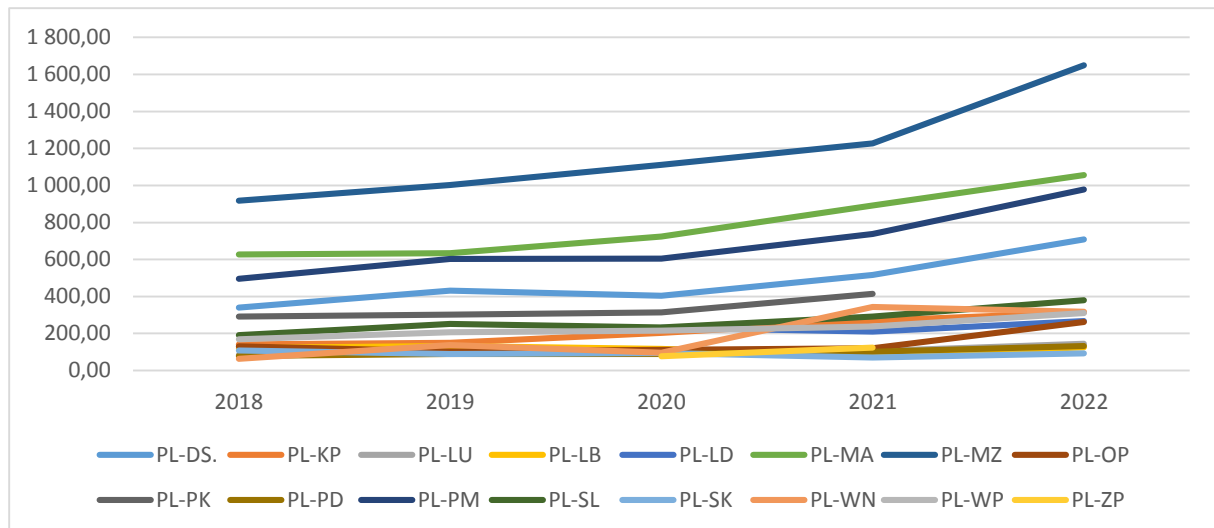


Legend: like in Figure 1.

**Figure 2.** Own funds for innovation activities of Polish firms (PLN) per inhabitant (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.



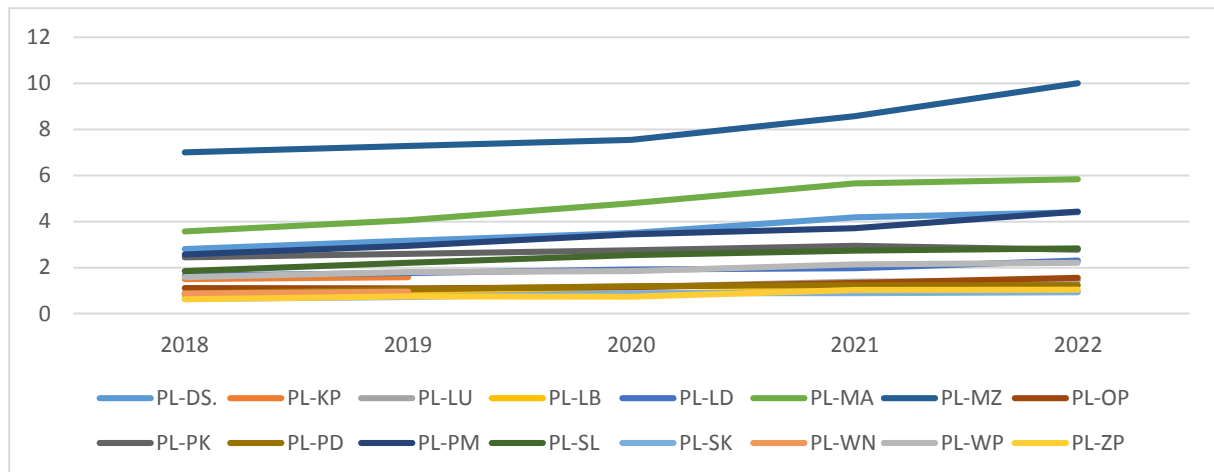


Legend: like in Figure 1. Lack of data: 2019 – PL-LD, PL-ZP; 2022 – PL-PK, PL-ZP.

**Figure 3.** Internal R&D expenditures in the business sector (PLN) per inhabitant in Poland (2018-2022).  
Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

This feature can be observed throughout the period 2018–2022, which indicates the attitude of Polish firms towards the development of products, services and processes as a necessity to adapt to changes and to maintain or increase competitive advantages. This is particularly evident in 2019, when firms from the majority of Polish NUTS-2 regions increase their attention to innovation processes, increasing both their own funds and internal expenditures on innovation activities in response to rising inflationary pressures. This is in line with the study by Pacheco et al. (2013), which highlights that firms' innovativeness strengthens their resilience to economic disturbances. The results suggest that the emphasis on firms' innovation processes was further strengthened in the majority of NUTS-2 regions in Poland when the covid pandemic forced them to face new requirements of environment. This is consistent with the empirical evidence provided by Do et al. (2022), Gajewski (2022) and Destefansis and Rehman (2023) that innovation processes allow firms to adapt to economic shocks. An interesting feature has also been identified for 2021-2022, when firms from the majority of Polish NUTS-2 regions continue to increase the use of own funds for innovation activities as well as internal expenditures on R&D. This may indicate that there is still need for Polish firms to adapt to changes and to strengthen their ability to withstand future economic shocks. This may lead to an increase in the competitiveness of firms and, consequently, to an increase in the competitiveness of regions. Such results are in line with the research of Pinto et al. (2019) that innovation processes can make firms more resilient in times of economic slowdown.

The results show that Polish firms from all NUTS-2 regions increased the number of internal R&D personnel between 2018 and 2022 (Figure 4). This may indicate that firms were aiming to raise their human resources potential as crucial for innovation activities and increasing competitiveness.



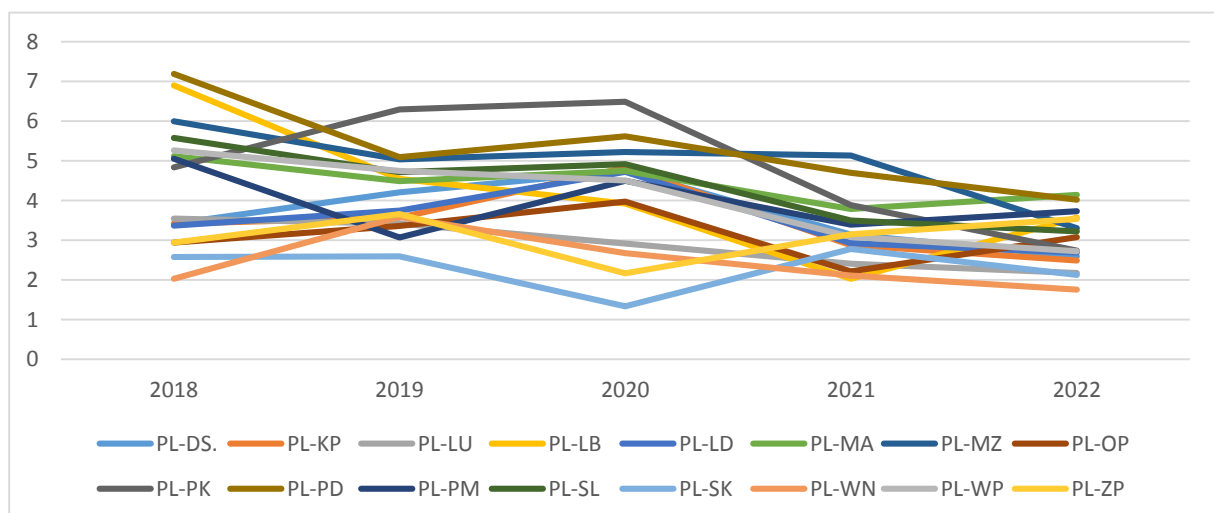
Legend: like in Figure 1. Lack of data: 2020-2021 – PL-KP, PL-WN; 2022 – PL-LB, PL-WN.

**Figure 4.** Internal R&D personnel in the business sector per 1000 inhabitants in Poland (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

This is also evident during the economic shock of the covid pandemic, suggesting that Polish firms were aware that their maintenance or development was linked to innovation processes. Importantly, the results show that Polish firms in all NUTS-2 regions continued to increase the number of internal R&D personnel after the covid pandemic, which may indicate the need for further potential building to increase the resilience of firms. This is in line with the evidence provided by Teixeira et al. (2013), Muštra (2020), and Wziątek-Kubiak and Pęczkowski (2021) that R&D personnel is crucial in facing economic disturbances and strengthening the resilience of firms.

Regarding patents as the ability of firms to absorb of knowledge and innovation potential, the results allow to point out a decrease in the number of patent applications of firms filed at the Patent Office of the Republic of Poland in the majority of NUTS-2 regions (Figure 5).



Legend: like in Figure 1.

**Figure 5.** Patent applications of firms filed at the Patent Office of the Republic of Poland per 100000 inhabitants (2018-2022).

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

According to the results, the decline in patenting is observed throughout 2018-2022 period and may indicate that Polish firms have focused on forms of innovation other than product innovation to increase firms' resilience. This is not consistent with the evidence provided by Bristow and Healy (2018) and requires further, detailed investigation. One reason for this may be that the need to adapt to changes in the environment requires a greater emphasis on service or process innovation.

#### 4.2. The results of zero unitarization method and the multivariate analysis

Table 2 shows the results of zero unitarization method and the multivariate analysis of the variables under consideration for the period 2018-2022.

**Table 2.**

*Firms' innovation activities as the adaptive attribute of firms' resilience in Poland at the NUTS-2 level in 2018–2022 (the multivariate analysis)*

2018			2019			2020			2021			2022											
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM									
Very High			Very High			Very High			Very High			Very High											
1.	PL-MZ	0.954	1.	PL-MZ	0.896	1.	PL-MZ	0.951	1.	PL-MZ	1.000	1.	PL-MZ	0.902									
2.	PL-MA	0.553	2.	PL-MA	0.636	2.	PL-MA	0.643	2.	PL-MA	0.641	2.	PL-PM	0.604									
High			High			High			High			High											
1.	PL-PM	0.533	1.	PL-PK	0.541	1.	PL-PM	0.490	1.	PL-PM	0.539	1.	PL-MA	0.582									
2.	PL-PK	0.368	2.	PL-DS.	0.457	2.	PL-PK	0.439	2.	PL-DS.	0.474	2.	PL-DS.	0.467									
3.	PL-SL	0.364	3.	PL-PM	0.410	3.	PL-DS.	0.416	3.	PL-PK	0.469	3.	PL-SL	0.444									
4.	PL-DS.	0.359	4.	PL-SL	0.358	4.	PL-SL	0.393	4.	PL-SL	0.389	Average											
5.	PL-PD	0.358	5.	PL-WP	0.355	Average			5.	PL-PD	0.370	1.	PL-PD	0.343									
Average			Average			1.	PL-WP	0.351	Average			2.	PL-KP	0.246									
1.	PL-WP	0.311	1.	PL-WN	0.196	2.	PL-PD	0.289	1.	PL-WP	0.265	3.	PL-OP	0.234									
2.	PL-LB	0.292	2.	PL-PD	0.195	3.	PL-LU	0.220	2.	PL-LD	0.246	4.	PL-WP	0.177									
3.	PL-LU	0.253	3.	PL-LB	0.154	4.	PL-LD	0.347	3.	PL-LU	0.178												
4.	PL-LD	0.220	4.	PL-KP	0.130	5.	PL-ZP	0.140	4.	PL-OP	0.123	5.	PL-LD	0.130									
5.	PL-KP	0.219	5.	PL-LU	0.113	Low			5.	PL-ZP	0.100												
6.	PL-OP	0.201	6.	PL-OP	0.106	1.	PL-OP	0.183	Low			Low											
Low			Low			2.	PL-LB	0.124	1.	PL-SK	0.079	1.	PL-SK	0.074									
1.	PL-ZP	0.142	1.	PL-SK	0.029										3.	PL-SK	0.076	2.	PL-LB	0.042	2.	PL-LU	0.056
2.	PL-SK	0.033																					
3.	PL-WN	0.017																					

Legend: like in Figure 1. Lack of data: like in Figure 3, Figure 4.

Source: own study based on data from Local Data Bank, Statistics Poland, 2023.

The results confirm the stated hypothesis and reveal a relatively high diversity between Polish regions at the NUTS-2 level in regard to firms' innovation activities as the adaptive attribute of firms' resilience to economic shocks. Some interesting features can be observed in this respect. First, the research shows that among the changes in the environment in the 2018-2022, including the economic shock related to the covid pandemic, the highest diversity between Polish NUTS-2 regions in the variables under consideration can be observed almost between the very same regions. The highest diversity can be seen between Masovian Voivodship, Lesser Poland Voivodship, Pomeranian Voivodship and Świętokrzyskie Voivodship, Lublin Voivodship. This indicates that despite the changes in the environment,

there have been no substantial differences in the distance between Polish regions with the highest and the lowest level of variables related to firms' innovation activities. Such an occurrence may result from the resilience of regions to economic shocks, which, together with innovation activities of firms, may have an impact on maintaining the resilience of firms under severe conditions - as provided by Bristow and Healy (2018). This may be also related to the conditions created by regions to stimulate the innovation potential of firms as an effect of interactions between the competitiveness of firms and the competitiveness of regions. For this reason, the observed feature for Polish NUTS-2 regions requires further detailed research. Another interesting feature is related to the relatively high level of variables related to innovation activities of firms in Polish regions at the NUTS-2 level in the period 2018-2022. This should be considered positive, as it may have broader impact on increasing the resilience of firms and regions to the changes in the environment. In this respect, the results show that in about half of the Polish NUTS-2 regions, despite the economic shocks that occurred during the period considered, the level of variables related to firms' innovation activities in Polish regions is very high or high. In addition, a large number of NUTS-2 regions show the average level of variables related to firms' innovation activities, which should also be seen as positive, as this potential did not decrease despite the occurrence of severe conditions. It is also positive that only a small number of regions were characterised by the low level of variables related to firms' innovation activities despite having to cope with substantial changes in their environment. This may be related to firms' awareness that innovation potential can support to maintain and increase firms' resilience.

## 5. Conclusions

This research contributes to the growing body of knowledge on innovation and firms' resilience. The study provides evidence on how Polish regions at the NUTS-2 level differ in terms of firms' innovation activities as the adaptive attribute of firms' resilience under conditions of high constraints. Particular attention was paid to the period 2018-2022, when Polish firms operated under inflationary pressures and the covid pandemic. The results indicate that, despite the economic shocks, the highest diversity among Polish NUTS-2 regions in the considered variables can be found almost between the very same regions. This can be explained by the resilience of regions to economic shocks, which, together with the innovative activities of firms, can help to maintain the resilience of firms under difficult conditions. The results also show that the majority of Polish NUTS-2 regions, despite the occurrence of high constraints, have a very high, high or average level of variables related to innovation activities of firms. This may be due to the fact that firms are aware that innovativeness can contribute to maintaining and improving firms' resilience.

The research offers implications for practitioners and policy makers. As firms' innovation activities is considered to have an impact on maintaining the resilience of firms under severe conditions, further strengthening of the innovation potential is crucial. Therefore, firms should take further actions to strengthen the drivers of innovation. It is also necessary for public institutions to continue to provide conditions that encourage firms to innovate.

This study is not without limitations, which are associated with the variables related to firms' innovation activities. As the research focuses on variables related to the firms' internal potential for innovation processes, it would be valuable to consider other drivers of firms' innovation activities in order to better understand the relationship between firms' innovativeness and firms' resilience. In this respect, it seems important for future studies to examine the diffusion of knowledge between firms and other firms, research organisations and government institutions as crucial for strengthening firms' innovation activities, which may increase firms' resilience to changes in the environment. Furthermore, as the decline in patenting by Polish firms is observed over the period, it would be valuable to conduct studies on the service or process innovation as important for firms' adaptation to changes in the environment. As the studies found that, despite the occurrence of severe conditions, there were no substantial differences in the distance between Polish regions with the highest and the lowest level of variables related to firms' innovation activities, future research should also further examine issues related to the mutual interactions between the competitiveness of firms and the competitiveness of regions as crucial for firms' resilience.

## References

1. Asheim, B.T., Herstad, S.J. (2021). Regional innovation strategy for resilience and transformative industrial path development: evolutionary theoretical perspectives on innovation policy. *Eastern Journal of European Studies*, Vol. 12, pp. 43-75, doi: 10.47743/ejes-2021-SI03
2. Audretsch, D.B., Belitski, M. (2024). Knowledge collaboration, firm productivity and innovation: A critical assessment. *Journal of Business Research*, Vol. 172, 114412, doi: 10.1016/j.jbusres.2023.114412
3. Brada, J.C., Gajewski, P., Kutan, A.M. (2021). Economic resiliency and recovery, lessons from the financial crisis for the COVID-19 pandemic: A regional perspective from Central and Eastern Europe. *International Review of Financial Analysis*, Vol. 74, 101658, doi: /10.1016/j.irfa.2021.101658
4. Bristow, G., Healy, A. (2018). Innovation and regional economic resilience: an exploratory analysis. *The Annals of Regional Studies*, Vol. 60, pp. 265-284, doi: 10.1007/s00168-017-0841-6

5. Conz, E., Magnani, G. (2020). A Dynamic Perspective on the Resilience of Firms: A Systematic Literature Review and a Framework for Future Research. *European Management Journal*, Vol. 38, Iss. 3, pp. 400-412, doi: 10.1016/j.emj.2019.12.004
6. D'Este, P., Iammarino, S., Savona, M., von Tunzelmann, N. (2012). What Hampers Innovation? Revealed Barriers versus Detering Barriers. *Research Policy*, Vol. 41, Iss. 2, pp. 482-488, doi: 10.1016/j.respol.2011.09.008
7. Destefanis, S., Rehman, N.U. (2023). Investment, innovation activities and employment across European regions. *Structural Change and Economic Dynamics*, Vol. 65, pp. 474-490, doi: 10.1016/j.strueco.2023.03.013
8. Do, H., Budhwar, P., Shipton, H., Nguyen, H-D., Nguyen, B. (2022). Building organizational resilience, innovation through resource-based management initiatives, organizational learning and environmental dynamism. *Journal of Business Research*, Vol. 141, pp. 808-821, doi: 10.1016/j.jbusres.2021.11.090
9. Dovbischuk, I. (2022), Innovation-oriented dynamic capabilities of logistics service providers, dynamic resilience and firm performance during the COVID-19 pandemic. *The International Journal of Logistics Management*, Vol. 33, No. 2, pp. 499-519, doi: 10.1108/IJLM-01-2021-0059
10. Dyduch, W., Chudziński, P., Cyfert, S., Zastempowski, M. (2021). Dynamic capabilities, value creation and value capture: Evidence from SMEs under Covid-19 lockdown in Poland. *PLoS ONE*, Vol. 16, Iss. 6, e0252423, doi: 10.1371/journal.pone.0252423
11. Engelen, A., Huesker, C., Rieger, V., Berg, V. (2021). Building a resilient organization through a pre-shock strategic emphasis on innovation. *Journal of Product Innovation Management*, Vol. 41, Iss. 1, pp. 36-61, doi: 10.1111/jpim.12697
12. Fritsch, M., Titze, M., Piontek, M. (2020). Identifying cooperation for innovation—a comparison of data sources. *Industry and Innovation*, 27, 6, pp. 630-659, doi:10.1080/13662716.2019.1650253
13. Gajewski, P. (2022). Regional resilience to the Covid-19 shock in Polish regions: how is it different from resilience to the 2008 Global Financial Crisis? *Regional Studies, Regional Science*, Vol. 9, Iss. 1, pp. 672-684, doi: 10.1080/21681376.2022.2137426
14. Gupta, A. (2020). R&D and firm resilience during bad times. *DICE Discussion Paper*, No. 352, ISBN 978-3-86304-351-3, Heinrich Heine University Düsseldorf, Düsseldorf Institute for Competition Economics (DICE), Düsseldorf.
15. Iammarino, S., Sodano, T., Vittorino, G. (2021). Firms' Perceptions of Barriers to Innovation and Resilience: The Italian Region of Friuli Venezia Giulia during the Crisis. *Scienze Regionali, Italian Journal of Regional Science*, Vol. 1, pp. 25-54, doi: 10.14650/97448
16. Kantabutra, S, Ketprapakorn, N. (2021). Toward an Organizational Theory of Resilience: An Interim Struggle. *Sustainability*. Vol. 13, No. 23, 13137, doi: 10.3390/su132313137

17. Kiselakova, D., Stec, M., Grzebyk, M., Sofrankova, B. (2020). A Multidimensional Evaluation of the Sustainable Development of European Union Countries – An Empirical Study. *Journal of Competitiveness*, 12(4), pp. 56-73, doi: 10.7441/joc.2020.04.04
18. Kukuła, K., Bogocz, D. (2014). Zero unitarization method and its application in ranking research in agriculture. *Economic and Regional Studies*, 7(3), pp. 5-13.
19. Muštra, V., Šimundi, B., Kuliš, Z. (2020). Does innovation matter for regional labour resilience? The case of EU regions. *Regional Science Policy et Practice*, Vol. 21, Iss. 5, pp. 955-970, doi: 10.1111/rsp3.12348ice
20. Pacheco, L.M., Moore, E., Brandl, K., White, R. (2023), Editorial: Exploring the resilience and innovation nexus – a call for interdisciplinary research. *Innovation & Management Review*, Vol. 20, No. 2, pp. 98-102, doi: 10.1108/INMR-04-2023-228
21. Pinto, H., Pereira, T.S., Uyarra, E. (2019). Innovation in firms, resilience and the economic downturn: Insights from CIS data in Portugal. *Regional Science Policy & Practice*, Vol. 11, Iss. 6, pp. 951-967, doi: 10.1111/rsp3.12243
22. Pyrkosz-Pacyna, J., Nawojczyk, M., Synowiec-Jaje, I. (2021). Entrepreneurial Resilience in the COVID-19 Crisis: A Qualitative Study of Micro and Small Entrepreneurs in Poland. *Polish Sociological Review*, Vol. 216, No. 4, pp. 571-592, doi: 10.26412/psr216/08
23. Samborski, A. (2022). Resilience of Polish Non-Financial Corporations under Economic Shocks. *Scientific Papers of Silesian University of Technology. Organization & Management [Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie]*, Vol. 163, pp. 505-519, doi: 10.29119/1641-3466.2022.163.31
24. Teixeira, E. de O., Werther, W.B. (2013). Resilience: Continuous renewal of competitive advantages. *Business Horizons*, Vol. 56, No. 3, pp. 333-342, doi: 10.1016/j.bushor.2013.01.009
25. Wziątek-Kubiak, A., Pęczkowski, M. (2021). Strengthening the Innovation Resilience of Polish Manufacturing Firms in Unstable Environments. *Journal of Knowledge Economy*, Vol. 12, pp. 716-739, doi: 10.1007/s13132-021-00725-w
26. Zygmunt, J. (2017). Enterprises' Development in Peripheral Regions: Patterns and Determinants. *Problemy Zarządzania*, Vol. 15, No. 1(65), pp. 226-236, doi: 10.7172/1644-9584.65.14
27. Zygmunt, A. (2017). Innovation activities of Polish firms. Multivariate analysis of the moderate innovator countries. *Oeconomia Copernicana*, Vol. 8, No. 4, pp. 505-521. doi: 10.24136/oc.v8i4.31





## **REVIEWERS**

PhD **Jarosław GORZAWSKI**, WSB University, Poland

Prof. **Wiesław GREBSKI**, The Pennsylvania State University, USA

Prof. **Magdalena JACIOW**, Economic University in Katowice, Poland

PhD **Judyta KABUS**, Czestochowa University of Technology, Poland

Prof. **Aleksander LOTKO**, Kazimierz Pułaski University of Technology and Humanities  
in Radom, Poland

Prof. **Andrzej PACANA**, Rzeszów Technical University, Poland

Prof. **Rafał PRUSAK**, Czestochowa University of Technology, Poland

Prof. **Robert SOCHA**, WSB University, Poland

Prof. **Radosław WOLNIAK**, Silesian University of Technology, Poland